DOE/OR/01-2535&D3

# Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee

**This document is approved for public release per review by:**

Lawrence M Sparks 3/30/15

**Lawrence M. Sparks** **Date**
**DOE ORO Classification Officer**

**Professional Project Services, Inc. (Pro2Serve®)**

Contributed to the preparation of this document and should not be considered an eligible contractor for its review.

DOE/OR/01-2535&D3

# Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee

Date Issued – March 2015

Prepared by
Professional Project Services, Inc. (Pro2Serve®)
Oak Ridge, Tennessee

Prepared for the
U.S. Department of Energy
Office of Environmental Management

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... viii
EXECUTIVE SUMMARY ..... ES-1
1. INTRODUCTION ..... 1-1
1.1 BACKGROUND ..... 1-1
1.2 PURPOSE ..... 1-3
1.3 SCOPE AND ORGANIZATION OF REPORT ..... 1-3
2. WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION ..... 2-1
2.1 CERCLA WASTE DEFINITION ..... 2-2
2.1.1 Exclusions ..... 2-2
2.1.2 Waste Types and Material Types ..... 2-4
2.1.3 Wastes that do not Meet Disposal Facility WAC ..... 2-5
2.2 RI/FS WASTE VOLUME ESTIMATES ..... 2-5
2.2.1 As-generated Waste Volume Estimate ..... 2-6
2.2.2 As-disposed Waste Volume Estimate ..... 2-8
2.2.3 Volume for Off-site Disposal Alternative ..... 2-11
2.3 RI/FS WASTE CHARACTERIZATION ..... 2-14
2.3.1 Radionuclide Characterization ..... 2-14
2.3.1.1 Data Collection ..... 2-15
2.3.1.2 Development of Data Set for Risk Evaluation ..... 2-15
2.3.1.3 Data Collection and Data Set Development Exceptions ..... 2-15
2.3.2 Chemical Characterization ..... 2-15
2.3.3 Mercury-contaminated Waste ..... 2-15
3. RISK EVALUATIONS ..... 3-1
3.1 EVALUATION OF BASELINE RISK (NO ACTION ALTERNATIVE) ..... 3-1
3.2 EVALUATION OF RISK FOR THE ON-SITE ALTERNATIVE ..... 3-6
3.3 EVALUATION OF RISK FOR THE OFF-SITE ALTERNATIVE ..... 3-8
4. REMEDIAL ACTION OBJECTIVES ..... 4-1
5. TECHNOLOGY SCREENING AND ALTERNATIVES ASSEMBLY ..... 5-1
5.1 IDENTIFICATION OF TECHNOLOGIES AND PROCESS OPTIONS ..... 5-1
5.1.1 No Action ..... 5-2
5.1.2 On-site Disposal ..... 5-2
5.1.2.1 New Facilities ..... 5-2
5.1.2.2 Existing Facilities ..... 5-9
5.1.3 Off-site Disposal ..... 5-9
5.1.3.1 Existing LLW and Mixed-Waste Facilities ..... 5-10
5.1.3.2 Existing RCRA/TSCA Facilities ..... 5-10

5.1.4 Treatment of Mercury-contaminated Debris ..... 5-10
5.1.4.1 Immobilization ..... 5-11
5.1.4.2 Thermal and Chemical Extraction ..... 5-11
5.1.5 Volume Reduction ..... 5-11
5.1.5.1 Recycle/Reuse ..... 5-12
5.1.5.2 Segregation ..... 5-12
5.1.5.3 Size Reduction Processing ..... 5-12
5.1.6 Waste Packaging and Transport ..... 5-12
5.1.6.1 Packaging ..... 5-12
5.1.6.2 Transport ..... 5-13
5.1.7 Institutional Controls ..... 5-13
5.1.7.1 Access and Use Restrictions ..... 5-13
5.1.7.2 Maintenance and Monitoring ..... 5-13
5.2 RETAINING/ELIMINATING PROCESS OPTIONS ..... 5-14
5.2.1 No Action ..... 5-14
5.2.2 On-site Disposal ..... 5-14
5.2.2.1 New Facilities ..... 5-14
5.2.2.2 Existing Facilities ..... 5-14
5.2.3 Off-site Disposal ..... 5-14
5.2.3.1 New Facilities ..... 5-14
5.2.3.2 Existing LLW and Mixed-Waste Facilities ..... 5-15
5.2.3.3 Existing RCRA/TSCA Facilities ..... 5-15
5.2.4 Volume Reduction ..... 5-15
5.2.5 Treatment of Mercury-contaminated Debris ..... 5-16
5.2.6 Waste Packaging and Transport ..... 5-16
5.2.6.1 Packaging ..... 5-16
5.2.6.2 Transport ..... 5-16
5.2.7 Institutional Controls ..... 5-17
5.3 ASSEMBLY OF ALTERNATIVES AND ABILITY TO MEET REMEDIAL ACTION OBJECTIVES ..... 5-17
5.4 COMBINED ON-SITE AND OFF-SITE DISPOSAL ..... 5-20
6. ALTERNATIVE DESCRIPTIONS ..... 6-1
6.1 NO ACTION ALTERNATIVE ..... 6-1
6.2 ON-SITE DISPOSAL ALTERNATIVE ..... 6-1
6.2.1 EMDF Site ..... 6-2
6.2.1.1 EMDF Site Characteristics ..... 6-5
6.2.2 EMDF Conceptual Design ..... 6-6
6.2.2.1 Remedial Design ..... 6-7

6.2.2.2 Early Actions ..... 6-8
6.2.2.3 Site Development ..... 6-9
6.2.2.4 Disposal Facility ..... 6-10
6.2.2.5 Support Facilities ..... 6-26
6.2.2.6 EMDF Conceptual Design Summary ..... 6-31
6.2.2.7 Process Modifications ..... 6-38
6.2.3 Waste Acceptance Criteria ..... 6-40
6.2.4 Construction Activities and Schedule ..... 6-40
6.2.5 Operations ..... 6-42
6.2.5.1 Waste Placement ..... 6-42
6.2.5.2 In-cell Macroencapsulation ..... 6-42
6.2.5.3 Wastewater Management ..... 6-42
6.2.6 Engineering Controls, Construction Practices, and Mitigation Measures ..... 6-43
6.2.7 Management of Waste Exceeding WAC ..... 6-44
6.2.8 Closure ..... 6-44
6.2.9 Post-Closure Care and Monitoring ..... 6-44
6.2.9.1 Surveillance and Maintenance ..... 6-45
6.2.9.2 Monitoring ..... 6-45
6.2.10 Lessons Learned Summary ..... 6-46
6.3 OFF-SITE DISPOSAL ALTERNATIVE ..... 6-47
6.3.1 Candidate Waste Streams ..... 6-47
6.3.2 Description of Representative Disposal Facility Options ..... 6-47
6.3.2.1 Energy*Solutions*, Clive Utah ..... 6-48
6.3.2.2 NNSS ..... 6-51
6.3.3 Waste Control Specialists, Texas ..... 6-52
6.3.4 Size Reduction Processing ..... 6-54
6.3.5 Off-site Disposal Alternative Description ..... 6-54
6.3.5.1 Characterization and Treatment ..... 6-54
6.3.5.2 Packaging of LLW and Classified Waste ..... 6-54
6.3.5.3 Packaging of Mixed Waste ..... 6-55
6.3.5.4 Local Transportation ..... 6-55
6.3.5.5 Transload Facility at ETTP ..... 6-58
6.3.5.6 Size Reduction Facility at ETTP ..... 6-58
6.3.5.7 Off-ORR Transportation ..... 6-59
6.3.5.8 Disposal ..... 6-60
6.3.5.9 Management of Waste Exceeding Off-site Disposal WAC ..... 6-60
6.3.5.10 Process Modifications ..... 6-60
7. DETAILED ANALYSIS OF ALTERNATIVES ..... 7-1

7.1 EVALUATION CRITERIA ..... 7-1
7.1.1 Overall Protection of Human Health and the Environment ..... 7-2
7.1.2 Compliance with ARARs and To Be Considered Guidance ..... 7-2
7.1.3 Long-term Effectiveness and Permanence ..... 7-3
7.1.4 Short-term Effectiveness ..... 7-3
7.1.5 Reduction of Toxicity, Mobility, or Volume by Treatment ..... 7-3
7.1.6 Implementability ..... 7-3
7.1.7 Costs ..... 7-3
7.1.8 State Acceptance ..... 7-4
7.1.9 Community Acceptance ..... 7-4
7.1.10 NEPA Considerations ..... 7-4
7.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES ..... 7-4
7.2.1 No Action Alternative Analysis ..... 7-4
7.2.1.1 Overall Protection of Human Health and the Environment (No Action) ..... 7-5
7.2.1.2 Compliance with ARARs (No Action) ..... 7-5
7.2.1.3 Long-term Effectiveness and Permanence (No Action) ..... 7-5
7.2.1.4 Short-term Effectiveness (No Action) ..... 7-5
7.2.1.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (No Action) ..... 7-5
7.2.1.6 Implementability (No Action) ..... 7-5
7.2.1.7 Cost (No Action) ..... 7-5
7.2.1.8 NEPA Considerations (No Action) ..... 7-6
7.2.2 On-site Disposal Alternative Analysis ..... 7-6
7.2.2.1 Overall Protection of Human Health and the Environment (On-site) ..... 7-6
7.2.2.2 Compliance with ARARs (On-site) ..... 7-7
7.2.2.3 Long-term Effectiveness and Permanence (On-site) ..... 7-8
7.2.2.4 Short-term Effectiveness (On-site) ..... 7-11
7.2.2.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (On-site) ..... 7-16
7.2.2.6 Implementability (On-site) ..... 7-16
7.2.2.7 Cost (On-site) ..... 7-18
7.2.2.8 NEPA Considerations (On-site) ..... 7-20
7.2.3 Off-site Disposal Alternative Analysis ..... 7-22
7.2.3.1 Overall Protection of Human Health and the Environment (Off-site) ..... 7-22
7.2.3.2 Compliance with ARARs (Off-site) ..... 7-23
7.2.3.3 Long-term Effectiveness and Permanence (Off-site) ..... 7-23
7.2.3.4 Short-term Effectiveness (Off-site) ..... 7-24
7.2.3.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (Off-site) ..... 7-25

7.2.3.6 Implementability (Off-site) ..... 7-25
7.2.3.7 Cost (Off-site) ..... 7-27
7.2.3.8 NEPA Considerations (Off-site) ..... 7-27
7.3 COMPARATIVE ANALYSIS OF ALTERNATIVES ..... 7-29
7.3.1 Overall Protection of Human Health and the Environment ..... 7-34
7.3.2 Compliance with ARARs ..... 7-34
7.3.3 Long-term Effectiveness and Permanence ..... 7-34
7.3.4 Short-term Effectiveness ..... 7-35
7.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment ..... 7-37
7.3.6 Implementability ..... 7-37
7.3.7 Cost ..... 7-38
7.3.8 NEPA Considerations ..... 7-38
7.3.9 Summary of Differentiating Criteria ..... 7-39
8. REFERENCES ..... 8-1
APPENDIX A: WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION DATA ..... A-1
APPENDIX B: WASTE VOLUME REDUCTION ..... B-1
APPENDIX C: ON-SITE TREATMENT AND DISPOSAL OPTIONS FOR MERCURY-CONTAMINATED WASTE ..... C-1
APPENDIX D: ON-SITE DISPOSAL ALTERNATIVE SITE SCREENING ..... D-1
APPENDIX E: PREFERRED SITE DESCRIPTION AND CHARACTERIZATION ..... E-1
APPENDIX F: ALTERNATIVES RISK ASSESSMENT AND FUGITIVE EMISSION MODELING ..... F-1
APPENDIX G: APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS ..... G-1
APPENDIX H: ON-SITE DISPOSAL FACILITY PRELIMINARY WASTE ACCEPTANCE CRITERIA ..... H-1
APPENDIX I: COST ESTIMATES FOR ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES ..... I-1

This page intentionally left blank.

# FIGURES

Figure ES-1. Bear Creek Valley Zones and Proposed Site for the Proposed EMDF ..... ES-4
Figure ES-2. Transportation Risk (Vehicle Accidents/Emissions) for On-site and Off-site Alternatives ..... ES-7
Figure 1-1. Oak Ridge Reservation, EMWMF, and Proposed EMDF Site Locations ..... 1-2
Figure 2-1. Annual, As-generated Waste Volume Estimates without Uncertainty ..... 2-7
Figure 2-2. Scenarios for Total Fill in Landfill ..... 2-9
Figure 2-3. (a) Cumulative CERCLA Waste Capacity Demand Estimate (b) Cumulative CERCLA Waste Capacity Demand Estimate for New EMDF ..... 2-13
Figure 3-1. Illustration of the Stages of an On-site Disposal Action and Resulting Risk Determinations ..... 3-7
Figure 5-1. OREM Hierarchy for Waste Disposition ..... 5-11
Figure 5-2. Risks Associated with Transportation for Various On-site and Off-site Disposal Scenarios. . . ..... 5-21
Figure 5-3. Costs Associated with On-site and Off-site Disposal Scenarios ..... 5-22
Figure 6-1. EMDF Location Map ..... 6-3
Figure 6-2. EMDF Site Plan ..... 6-4
Figure 6-3. Typical Cross-section of EMDF ..... 6-12
Figure 6-4. Typical Riprap Buttress Detail ..... 6-13
Figure 6-5. Typical Upgradient Ditch and Shallow French Drain Detail ..... 6-14
Figure 6-6. EMDF Liner and Cover Layers ..... 6-15
Figure 6-7. Typical Details of EMDF Leachate Collection and Removal System and Leak Detection and Removal System ..... 6-16
Figure 6-8. EMDF Underdrain System Plan ..... 6-17
Figure 6-9. Typical Underdrain System Detail ..... 6-18
Figure 6-10. EMDF Site and Surrounding Facilities ..... 6-28
Figure 6-11. Proposed Locations for Water Treatment Systems ..... 6-29
Figure 6-12. EMDF Final Cover and Grading Plan ..... 6-32
Figure 6-13. EMDF Cross-sections ..... 6-33
Figure 6-14. On-site Disposal Alternative Schedule ..... 6-41
Figure 6-15. Schematic of Responsibilities for Waste Shipments to Energy*Solutions* or WCS for Off-site Disposal Alternative ..... 6-56
Figure 6-16. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative ..... 6-57
Figure 6-17. Rail Routes from ETTP ..... 6-61
Figure 6-18. Typical Off-site Transportation Routes ..... 6-62
Figure 7-1. Comparison of Transportation Risk for On-site and Off-site Disposal Alternatives ..... 7-30

# TABLES

Table ES-1. Risks and Cost Implications for On-site and Off-site Disposal Alternatives ..... ES-8
Table 1-1. Outline of RI/FS Document Content ..... 1-4
Table 2-1. RI/FS Alternative Components Supported by Waste Volume Estimates and Waste Characterization ..... 2-3
Table 2-2. Post-EMWMF Base As-generated Waste Volume Estimate (FY 2022 - FY 2043) without Uncertainty ..... 2-8
Table 2-3. As-Disposed Waste Volume Determination ..... 2-10
Table 2-4. Uncertainty (Contingency) and Corresponding Projected Disposal Capacity Need ..... 2-11
Table 2-5. Post-EMWMF As-generated Waste Volume Estimate (FY 2022 - FY 2043) with Uncertainty ..... 2-12
Table 2-6. Data Set for Natural Phenomena and Transportation Risk Evaluation ..... 2-17
Table 2-7. Chemical Constituents ..... 2-18
Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects ..... 3-2
Table 3-2. Short-term Risks Associated with the On-site Disposal Alternative[a] ..... 3-6
Table 3-3. Short-term Risks Associated with the Off-site Disposal Alternative[a] ..... 3-8
Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options ..... 5-3
Table 5-2. Alternatives Assembly, RI/FS for CERCLA Waste Disposal ..... 5-19
Table 6-1. Final Design Topics and Considerations ..... 6-34
Table 6-2. Summary of EMWMF Lessons Learned ..... 6-46
Table 6-3. Candidate Waste Stream As-generated Volumes by Waste Type, Material Type, and Disposal Facility for Off-Site Disposal Alternative with 25% Uncertainty ..... 6-48
Table 7-1. Summary of the On-site Disposal Alternative Costs ..... 7-19
Table 7-2. EMDF Impacted Areas and Disposal Capacity at the EBCV Site ..... 7-21
Table 7-3. Summary of Off-site Disposal Alternative (Options 1 and 2) Costs ..... 7-28
Table 7-4. Comparative Analysis Summary for Disposal of ORR CERCLA Waste ..... 7-31
Table 7-5. Comparison of Risk Factors for On-site and Off-site Disposal Alternatives, All Shipments ..... 7-36

# ACRONYMS

| | |
|---|---|
| ALARA | as low as reasonably achievable |
| ALR | action leakage rate |
| ANA | aquatic natural area |
| ARAP | Aquatic Resources Alteration Permit |
| ARAR | applicable or relevant and appropriate requirement |
| ARRA | American Recovery and Reinvestment Act of 2009 |
| AWQC | ambient water quality criteria |
| B | Billion |
| BCV | Bear Creek Valley |
| BCBG | Bear Creek Burial Grounds |
| BHHRA | Baseline Human Health Risk Assessment |
| BMP | best management practice |
| BNSF | Burlington Northern Santa Fe |
| BV | Bethel Valley |
| BY/BY | Boneyard/Burnyard |
| CA | composite analysis |
| CARAR | Capacity Assurance Remedial Action Report |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CFR | Code of Federal Regulations |
| COPC | contaminant of potential concern |
| D&D | deactivation and decommissioning |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| DQO | data quality objectives |
| DU | depleted uranium |
| EBCV | East Bear Creek Valley |
| ELCR | Excess Lifetime Cancer Risk |
| EM | Office of Environmental Management |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| ETTP | East Tennessee Technology Park |
| FFA | Federal Facility Agreement |
| FFS | Focused Feasibility Study |

| | |
|---|---|
| FS | Feasibility Study |
| FWD | Federal Waste Disposal |
| FY | Fiscal Year |
| GCL | geosynthetic clay liner |
| HA | habitat area |
| HCDA | Hazardous Chemical Disposal Area |
| HDPE | high-density polyethylene |
| HI | Hazard Index |
| IFDP | Integrated Facility Disposition Program |
| IHB | Indiana Harbor Belt |
| IWM | Integrated Water Management |
| LCRS | leachate collection and removal system |
| LDR | land disposal restriction |
| LDRS | leak detection and removal system |
| LFRG | Low-Level Waste Disposal Facility Federal Review Group |
| LLW | low-level (radioactive) waste |
| LMD | legacy material disposition |
| M | million |
| MCC | Modular Concrete Canister |
| MCL | maximum concentration limit |
| MEI | maximum exposed individual |
| MV | Melton Valley |
| NA | natural area |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NEPA | National Environmental Policy Act of 1969 |
| NNSA | National Nuclear Security Administration |
| NNSS | Nevada National Security Site |
| NRC | Nuclear Regulatory Commission |
| NT | Northern Tributary |
| O | Order |
| OMB | Office of Management and Budget |
| OREM | Oak Ridge Office of Environmental Management |
| ORERP | Oak Ridge Environmental Research Park |
| ORNL | Oak Ridge National Laboratory |
| ORO | Oak Ridge Office |
| ORR | Oak Ridge Reservation |

| | |
|---|---|
| ORSSAB | Oak Ridge Site Specific Advisory Board |
| OSHA | Occupational Safety and Health Administration |
| P&A | plugging and abandonment |
| PCB | polychlorinated biphenyl |
| PCCR | Phased Construction Completion Report |
| PM | particulate matter |
| PPE | personal protective equipment |
| PreWAC | Preliminary Waste Acceptance Criteria |
| PWTC | Process Waste Treatment Complex |
| RA | Reference Area |
| RAO | remedial action objective |
| RAWP | Remedial Action Work Plan |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RDR | Remedial Design Report |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| RWCM | Radioactive Waste Management Complex |
| S&M | surveillance and maintenance |
| SPCC | safety and spill prevention, control, and countermeasures |
| SRF | size reduction facility |
| TBC | to be considered |
| TCLP | toxicity characteristic leaching procedure |
| TDEC | Tennessee Department of Environment and Conservation |
| TRU | transuranic |
| TSCA | Toxic Substances Control Act of 1976 |
| TSDRF | treatment, storage, disposal, and recycling facility |
| UCL | upper confidence limit |
| UEFPC | Upper East Fort Poplar Creek |
| UPF | Uranium Processing Facility |
| U.S. | United States |
| VR | volume reduction |
| WAC | waste acceptance criteria |
| WBCV | West Bear Creek Valley |
| WCS | Waste Control Specialists LLC |
| WGF | waste generation forecast |
| WIPP | Waste Isolation Pilot Plant |

| | |
|---|---|
| WL | waste lot |
| WMI | Waste Management, Inc. |
| WWSY | White Wing Scrap Yard |
| Y-12 | Y-12 National Security Complex |

# EXECUTIVE SUMMARY

This Remedial Investigation/Feasibility Study (RI/FS) report evaluates disposal alternatives for future waste generated by cleanup actions at the United States (U.S.) Department of Energy's (DOE) Oak Ridge Reservation (ORR) and associated sites. The report follows previous Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) evaluations, decisions, and actions that resulted in an existing on-site disposal facility, referred to as the Environmental Management Waste Management Facility (EMWMF). Because EMWMF is predicted to reach capacity before all estimated ORR cleanup waste has been generated and dispositioned, DOE has determined the need to evaluate disposal alternatives for future CERCLA waste.

As lead agency for ORR cleanup, DOE is working with the other Federal Facility Agreement (FFA) parties (DOE 1992), the U.S. Environmental Protection Agency and Tennessee Department of Environment and Conservation, to evaluate alternatives for disposal of low-level waste (LLW), mixed waste, and certain classified waste. Mixed waste has components of radiological and other regulated waste such as Resource Conservation and Recovery Act of 1976 (RCRA) hazardous waste and/or Toxic Substances Control Act of 1976 (TSCA) regulated waste. In addition to satisfying CERCLA requirements, this RI/FS incorporates National Environmental Policy Act of 1969 (NEPA) values in accordance with the DOE's Secretarial Policy on NEPA (DOE 1994).

This report will serve as the initial document supporting DOE's selection of a preferred alternative for CERCLA waste disposition post-EMWMF. The EMWMF RI/FS (DOE 1998) was the first document in the CERCLA process that led to the construction and operation of EMWMF. As a follow-on to that process, this RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions. Consistent with the EMWMF RI/FS, this RI/FS analyzes three alternatives:

1. **No Action Alternative:** No coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions.
2. **On-site Disposal Alternative:** Consolidated disposal of most future waste in a newly-constructed, engineered waste disposal facility (i.e., landfill) on the ORR, referred to as the Environmental Management Disposal Facility (EMDF). The proposed EMDF site is located in East Bear Creek Valley near the existing EMWMF.
3. **Off-site Disposal Alternative:** Transportation and disposal of future waste at approved, off-site disposal facilities.

## RI/FS APPROACH

Unlike a typical remediation project, the purpose of this RI/FS is not to evaluate alternatives for cleaning up a contaminated site. The purpose of this RI/FS is to develop, screen, and evaluate the alternatives for waste disposal against CERCLA criteria designed to address statutory requirements and feasibility. The RI/FS provides support for an informed selection decision about disposal of CERCLA waste.

Remedial decisions for cleanup of individual sites are outside the scope of this evaluation; consequently, a conventional Baseline Human Health and Risk Assessment is not relevant to the RI/FS evaluation. For the remediation projects that will generate future waste streams to be disposed after EMWMF reaches maximum capacity, the RI/FS lists the applicable existing CERCLA documents that contain risk evaluations and identifies the projects for which a CERCLA risk evaluation and decision document have yet to be completed.

The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are:

- Prevent direct or indirect exposure of a human receptor to future-generated CERCLA waste that exceeds a human health risk of $10^{-4}$ to $10^{-6}$ Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1 to 3[1].
- Prevent releases of future-generated CERCLA waste, or waste constituents that exceed a human health risk of $10^{-4}$ to $10^{-6}$ ELCR or an HI of 1 to 3[1], or that do not meet applicable or relevant and appropriate requirements (ARARs) for environmental media. This is accomplished through compliance with chemical specific ARARs, maximum concentration limits in waters that are current or potential sources of drinking water considering site-specific background levels, or risk-based levels for chemicals without ARARs.
- Prevent ecological exposure to future-generated CERCLA waste.
- Facilitate timely cleanup of ORR and associated facilities.

The development and analysis of alternatives for the RI/FS relies on the established RAOs and estimates of future waste volumes and characteristics.

## WASTE VOLUMES AND CHARACTERIZATION

This RI/FS presents waste volume estimates for future CERCLA waste disposal, including generation rates, and information about waste characteristics of future CERCLA waste streams. The waste volumes and characterization are used as the basis for development and analysis of the disposal alternatives.

For the RI/FS waste volume estimates, waste streams are delineated by both waste type (regulatory classifications) and material type (waste forms). Waste types are LLW and mixed waste with components of radiological and other regulated waste (LLW/RCRA, LLW/TSCA). Material types may consist of various forms of soil and debris. Soil includes soil, sediment, and sludge. Debris includes a mixture of various forms of construction and demolition debris. For the RI/FS evaluation, material types are defined as either soil or debris with no further definition of soil or debris type. This approach is consistent with many waste volume estimates for future projects that delineate material types as soil or debris only.

The "as-generated" waste volume estimate was developed by using existing Waste Generation Forecast data and modifying it for use in the RI/FS. Updated waste volume estimates for specific projects were used where available. Projects and corresponding waste volume estimates were sequenced based on an assumed funding scenario of $420 Million (M) per year for ORR cleanup projects, with ORR CERCLA waste generation occurring through Fiscal Year (FY) 2043.

The as-generated waste volume estimate was used to calculate the "as-disposed" waste volume estimate in order to predict when maximum EMWMF capacity would be reached. Cumulative CERCLA waste capacity demand estimates through FY 2043, including a 25% uncertainty allowance, show maximum capacity of EMWMF (2.18 M $yd^3$) is estimated to be reached in FY 2024. Based on these estimates, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2022, providing up to a two-year overlap of the facilities to allow operational flexibility. In addition to uncertainty in future waste volume estimates, other factors such as funding, project sequencing, and contracting can impact project implementation plans and the RI/FS waste volume estimates. A lower annual funding scenario could delay EMWMF reaching maximum capacity and the operational start of a new facility. Likewise, a higher funding scenario could result in EMWMF reaching capacity sooner.

---

[1] Non-carcinogenic contaminant exposure is modeled to determine preliminary waste acceptance criteria limits based on an HI equal or less than 1.0 for up to 1,000 years. As the modeled time increases, prediction uncertainty increases and therefore the target HI is increased to 3.0 past 1,000 years. Likewise, an order of magnitude target ELCR increase (e.g., from $10^{-5}$ to $10^{-4}$) for the pre-1,000 year modeling to the post-1,000 year modeling is considered for carcinogenic contaminant modeling.

The approach used to estimate as-disposed waste volumes follows a methodology similar to calculations used to predict as-disposed volumes in the Capacity Assurance Remedial Action Report (now reported in the Phased Construction Completion Report) prepared annually for EMWMF. The capacity needed for disposal of future CERCLA waste depends on the as-generated waste volumes, the relative mix of debris waste and waste suitable for use as fill material, and volume reduction efforts such as waste sequencing. The conceptual design capacity of the proposed EMDF site for the On-site Disposal Alternative is 2.5 M $yd^3$.

The as-generated waste volume estimate used in the RI/FS for FY 2022 through FY 2043 (post-EMWMF) is approximately 1.95 M $yd^3$, including a 25% uncertainty allowance. Approximately 70% of the 1.95 M $yd^3$ is debris. This estimate is used as the basis for analyzing waste shipments in the Off-site Disposal Alternative. Calculation of the as-disposed volume (from the as-generated volume) for the On-site Disposal Alternative indicates the capacity required to dispose of this waste on-site is 2.2 M $yd^3$.

Because detailed characterization data do not exist for many of the individual deactivation and decommissioning and remediation projects, characterization of future waste streams for this RI/FS is based on available data for waste disposed at EMWMF. This methodology relies on the assumption that available data for waste disposed at EMWMF approximately represent the waste characteristics of future waste streams with the exception of mercury-contaminated waste. Data sets of radionuclide contaminants were derived from EMWMF waste data to calculate transportation risk for the On- and Off-site Disposal Alternatives and risk associated with natural phenomena (wind-borne [tornadic] contamination risk) for the On-site Disposal Alternative.

Demolition of several large facilities at the Y-12 National Security Complex will result in large volumes of mercury-contaminated debris. This debris is assumed to be treated and disposed by macroencapsulation within EMDF, as part of the On-site Disposal Alternative, or transported off-site for compliant treatment/disposal in the Off-site Disposal Alternative.

## REMEDIAL ALTERNATIVES

Three alternatives were developed and evaluated for this RI/FS: No Action Alternative, On-site Disposal Alternative, and Off-site Disposal Alternative.

### *No Action Alternative*

The No Action Alternative provides a benchmark for comparison with the action alternatives, and is required under CERCLA. Unlike the typical No Action Alternative which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative for this RI/FS is based on the assumption that a comprehensive, site-wide strategy to address the disposal of waste resulting from any future CERCLA remedial actions at ORR after EMWMF capacity is reached would not be implemented. Future waste streams from site cleanup that require disposal after EMWMF capacity is reached would be addressed at the project-specific level.

### *On-site Disposal Alternative*

The On-site Disposal Alternative would provide consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, engineered facility. This alternative includes designing and constructing a landfill and support facilities similar to EMWMF; receiving waste that meets the facility's waste acceptance criteria (WAC); and managing the waste and landfill during the construction, operations, closure, and post-closure periods. A proposed site for EMDF near the existing EMWMF was identified utilizing a screening evaluation that included many sites identified in a previous 1996 siting study (DOE 1996) as well as other possible favorable

locations/footprints. A thorough examination is presented that first considers 16 sites. Secondary screening narrows consideration to ten sites, with two of those sites offering multiple (two) landfill footprints. Ultimately, four sites are compared in detail, with the final proposed site adjacent to EMWMF (see Figure ES-1) selected based on two concluding factors: (1) site is in a brownfield area of the ORR, surrounded by other waste management areas with a future land use designated as *DOE-Controlled Industrial Use* and (2) site is adjacent to EMWMF offering infrastructure cost savings.

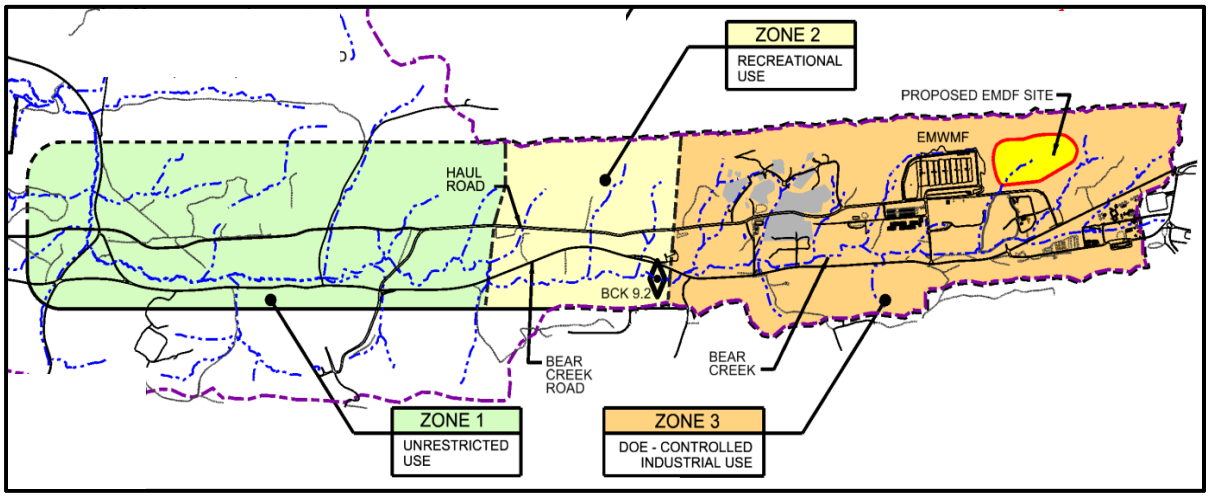



**Figure ES-1. Bear Creek Valley Zones and Proposed Site for the Proposed EMDF**

By design, the analytic WAC of a new facility would ensure risk to future receptors would not exceed risk criteria ($10^{-5}$ ELCR or an HI of 1 in the first 1,000 years and maximum concentration limits in current or potential drinking water). This RI/FS provides results of fate and transport analysis which demonstrate that analytic preliminary waste acceptance criteria (PreWAC) for the proposed EMDF would meet applicable risk and dose criteria and be protective. Based on these results, it can be concluded that most future CERCLA waste to be generated after EMWMF reaches maximum capacity would be able to be disposed at the proposed EMDF. It is acknowledged that the PreWAC identified in this RI/FS are a preliminary data set provided to show viability of land disposal at the proposed site. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC would be approved for the new facility by FFA parties prior to waste receipt and documented in a primary FFA document, the WAC Attainment Plan.

The approximate area which may be cleared or otherwise impacted by construction and operations would be up to 92 acres for the proposed EMDF site. The landfill footprint would be kept permanently cleared, representing long-term impact on the direct use of land of up to 70 acres. Locating the proposed EMDF immediately east of EMWMF offers advantages such as sharing existing EMWMF infrastructure and being in close proximity to existing utilities.

The estimated average annual project cost for implementing the On-site Disposal Alternative at the proposed EMDF site is $18.1M (FY 2012 dollars) over a project life-cycle of 43 years. In terms of Present Worth (FY 2015 dollars) this is $20.3M annually for 43 years. The cost estimate is based on a conceptual design that yields an approximate landfill waste disposal capacity (i.e., air space volume) of 2.5 M $yd^3$, but does not include the cost for construction of the sixth cell as the current waste generation

forecast (with a 25% volume contingency) would only fill five cells.[2] To compare this directly to the off-site alternative, which has a life-cycle timeframe of 22 years, these costs would equate to an average annual project cost of $35.3M (FY 2012 dollars) or $39.6M (Present Worth). All costs include contingency.

***Off-site Disposal Alternative***

Under the Off-site Disposal Alternative, future CERCLA waste would be transported off-site for disposal at approved disposal facilities, primarily by rail transport. Representative routes were assumed for the cost estimate and risk evaluation. Two options are analyzed. In Option 1, approximately 92% of the waste (non-classified LLW and LLW/TSCA waste) would be shipped to the Nevada National Security Site (NNSS) in Nye County, Nevada, by rail transport from the East Tennessee Technology Park (ETTP) to a transfer facility in Kingman, Arizona. Intermodal containers would then be transferred to trucks for the final leg of the shipment to NNSS. Mixed (LLW/RCRA) waste would be shipped for treatment and disposal by rail shipment from ETTP directly to Energy*Solutions*, Clive, Utah, or Waste Control Specialists, Andrews, Texas. Classified LLW waste would be shipped by truck to NNSS. In the second Option, the non-classified LLW and LLW/TSCA waste would be shipped by rail to Energy*Solutions* for disposal; the remaining waste would be disposed as per Option 1.

The estimated average annual project cost for implementing the Off-site Disposal Alternative Option 1 is $85.1M (FY 2012 dollars) or $96.3M (Present Worth, FY 2015) with contingency. Option 2 is a lower estimate, $73.0M (FY 2012 dollars) or $87.3M (Present Worth), due mainly to the ability to rail ship the waste directly to the disposal site. Both options have a 22 year life-cycle timeframe.

Key assumptions regarding responsibilities of the waste generators are common to both the On- and Off-site Disposal Alternatives. The waste generators are considered to be responsible for removal of waste during cleanup actions; waste characterization and treatment as necessary to meet disposal facility WAC; and local transport to the EMDF (On-site Disposal Alternative) or the ETTP transfer facility (Off-site Disposal Alternative). Except for the cost for purchase of waste containers for transport to off-site facilities, costs associated with generator responsibility elements are not included in the cost estimates.

**VOLUME REDUCTION**

Volume reduction (VR) approaches and potential benefits for the On-site and Off-site Disposal Alternatives are evaluated in this RI/FS. Sequencing of waste generation, as much as possible, is recommended for the on-site alternative to reduce the amount of clean fill required by utilizing soil waste as fill. Waste segregation is recommended for either alternative, to maximize recycle or disposal of wastes in less costly industrial landfills. Both of these VR methods are implemented by generators.

For the On-site Disposal Alternative, VR processing of suitable waste debris was determined to be a net expense; that is, the construction and operation of a VR facility cost more to implement than the savings it would achieve through reducing volume and conserving air space in the EMDF (e.g., building a smaller facility). For the Off-site Disposal Alternative, VR processing could result in an avoided shipping volume of over 160,000 $yd^3$ and a net estimated cost savings of up to $81M in 2012 dollars, making it feasible. Thus VR is included as part of the Off-site Disposal Alternative for Option 1 only (primarily disposal at NNSS). Option 2, Energy*Solution*s disposal, uses transport containers that are limited by weight rather than volume, thus VR is not cost effective for Option 2.

[2] A phased construction of the on-site facility is planned. Cells 1 and 2 will be constructed initially (Phase I) followed by Phase II, Cells 3 and 4 construction. The third Phase will involve construction of Cell 5 and if needed Cell 6, although this RI/FS On-site Disposal Alternative assumes that Cell 6 is not constructed.

## EVALUATION CRITERIA COMPARISON

In the CERCLA process, alternatives for remedial action are assessed against nine evaluation criteria, which include two threshold criteria, five primary balancing criteria, and two modifying criteria. All three alternatives evaluated would meet the two threshold criteria of overall protection of human health and the environment and compliance with ARARs. For the On-site Disposal Alternative, two waivers would be requested:

1. A waiver of one hydrologic condition ARAR would be requested on the basis of equivalent protectiveness provided by the landfill design.
2. A waiver from Land Disposal Restrictions prohibition on placement of untreated waste in the landfill for the purpose of treatment would be requested (as an interim measure).

The two final modifying criteria, state and community acceptance, will be addressed in the Record of Decision (ROD) following state and public comments on the Proposed Plan. The ROD will address a comprehensive decision for disposal of waste resulting from the implementation of remedial actions that are specified in separate existing and future CERCLA decisions.

The remaining five primary balancing criteria address performance viability of the alternatives and include: (1) long-term effectiveness and permanence; (2) reductions in toxicity, mobility, and volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost.

*Long-term Effectiveness and Permanence:* The No Action Alternative may not meet the RAO to facilitate timely cleanup of the ORR. Both the On-site and Off-site Disposal Alternatives would be considered protective long-term of human health and the environment by disposal of waste in a landfill designed for site-specific conditions. Off-site disposal at Energy*Solutions* and NNSS may be more effective long-term in preventing exposure to or migration of contamination because of the climatic and geologic conditions. Fewer receptors exist in the vicinity of Energy*Solutions* and NNSS than near the ORR. The Off-site Disposal Alternative would be more effective in preventing future releases on the ORR because CERCLA waste would be disposed in off-site facilities.

*Reductions in Toxicity, Mobility, and Volume through Treatment:* The No Action Alternative does not consider consolidated management of CERLCA generated wastes. Although the disposal alternatives evaluated do not directly establish waste treatment requirements, wastes would be treated as needed to meet WAC either before shipment or at the receiving facility (e.g., the Energy*Solutions* facility has treatment capabilities). Waste treatment prior to shipment would remain the responsibility of the waste generator. Waste treatment by the generator or at the receiving facility could reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied.

*Short-term Effectiveness:* In terms of short-term effectiveness, risk to human health is the most differentiating element. Under all the alternatives evaluated, risks to workers and the community from actions at the remediation sites and disposal facilities would be controlled to acceptable levels through compliance with regulatory requirements and health and safety plans. However, for the No Action Alternative, more wastes may be managed in place; less aggressive remediation would result in fewer short-term risks. For both disposal alternatives, the most significant risk of death or injury would result from waste transportation. Off-site transportation carries a much higher risk to human health than does on-site transportation, due to the public roads/railroads travelled and the long distances involved (see Figure ES-2). The estimated risk increase varies depending on the receptor and whether the risk is radiological or vehicular, but can range from two times higher to as much as four orders of magnitude higher. Radiation exposure and vehicle-related risk would significantly increase if rail shipments in the Off-site Disposal Alternative were replaced by truck shipments (for Option 1 the majority of shipments evaluated in the Off-site Disposal Alternative are by rail to NNSS with a final short truck transport leg).

Likewise, if the majority of waste were shipped to Energy*Solutions* in Utah, the off-site risk would decrease by a factor of about three, but still significantly outweigh the on-site risk.

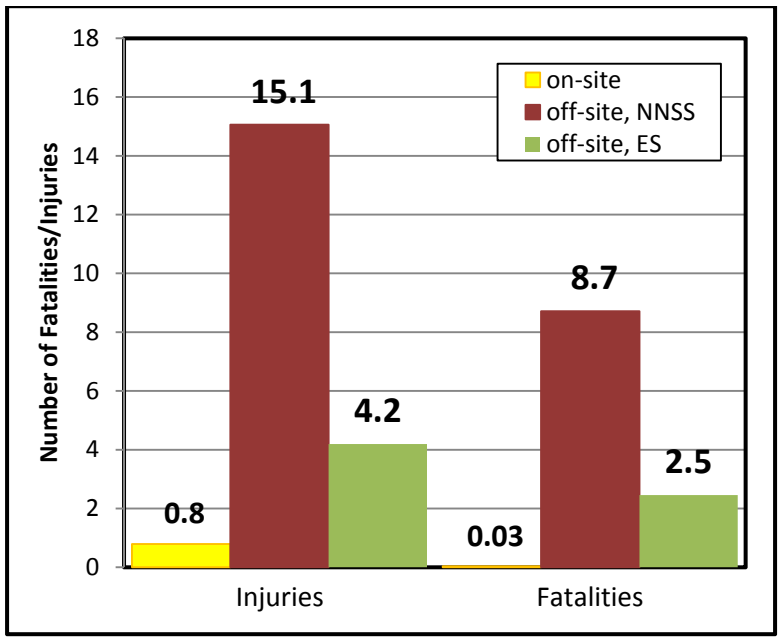



**Figure ES-2. Transportation Risk (Vehicle Accidents/Emissions) for On-site and Off-site Alternatives**

*Implementability:* Implementability for the No Action Alternative is not applicable. In terms of implementability of the two disposal alternatives, availability of services and materials is most significant. Currently services and materials needed for pre-construction investigations, construction, and operation of the On-site Disposal Alternative, and transportation and disposal capacity for the Off-site Disposal Alternative, are available. No impediments to future operation of the On-site Disposal Alternative are likely to arise. State equity issues and reliance on off-site facilities introduce an element of uncertainty into the continued viability of off-site disposal during the anticipated operational period. Because CERCLA waste generation on the ORR is projected to continue through the 2043 timeframe, on-site disposal would provide much greater certainty that sufficient disposal capacity is actually available at the time the wastes are generated.

*Cost:* The No Action Alternative does not have a direct cost; costs would reside within each project, and efficiencies that result from consolidation and economies of scale would not be achieved. The Off-site Disposal Alternative (Option 2) estimated cost for disposal of the projected volume of CERCLA waste is $824/yd$^3$ (FY 2012 dollars) or $986/yd$^3$ (Present Worth). This is approximately two times the estimated cost for disposing of the waste in the On-site Disposal Alternative ($399/yd$^3$ [FY 2012 dollars] or $447/yd$^3$ [Present Worth]). Risks identified for the Off-site Disposal Alternative outnumber and exceed in cost the risks identified for the On-site Disposal Alternative. Table ES-1 is a summary of identified risks, with indications as to the extent the cost estimate would be affected, and indications as to the likelihood of the risk being realized. Two significant risks, which are not included in the off-site cost estimate although they will almost certainly be realized, were identified.

The transport of waste by truck from the demolition site to the transloading station at the East Tennessee Technology Park will likely be considered travel on public roads as that site moves to become a public industrial park, thus incurring high additional costs to meet applicable requirements.

Fuel surcharges and size/weight/water content surcharges have not been included as part of the off-site estimate. Additional fuel surcharges will almost certainly be incurred, and other surcharges will be incurred (especially in terms of large pieces of equipment) resulting in higher off-site costs. They remain as risks because the cost may or may not be significant, and cannot be quantified at this time.

**Table ES-1. Risks and Cost Implications for On-site and Off-site Disposal Alternatives**

| **On-site Disposal Alternative** | | |
|---|---|---|
| **Risk** | **Cost Implications** | **Probability of Occurrence** |
| • Material and/or labor cost increases during construction or operation | Moderate cost | Moderate |
| • Waste not meeting facility WAC and requiring off-site disposal | Moderate cost | Unlikely |
| • Compliance issues/operational issues requiring corrective actions | Low cost | Unlikely |
| • Increased long-term surveillance and maintenance costs | Moderate cost | Moderate |
| • Disposal site shutdown during operations | High cost | Unlikely |
| • Post-closure, extreme maintenance issues | High cost | Unlikely |
| **Off-site Disposal Alternative** | | |
| **Risk** | **Cost Implications** | **Probability of Occurrence** |
| • Public road travel from demolition site to rail transloading station located at ETTP | High cost | Very likely |
| • Fuel, debris size/weight, soil water content surcharges | Low to high cost | Very likely |
| • Shutdown of off-site facilities due to violations | Very high cost | Unlikely |
| • Unavailability of facilities due to state equity issues | Very high cost | Unlikely |
| • Multi-state travel; equity issues | Moderate to very high cost | Moderate |
| • Long-term DOE liability at an off-site location | Moderate to very high cost | Unlikely |

## PREFERRED ALTERNATIVE

The CERCLA evaluation process identified the On-Site Alternative as the preferred alternative because it achieves remedial action goals at the lowest risk and cost.

## SITE SELECTION AND CHARACTERISTICS

Numerous sites within the ORR were evaluated and all but three were eliminated from further consideration. The three remaining sites, White Wing Scrap Yard (WWSY), West Bear Creek Valley (WBCV), and East Bear Creek Valley (EBCV) were examined in closer detail. All three sites encompass sufficient land area and all are within the ORR. The WWSY site was eliminated because it is adjacent to State Route 95 and would require extensive additional infrastructure (access road, power, water, communications, office space, parking) construction in order to be used. Underlying geology is complex, and karst may be present on the west side of the site. Further, the site is adjacent to sensitive habitats that contain threatened or endangered plant and animal species.

The WBCV and EBCV sites are both situated on the south flank of Pine Ridge and have very similar geology and hydrogeology. Both are adjacent to the existing Haul Road. The WBCV site is marginally better than the EBCV site from a construction standpoint. It was eliminated, however, because land use in the western third of the Bear Creek Valley is potential future recreational, the site is closer to the karstic Maynardville Limestone and Bear Creek, and would require substantial additional infrastructure (power, water, communications, office space, parking). The WBCV site is less than 0.5 mile from State Route 95, raising public access and security concerns.

The EBCV site was selected as the preferred site because it is adjacent to the current EMWMF and can therefore share existing infrastructure. EBCV has been used for waste disposal since World War II, and area land use is and will remain DOE-Controlled Industrial for the foreseeable future. The EBCV is approximately four miles from a public highway and 0.84 mile from the nearest residential area. It is on the south flank of Pine Ridge immediately east of EMWMF and north of the existing Haul Road. A small stream, Northern Tributary 3, bisects the site, and there are several small wetlands within the area.

The geology and hydrogeology of Bear Creek Valley have been the subject of numerous studies, although none directly addressed the preferred EMDF site. There were no borings or wells in the EMDF site. Based on these studies, the proposed EMDF site is underlain by geologic units that are predominantly shales, mudstones, siltstones, and sandstones with thin limestone beds. Beds dip at an average of 45° to the SE, and micro- to meso-scale folds are evident. Ground water in this area occurs and moves primarily in fractures and along bedding planes. Ground water flow is anisotropic, tending to flow along strike (SW-NW) and down dip until intersecting fractures that allow flow to move across beds to reach Bear Creek. Most ground water flow occurs in the upper 100 feet, and especially near the contact of the soil/saprolite with unweathered bedrock. Ground water discharges to small streams flowing from Pine Ridge into Bear Creek and directly to Bear Creek and the Maynardville Limestone subsurface conduits.

A limited Phase I Site Characterization study was conducted to provide site-specific geologic and hydrogeologic data for the proposed site. Five shallow-deep well pairs and three surface water flumes were installed to measure water levels, stream flow, and water quality parameters. Two wells were cored to a depth of 100 feet, and results confirmed that dominant rock types are thin-bedded siltstones and shales, with minor thin limestones. Soil and weathered rock (saprolite) occur to depths of 20 to 30 feet, and evidence of weathering was observed at even greater depths. Calcite-filled fractures are common in some zones, but open fractures are rather sparsely distributed; no evidence of conduits or karst was observed. Ground water depth in both shallow and deep wells exhibits response to rainfall events, then slowly declines to base level within a few days. Temperature in shallow wells and some deep wells also responds to rain events, suggesting that actual flow is occurring. Temperature in two deep wells does not respond to rain events, suggesting that the ground water level changes in those wells may be pressure pulses, not actual flow.

Hydrographs of surface water show a rapid rise in response to rain, then rapid declines to near base flow conditions. One well pair on the flank of Pine Ridge is artesian, indicating that at least some of the fracture system is under confined conditions.

This page intentionally left blank.

# 1. INTRODUCTION

This document is a Remedial Investigation/Feasibility Study (RI/FS) to evaluate disposal alternatives for waste generated from cleanup actions implemented under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) at the United States (U.S.) Department of Energy's (DOE) Oak Ridge Reservation (ORR). The report follows previous CERCLA evaluations, decisions, and actions that resulted in an existing on-site disposal facility, referred to as the Environmental Management Waste Management Facility (EMWMF). Because the EMWMF is predicted to reach capacity before all estimated ORR cleanup waste has been generated and dispositioned, DOE has determined the need to evaluate disposal alternatives for future CERCLA waste.

## 1.1 BACKGROUND

DOE is responsible for site-wide waste management and environmental restoration activities at the ORR under its Office of Environmental Management (EM) Program at the national level, and locally under the Oak Ridge Office of Environmental Management (OREM) Program. The OREM Program is responsible for minimizing potential hazards to human health and the environment associated with contamination from past DOE practices and addressing the waste management and disposal needs of the ORR. Under the requirements of the ORR Federal Facility Agreement (FFA) (DOE 1992) established between DOE, the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation (TDEC), all environmental restoration activities on the ORR are performed in accordance with CERCLA.

The 33,542-acre ORR is mostly within the city limits of Oak Ridge, Tennessee, which is approximately 12.5 miles west-northwest of Knoxville in Roane and Anderson counties (see Figure 1-1). The figure includes a map of the three major industrial research and production installations on the ORR managed by DOE and originally constructed as part of the World War II-era Manhattan Project: East Tennessee Technology Park (ETTP), formerly the K-25 Site; Oak Ridge National Laboratory (ORNL); and Y-12 National Security Complex (Y-12). Figure 1-1 also shows the location of the existing EMWMF Site and a potential new facility referred to as the Environmental Management Disposal Facility (EMDF) evaluated in this RI/FS.

The OREM Program's major focus has been CERCLA remediation of facilities within the installations that are contaminated by historical Manhattan Project and Cold War activities. This cleanup mission is projected to take the next three decades to complete and result in large volumes of radioactive, hazardous, and mixed waste requiring disposal.

The principal mission of ETTP was uranium enrichment, which has been completed, and the facilities and site are undergoing deactivation and decommissioning (D&D)[3] and remediation under CERCLA. ORNL currently and historically has hosted a variety of research and development facilities and nuclear reactors under DOE. Y-12 has served several missions: uranium enrichment, lithium refining, nuclear weapons component manufacturing, and weapons disassembly, and continues to perform in some of these capacities under direction of the National Nuclear Security Administration (NNSA). Over the past several years, DOE, NNSA, and their contractors have made significant cleanup progress at all three sites.

[3] The acronym D&D encompasses a range of disposition activities, including transition, stabilization, deactivation, cleanout, decontamination, decommissioning, demolition, and restoration.

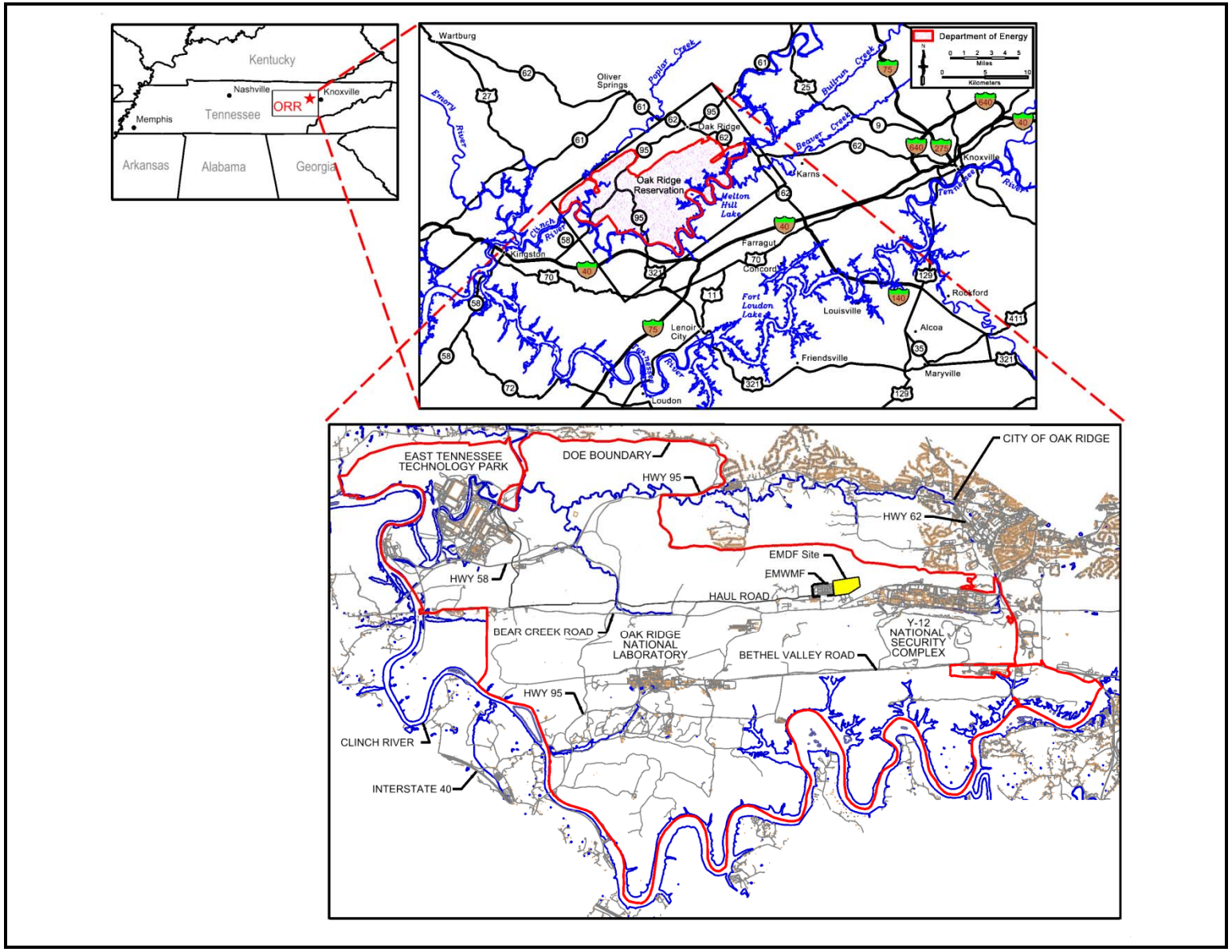



**Figure 1-1. Oak Ridge Reservation, EMWMF, and Proposed EMDF Site Locations**

A 1999 Record of Decision (ROD) (DOE 1999) authorized construction of a facility located on the ORR to provide permanent disposal for radioactive, hazardous, and mixed wastes that present unacceptable risks to human health and the environment in their current setting at ORR and associated sites. This facility, EMWMF, has been constructed and is accepting CERCLA cleanup wastes. The capacity of EMWMF is 2.2 Million (M) $yd^3$ as authorized by the ROD and a subsequent Explanation of Significant Difference (DOE 2010b).

A widening of the scope of the OREM Program has occurred since the original waste estimates were made in the RI/FS that led to the construction of EMWMF (referred to herein as the EMWMF RI/FS) (DOE 1998). Extensive, new cleanup actions identified in the Integrated Facility Disposition Program (IFDP) were added by a major modification to the FFA in 2009 (DOE 2009b). Some of the actions have progressed into projects which are being, or recently have been, performed under the American Recovery and Reinvestment Act of 2009 (ARRA). The added cleanup actions, recently completed under ARRA and forecasted to occur over the next three decades, significantly increase the volume of CERCLA waste projected to be generated. The EMWMF ROD (DOE 1999) estimated a waste[4] volume of 280,000 $yd^3$ would require disposal. Currently, a projected waste volume of 1.4 M $yd^3$ will be disposed in EMWMF at the time of its closure. Approximately 1.6 M $yd^3$ of additional CERCLA waste is expected to be generated and require disposal after EMWMF has reached capacity.

## 1.2 PURPOSE

The purpose of this RI/FS is to evaluate alternatives for disposal of CERCLA waste (after EMWMF capacity is reached) that will be generated from cleanup of portions of the ORR, including local sites outside the ORR boundary, but within OREM's domain of responsibility. As lead agency for ORR cleanup, DOE is working with the other FFA parties, EPA and TDEC, to evaluate alternatives for disposal of low-level waste (LLW); hazardous waste regulated under the Resource Conservation and Recovery Act of 1976 (RCRA) and/or hazardous waste regulated under the Toxic Substances Control Act of 1976 (TSCA) that are also LLW (mixed waste); and certain classified waste. This RI/FS was prepared in accordance with CERCLA requirements and incorporates National Environmental Policy Act of 1969 (NEPA) values in accordance with the DOE's Secretarial Policy on NEPA (DOE 1994) and DOE Order (O) 451.1B (DOE 2010c).

This report will serve as the initial document supporting the selection of a preferred alternative for CERCLA waste disposition post-EMWMF. This report will be followed by a proposed plan that presents the preferred alternative to the public, and subsequently by a ROD that documents the selected alternative and addresses public comments on the proposed plan. The ROD will address a comprehensive decision for disposal of waste resulting from the implementation of remedial actions that are specified in separate existing and future CERCLA decisions.

## 1.3 SCOPE AND ORGANIZATION OF REPORT

The EMWMF RI/FS was the first document in the CERCLA process that led to the construction and operation of the EMWMF. As a follow-on to that process, this RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions. Consistent with the EMWMF RI/FS, this RI/FS analyzes three alternatives: no action, on-site disposal in a newly constructed facility on the ORR, and off-site disposal at permitted and licensed facilities. The EMWMF RI/FS analyzed three siting options under the On-site Disposal Alternative:

- East Bear Creek Valley (EBCV), the site that was ultimately selected for the EMWMF

[4] The volumes given are waste debris and soils only (as-generated); does not include additional fill material used in land disposing of waste, nor does it include any uncertainty.

- West Bear Creek Valley (WBCV)
- White Wing Scrap Yard (WWSY)

This RI/FS analyzes a site east of the existing EMWMF, also in EBCV, for the proposed new EMDF (see Figure 1-1) as part of the On-site Disposal Alternative, and provides a multi-stage screening evaluation of other considered sites. The WBCV (two conceptual footprints) and WWSY sites were considered along with other candidate sites and a combination of smaller on-site facilities with off-site disposal, but were eliminated from further evaluation as discussed in Appendix D and Chapter 5.

This document consists of eight chapters and supporting appendices as listed in Table 1-1 and described below.

**Table 1-1. Outline of RI/FS Document Content**

| Chapter | Chapter Title |
|---|---|
| 1 | *Introduction* |
| 2 | *Waste Volume Estimates and Waste Characterization* |
| 3 | *Risk Evaluations* |
| 4 | *Remedial Action Objectives* |
| 5 | *Technology Screening and Alternatives Assembly* |
| 6 | *Alternatives Descriptions* |
| 7 | *Detailed Analysis of Alternatives* |
| 8 | *References* |
| **Appendix** | **Appendix Title** |
| A | *Waste Volume Estimates and Waste Characterization Data* |
| B | *Waste Volume Reduction* |
| C | *On-site Treatment and Disposal Options for Mercury-contaminated waste* |
| D | *On-site Disposal Alternative Site Screening* |
| E | *Preferred Site Description and Characterization* |
| F | *Alternatives Risk Assessment and Fugitive Emissions Modeling* |
| G | *Applicable or Relevant and Appropriate Requirements (ARARs)* |
| H | *On-site Disposal Facility Preliminary Waste Acceptance Criteria* |
| I | *Cost Estimates for On-site and Off-site Disposal Alternatives* |

As with the EMWMF RI/FS, Chapter 2 of this RI/FS, *Waste Volume Estimates and Waste Characterization* corresponds to the "nature and extent of contamination" discussion found in RI/FS documents that addresses individual contaminated sites. While the EMWMF RI/FS relied on estimates of waste volumes and characteristics based on a limited set of existing data for individual sites expected to be remediated, this RI/FS uses information available for the ORR CERCLA cleanup that has been conducted over the last decade, including characteristics of waste disposed and operational experience at the EMWMF.

The EMWMF RI/FS provided an evaluation of baseline risk for the cleanup projects identified at that time. For the remediation projects that will generate candidate waste streams evaluated in this RI/FS, Chapter 3, *Risk Evaluations,* lists the applicable existing CERCLA documents that contain risk evaluations and planned future remediation projects for which a CERCLA risk evaluation and decision document have yet to be completed. Additionally, this Chapter addresses the preliminary risk evaluation of the on-site alternative, and addresses how that risk evaluation will evolve through the CERCLA process.

The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are specified in Chapter 4.

Chapter 5 of the RI/FS, *Technology Screening and Alternatives Assembly*, is based largely on the general response actions, technology types, and process options that were presented in the EMWMF RI/FS, supplemented with new information and lessons learned from ORR cleanup actions and the EMWMF.

Chapters 6 and 7 of the RI/FS describe the alternatives and provide a detailed analysis of alternatives, respectively. Chapter 8 provides references for supporting documents used and cited in the preparation of this report.

Appendices A through I contain supporting data and information.

Appendix A provides supporting waste volume and characterization data for Chapter 2, *Waste Volume Estimates and Waste Characterization*

Appendix B, *Waste Volume Reduction*, contains an evaluation of different potential approaches for reducing the volume of CERCLA waste to be disposed.

Appendix C is an evaluation of options for treating mercury-contaminated debris. It is included since many of the options considered would have portions of scope incorporated into the On-site Alternative.

Appendix D examines multiple on-site disposal locations on the ORR, and evaluates them through a multi-stage screening process to ultimately down-select to a proposed site for the EMDF.

Appendix E provides applicable information about the region, updated as appropriate, and the proposed EMDF site. Site-specific characterization data, completed under a limited Phase I characterization effort, is incorporated in this appendix. The EMWMF RI/FS is a reference for additional information about the regional environmental setting.

Appendix F presents the methodology and results of risk assessments for the On-site and Off-site Disposal Alternatives.

Appendix G provides a discussion and listing of applicable or relevant and appropriate requirements (ARARs) for the On-site and Off-site Disposal Alternatives.

The EMWMF RI/FS contained preliminary analytic waste acceptance criteria (WAC) derived from a risk assessment model. The EMWMF preliminary WAC (PreWAC) was later finalized and approved in the WAC Attainment Plan (DOE 2001b). Appendix H of this RI/FS, *On-site Disposal Facility Preliminary Waste Acceptance Criteria*, provides PreWAC for the proposed EMDF developed using fate and transport analysis to meet applicable risk and dose criteria. The analysis provides the basis for demonstrating that waste disposed in a potential new disposal facility would be protective and a viable disposal option for most CERCLA waste.

Appendix I provides summary cost estimate information and supporting assumptions for the On-site and Off-site Disposal Alternatives.

This page intentionally left blank.

# 2. WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION

This section corresponds to the "nature and extent of contamination" discussion found in RI/FS documents that address individual contaminated sites. It defines CERCLA waste and material types, presents a waste volume estimate for future CERCLA waste disposal, including generation rates, and provides information about waste characteristics of future CERCLA waste streams. The waste volumes and characterization are used as the basis for development and analysis of the On-site and Off-site Disposal Alternatives for this RI/FS as shown in Table 2-1.

The RI/FS and a number of other CERCLA documents for the existing EMWMF were prepared over a decade ago. The environmental cleanup program on the ORR has progressed in a number of ways since that time, including:

- Approval of multiple CERCLA documents which delineate selected remedies for cleanup (e.g., RODs) and describe remedy implementations (e.g., Remedial Action Work Plans).
- Development of project-specific waste generation forecasts (WGFs) that are updated regularly.
- Accumulation of operational experience and knowledge from waste disposal practices at the EMWMF, including:
  - An approved WAC and WAC attainment process.
  - Approved waste profiles with waste characterization data for CERCLA waste streams.
  - An annual *Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Waste Management Facility* (PCCR), formerly the Annual Capacity Assurance Remedial Action Reports (CARARs), to predict disposal capacity needs.

The approach to waste volume estimates and waste characterization in this RI/FS takes into account substantial additional information available for ORR CERCLA cleanup. However, the specific volumes and composition of waste that will be generated from the implementation of future CERCLA actions cannot be fully defined at this time. Development of waste volume estimates and characterization for this RI/FS relies on reasonable assumptions for proposed future remedial actions. Uncertainty is accounted for in the waste volume estimates based on a modified approach to that taken in the Fiscal Year (FY) 2014 PCCR. Uncertainty for this analysis is added as a straight percentage (increase only, to be conservative) to the annual predicted volumes. Uncertainty/sensitivity assumptions are not applied to waste characterization since it serves mainly as an input to risk calculations for on-site versus off-site alternatives (refer to Table 2-1), and that comparison may be made using only a deterministic data set. Looking at variability in that data set would not alter the comparison conclusions.

The volume and characterization estimate processes are outlined below.

Waste Volume Estimates

The RI/FS waste volume estimates of future CERCLA waste were developed based on an individual project basis, as reported in WGF[5] data. The data were modified based on ongoing planning and estimating efforts. Sequencing of waste volumes for this RI/FS was based on the latest information for OREM baseline planning efforts (March 2014). This sequencing has resulted in a slightly different annual waste volume profile from that reported in the FY 2014 PCCR. Additionally, some project volumes were adjusted based on more recent information (e.g., waste volume for K-31 demolition was updated and Alpha-4 waste volume was corrected) which resulted in a slightly lower total forecasted waste volume

[5] WGF download September 2014.

than is reported in the FY 2014 PCCR (~10% lower). A more detailed discussion of the waste volume estimates used in this document is given in Section 2.2.

Waste Characterization

Representative radioactive contaminant concentrations for a unit of waste were determined based on waste characterization profiles, volumes, and weight data for waste disposed through FY 2011 at EMWMF. This source term is used in the transportation and natural disaster risk analysis. As mentioned, no uncertainty is applied to these data. A full discussion of waste characterization is given in Section 2.3.

## 2.1 CERCLA WASTE DEFINITION

Multiple waste and material types are expected to be encountered during future CERCLA actions. Wastes that are excluded from consideration in the RI/FS evaluation are described below. Waste and material types evaluated in this RI/FS are also described below.

### 2.1.1 Exclusions

Several waste types generated on the ORR are excluded from consideration in the RI/FS because they are not acceptable at an on-site facility from a WAC standpoint, are limited to disposal at very specific locations (e.g., DOE transuranic [TRU] waste must be disposed at the Waste Isolation Pilot Plant [WIPP]), or because disposition will be addressed by other established programs or by projects generating the waste. Additionally, many of those waste types are expected to be small volumes (e.g., listed waste) and costs to include them in an on-site facility would far outweigh the cost of individually sending them off-site. Excluded wastes include the following:

- Waste generated by DOE activities that are not CERCLA clean-up actions (e.g., RCRA waste from ongoing operations) is excluded because it is outside the scope of this RI/FS.
- RCRA waste defined as listed waste or that contains a listed waste is excluded (these volumes [listed waste] are projected to be very small, and accommodating them in an on-site alternative would incur on-site costs that exceed the cost of sending the waste off-site).
- RCRA waste that is not land disposal restriction (LDR) compliant (other than mercury-contaminated debris, see Section 2.3.3) is excluded.
- TSCA waste that is not LDR-compliant is excluded.
- High-level waste, Atomic Energy Act 11(e)2 by-product waste, and spent fuel rods are excluded.
- Fissionable materials that have the potential to become critical are excluded.
- Greater than Class C LLW materials are excluded.
- TRU waste is excluded because it will be treated on-site at the TRU Waste Processing Center for disposal at the WIPP.
- Industrial/sanitary (non-regulated) waste is excluded because there are less expensive options for disposal (i.e., ORR Landfills at Y-12).
- Recycle/reuse wastes are excluded because they will be returned to useful services or recycled through commercial vendors.
- No path for disposal wastes, an anticipated small volume of waste with no currently defined path for disposal, are excluded from the RI/FS waste volume estimates, but are qualitatively addressed in Chapter 7.

The current EMWMF WAC Attainment Plan (DOE 2001b) provides additional details regarding excluded materials and conditions of acceptance.

**Table 2-1. RI/FS Alternative Components Supported by Waste Volume Estimates and Waste Characterization**

| RI/FS Alternative | Alternative Component | Location in RI/FS | Items Determined By Waste Volume Estimates | Items Determined By Waste Characterization |
|---|---|---|---|---|
| **On-Site Disposal** | **Conceptual Design and Cost Estimate** | **Chapter 6 and Appendix I** | Disposal capacity for new disposal facility (Based on "as-disposed" waste volume estimate) | |
| | **Schedule** | **Chapter 2 and Appendix I** | When maximum EMWMF capacity is reached and operation of new disposal facility begins (Based on "as-disposed" waste volume estimate)<br><br>When capacity of cells in new disposal facility are reached (Based on "as-disposed" waste volume estimate) | |
| | **Risk (Natural Phenomenon)** | **Appendix F** | | Waste contamination released by a tornado strike |
| | **Risk (Transportation)** | **Appendix F** | Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate) | Waste contaminants in waste shipments |
| | **Preliminary WAC Evaluation** | **Appendix H** | | Preliminary WAC allows most future CERCLA waste to be disposed<br><br>Proposed conceptual design provides adequate assurance that disposed contaminants would pose acceptable risks |
| **Off-site Disposal** | **Conceptual Design and Cost Estimate** | **Chapter 6 and Appendix I** | Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate) | |
| | **Risk (Transportation)** | **Appendix F** | Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate) | Waste contaminants in waste shipments |

### 2.1.2 Waste Types and Material Types

For volume estimates to support the RI/FS, waste streams are delineated by both waste type (regulatory classification) and material type (waste form). Waste types are LLW and mixed waste. Mixed waste has components of radiological and RCRA hazardous waste as defined in 40 Code of Federal Regulations (CFR) 261 Subpart D. Material types may consist of various forms of soil and debris. Soil includes soil, sediment, and sludge. Debris includes a mixture of various forms of construction and demolition debris, including, but not limited to, the following:

- Reinforced concrete, block, brick, and shield walls
- Thick plate steel, structural steel, large piping, heavy tanks, and bridge cranes
- Glove boxes, fume hoods, ventilation ductwork, small piping, and conduit
- Insulation, floor tiles, siding materials, and transite
- Small buildings, small cooling towers, wood framing, and interior and exterior finishes
- Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, and felt
- Containers, furniture, trash, and personal protective equipment (PPE)

For the RI/FS evaluation, material types are defined as either soil or debris with no further definition of soil or debris type. This approach is consistent with many waste volume estimates for future projects that delineate material types as soil or debris only.

There is often a lower level of confidence in waste type and material type volume estimates for future projects due to a lack of characterization data and because detailed planning has not yet occurred. More definitive estimates are made when a project receives funding. For example, the determination of whether the waste type is a RCRA listed waste as identified in 40 CFR 261 Subpart D is part of waste characterization for disposition. Only a few, small volume solid waste streams (<6,000 $yd^3$) projected to contain RCRA “listed wastes" are identified in the OREM program WGF; these are projected for off-site disposal. Future potential sources of listed waste on the ORR include soil contaminated with a listed groundwater plume (e.g., F039) that may be determined to require remediation. Further definition of soil quantities requiring remediation and a determination of whether the soil contains listed waste would occur when project characterization funding is received; however, listed waste will be restricted from disposal in an on-site disposal facility.

### 2.1.3 Wastes that do not Meet Disposal Facility WAC

An evaluation of ORR CERCLA waste disposal practices since FY 2002 shows that between 1% and 4% of total CERCLA waste generated annually[6] was packaged, shipped, and disposed at approved off-site facilities. The waste was shipped off-site because it did not meet the EMWMF WAC or because of other project-specific factors. As discussed in Section 2.3 and Appendix H, respectively:

- The characteristics of future CERCLA waste generated are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002, with the exception of the introduction of mercury-contaminated waste expected from Y-12 cleanup projects. Small amounts of ORNL and Y-12 demolition and remediation waste have been received at EMWMF, and have introduced a broader variety of isotopes than ETTP waste alone. It is expected that with ORNL contributing a higher volume of waste in the future facility those isotopic concentrations will increase, but the representative isotopes are accounted for in the current EMWMF waste profile.
- PreWAC at a new on-site disposal facility would allow most CERCLA waste to be disposed.

Based on the evaluation of CERCLA disposal practices to date and assumptions about similarities in current and future CERCLA waste generation, a small percentage of future total CERCLA waste generated annually is assumed to require shipment off-site. Because it is not a differentiator between the On-site and Off-site Disposal Alternatives, this small percentage of waste is excluded from the RI/FS waste volume estimate information (for both alternatives) and is addressed qualitatively in the alternatives analysis (Chapter 7).

The RI/FS waste volume estimate information below includes only those waste volumes that are projected to meet on-site disposal facility WAC and be either:

- Disposed at a new on-site CERCLA waste disposal facility (following closure of EMWMF) under the On-site Disposal Alternative, or
- Shipped for off-site disposal at an approved facility under the Off-site Disposal Alternative.

## 2.2 RI/FS WASTE VOLUME ESTIMATES

The waste volume estimates included in this RI/FS are limited to future CERCLA waste that will be generated from facility D&D and environmental restoration activities on the ORR. Development of waste volume estimates for this RI/FS relies on waste disposal practices and experiences on the ORR to date and reasonable assumptions about planned future D&D and remedial action activities.

Starting in 2013, reporting of anticipated disposal capacity needs on the ORR is given in the annual *Phased Construction Completion Reports for the Oak Ridge Reservation Environmental Management Waste Management Facility,* rather than the CARARs as has been done in the past. The waste definitions and general reporting approach have not changed with the change of report title. Similar to the definitions in the CARAR (DOE 2012a), there are two types of quantitative waste volume estimates used in this RI/FS, "As-generated" and "As-disposed," as described below:

- "As-generated" waste volumes:
  - Volume estimate based upon excavated bulk volumes of soils/sediments and demolished building debris that includes void space.

[6] Total excludes CERCLA waste disposed at ORR Landfills

- As-generated volumes are roughly equivalent to the volumes expected to be shipped (i.e., used for Off-site Disposal Alternative).
- Includes higher amount of void space and has lower density than as-disposed volumes because as-disposed volumes reflect compaction of the waste in the landfill.

The as-generated volumes are used in project planning to determine the number of truckloads and associated cost and duration necessary to move wastes from the work site to the disposal facility (on-site or off-site).

EMWMF disposal experience has allowed for development of formulas that are used to determine the amount of landfill space (volume) required for a given volume of as-generated waste material. The PCCR uses these formulas, including density conversion factors, to estimate total occupied or as-disposed volume after compaction in the landfill. Estimates of compacted waste and required fill material (fill material is used to fill voids, provide structural stability, and conduct operations; e.g., provide dump ramps) are used to convert as-generated volume to an as-disposed volume in order to predict future landfill space requirements.

- "As-disposed" waste volumes:
  - Volume estimate of waste after disposal in the disposal facility, at which point debris wastes, waste (soil) suitable for use as fill, and clean (additional) fill have been mixed and processed to meet compaction, void space, and operational requirements (i.e., used to determine the volume required for an on-site disposal facility).
  - Physically equivalent to survey results taken quarterly to estimate disposal facility airspace utilized.
  - Includes lower amount of void space than as-generated waste volumes because voids have been filled and it reflects compaction of the waste in the landfill.

The as-disposed waste volume estimate is used to predict when the EWMMF capacity will be reached, a key factor in evaluating post-EMWMF disposal alternatives. The as-disposed waste volume estimate is also used as the basis for determining the required capacity of a new disposal facility for the On-site Disposal Alternative.

As-generated and as-disposed waste volume estimates were developed for the RI/FS as described in the following two sections.

### 2.2.1 As-generated Waste Volume Estimate

The base as-generated waste volume estimate was developed using the most recent existing contractor and planning package WGF data[7] and modifying it for use in the RI/FS as follows:

- Waste to be disposed at facilities other than EMWMF was excluded from the total.
- A correction to the waste volume estimate for Building 9201-4 (Alpha-4) demolition was used.
- Waste soil sequencing was adjusted to better represent actual planning for Y-12 UEFPC remediation work.
- A revision to all assumed mercury-contaminated building debris, to split the debris into two volumes: LLW and mixed LLW. Previously these volumes were considered all LLW under the assumption that waste was treated to meet LDRs at the project level (thus rendering them non-hazardous or only LLW). The revised assumption for this document is that the mixed waste

[7] WGF download September 2014.

(mercury-contaminated) will be treated at the on-site disposal facility and thus will be considered mixed waste as received at the site. The schedule for ORR cleanup projects and associated waste generation used to generate the WGF is based on an assumed $385M - $420M funding scenario[8] for ORR cleanup projects from FY 2015 through FY 2047, with ORR CERCLA waste generation occurring through FY 2043.

The base as-generated waste volume estimate covers the FY 2014 through FY 2043 timeframe and does not include applied uncertainty. The annual estimate for base as-generated waste volumes ranges from about 2,400 $yd^3$ per year to 150,000 $yd^3$ per year as shown in Figure 2-1. These projected volumes are quite variable, and are a result of planned project scheduling and sequencing. Planning this far in advance does not take into account details regarding staging and movement/placement of waste. It is expected that actual execution and operation would "smooth" the profile shown in the figure.

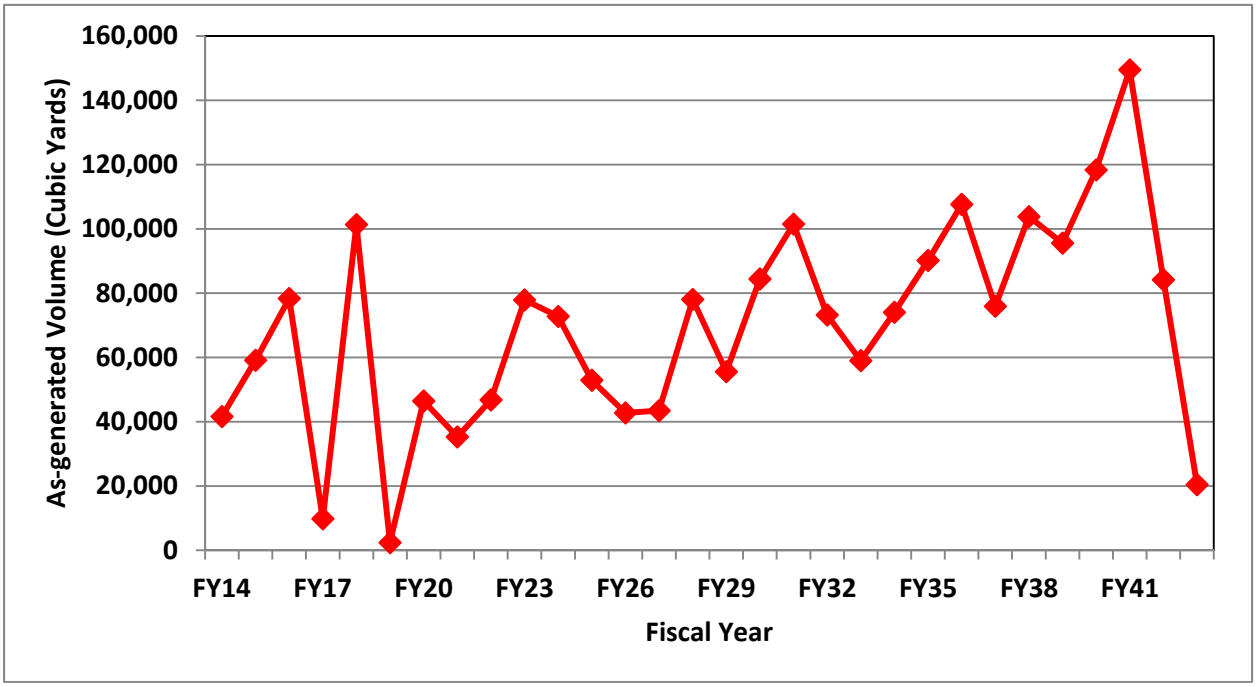



**Figure 2-1. Annual, As-generated Waste Volume Estimates without Uncertainty**

A calculated average of 69,410 $yd^3$ of waste per year is well within the EMWMF annual operational range of waste processed thus far (approximately 40,000 up to 150,000 $yd^3$ per year, which is rather variable).

Using the modified PCCR approach and assumptions about uncertainty to calculate the as-disposed volume described in Section 2.2.2, it is estimated, for the purposes of this RI/FS, that EMWMF will be filled to capacity in FY 2024. Any accelerated waste generation during the FY 2014 to FY 2024 timeframe would require a significantly large increase in funding, and while this is highly unlikely given

[8] The RI/FS waste volume estimate and WGF download is based on an approximation of project sequencing for a scenario that assumes funding of $385M in FY 2015, annual funding of $420M for FY 2016 through FY 2018, and annual funding of $420M escalated each year through the end of the program (FY 2047).

the current and foreseeable economic situation, such a large funding increase would also provide for corresponding acceleration in the planning and construction of an on-site facility.

The new facility will begin receiving waste in FY 2022; therefore, an overlap of approximately two years is built into the schedule for a new facility. The new facility portion of the as-generated waste volume estimate (FY 2022 - FY 2043) is used in the disposal alternatives as follows:

- To calculate the as-disposed volume estimate used to predict: (1) the required disposal facility capacity needed for the On-site Disposal Alternative and (2) when individual cells of the new disposal facility would be filled.
- To analyze waste shipments in the Off-site Disposal Alternative.

A summary of the post-EMWMF base as-generated waste volume estimate by material type and waste type is presented in Table 2-2. Note that the waste form, LLW/TSCA, is included with LLW. The waste volumes are summarized in this way to aid the off-site analysis, because LLW/TSCA waste can be disposed off-site at the Nevada National Security Site (NNSS) as LLW, while mixed waste that may require treatment is disposed at Energy*Solutions* or Waste Control Specialists LLC (WCS). Appendix A provides detailed as-generated waste volume estimates by project and year.

**Table 2-2. Post-EMWMF Base As-generated Waste Volume Estimate (FY 2022 - FY 2043) without Uncertainty**

| Material Type | Waste Type | | TOTAL by Material Type ($yd^3$) | % by Material Type |
|---|---|---|---|---|
| | LLW (includes LLW/TSCA) | Mixed (LLW/RCRA, LLW/RCRA/TSCA) | | |
| Debris | 921,152 | 119,534 | 1,040,686 | 67% |
| Debris/Classified[a] | 28,489 | 3,697 | 32,186 | 2%[a] |
| Soil | 432,092 | 53,882 | 485,974 | 31% |
| Total | 1,381,734 | 177,113 | **1,558,846** | |
| % by Waste Type | 89% | 11% | | |

[a] Some percentage of debris waste is expected to be classified, but is currently not specified as such in the Waste Generation Forecast. Three percent of generated debris is assumed to be classified for purposes of off-site disposal evaluation (based on 3% of waste from ETTP considered classified in the WGF).

### 2.2.2 As-disposed Waste Volume Estimate

The approach used to estimate as-disposed waste volumes follows a methodology similar to calculations used to predict as-disposed volumes in the FY 2014 PCCR and the CARARs that had been previously prepared annually for the EMWMF. The capacity needed for disposal of future CERCLA waste depends on the as-generated waste volumes, the relative mix of debris waste and waste suitable for use as fill material (e.g., soil), the volume of clean fill needed for filling voids and for operational purposes, and the compaction of the combined materials. The optimum fill material is contaminated soil or soil-like material from a remediation project that can be mixed with the debris or be placed around or among containers. When contaminated fill is not available, clean fill must be used. Sequencing of waste soil and debris to take advantage of this optimization is carried out to the extent possible at the disposal cell. Sequencing projects to take advantage of the waste soil/debris optimization is discussed further in Appendix B, *Waste Volume Reduction*.

The PCCR and previous CARARs utilize density conversion factors that reflect compaction of waste in the landfill for many different waste material types to predict as-disposed waste volumes from as-generated waste volumes. A formal Monte Carlo uncertainty analysis is performed for the PCCR and a calculated 95% upper confidence limit (UCL) uncertainty allowance is added to the total waste volume (debris, soil waste, and clean fill) to account for uncertainty in waste volume estimates and fill demand projections. The UCL-95 uncertainty allowance is applied to future volumes. For purposes of this RI/FS analysis, it was conservatively assumed that volume uncertainty would result in increased rather than decreased need for landfill space. A straight 25% uncertainty on waste volumes is assumed in this document.

Prediction of as-disposed volumes for the RI/FS uses a simplified methodology from that of the PCCR, as described in general in the bullets below (detailed calculations are given in Appendix A):

- Start with the base as-generated waste volume estimate as described in Section 2.2.1 and summarized in Table 2-2.
- Use the simplifying assumption of two waste material types (soil and construction debris) and corresponding density conversion factors (per the FY 2013 PCCR) to calculate as-disposed volumes of debris and soil that reflect compaction of waste in the landfill.
- Establish total fill needed using a multiplication factor of 2.26 applied to the as-disposed debris volume. The factor 2.26 is based on a field-determined ratio of total fill density to as-disposed debris density.
- Take the total fill volume and subtract the as-disposed soil waste volume (which is used as fill) to calculate the volume of clean fill soil required. (Note: excess soil waste fill could potentially occur when more waste soil fill is generated than is needed for void space management; however, this does not occur in the current volume analysis).
- Add the assumed uncertainty allowance to get future volumes of total waste (debris, soil waste, and clean fill).

Table 2-3 provides as-disposed volumes of debris and soil based on the as-generated volumes given in Table 2-2 and calculated per the above described method. Density conversion factors (from the PCCR) are given for the as-disposed volume determinations. These as-disposed volumes include the soil fill (made up of soil waste and clean fill). As much as possible, projects are sequenced to take advantage of using soil waste as fill (see Figure 2-2 and Appendix B).

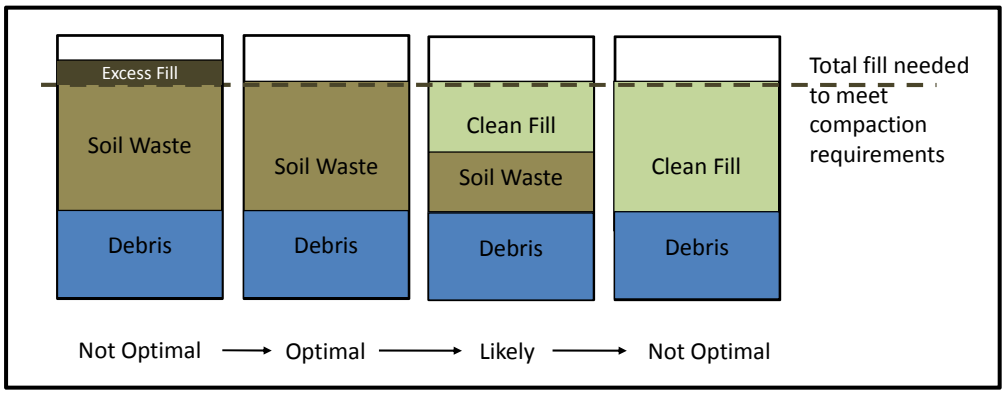



**Figure 2-2. Scenarios for Total Fill in Landfill**

If soil waste exceeds the total fill required, it is labeled excess fill. Proper sequencing of soil remediation and demolition projects allows maximizing the use of soil waste as fill (the likely situation in Figure 2-2). The optimal situation is not likely simply because soil remediation volumes are not that large, and clean fill must make up the rest of the fill required for compaction and stability requirements in the landfill.

Using the as-disposed volume (1,746,430 $yd^3$) as shown in both Table 2-3 and Table 2-4, an allowance of 25% uncertainty is applied and results in a needed ~2.2 M $yd^3$ of additional capacity. This is about 15% less than the 2.5 M $yd^3$ provided by the landfill conceptual design. This additional capacity of 15% has resulted due to changes in volume estimates over several years during development of this RI/FS and earlier conceptual design of the on-site facility. Previous waste volume estimates required a facility size of 2.5 M $yd^3$ and as this is only a conceptual design, the difference between 2.2 and 2.5 M $yd^3$ will allow for final design changes (e.g., slope recalculations, cut/fill changes, height of waste, etc.); the conceptual design has not been modified. As explained in Table 2-4, the additional 25% volume uncertainty adds approximately the volume of one cell (Cell 5) to the projected disposal capacity without uncertainty. The additional 15% capacity is approximately equivalent to the size of cell 6, and as discussed, this contingency in capacity will accommodate final design changes.

**Table 2-3. As-Disposed Waste Volume Determination**

| Waste Type | Volume ($yd^3$) | Basis |
|---|---|---|
| AD Debris (compacted) | 533,011 (A) | AG debris volume divided by 2.01<br>(as defined in Appendix A) |
| AD Waste Soil (compacted) | 365,612 (B) | AG waste soil volume divided by 1.30<br>(as defined in Appendix A) |
| Total Fill | 1,204,606 | AD debris volume multiplied by 2.26<br>(as defined in Appendix A for filling void space and for operational needs) |
| Clean Fill | 838,994 (C) | AD Waste Soil subtracted from Total Fill |
| Total AD Volume | 1,737,617 | Add values A, B, and C |
| Excess Waste Soil (compacted) | 8,812 | This is the calculated excess waste soil that occurs under the sequencing scenario |
| Total AD Volume includes excess waste soil | 1,746,430 | This is the total volume required<br>(no uncertainty) |

AD As-disposed
AG As-generated

The *Fiscal Year 2014 Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Facility* (DOE 2014) predicts that a total CERCLA waste volume of 4.1 M $yd^3$ is required at the 95% UCL. Subtracting 2.18 M $yd^3$ (capacity of the EMWMF) leaves 1.92 M $yd^3$ additional disposal capacity needed. The difference between the two estimates, 2.2 M $yd^3$ needed per this RI/FS and 1.92 M $yd^3$ needed per the FY 2014 PCCR, is a result of the following:

- A greater uncertainty is assumed and applied to volumes in this RI/FS (25% versus the 95% UCL in the PCCR).
- A 4% difference in waste generation estimates in the RI/FS versus the PCCR (mainly attributed to a correction in the Alpha-4 waste volume and a re-estimate of the K-31 waste volume).

In addition to the differences in needed disposal capacity, the FY 2014 PCCR predicts the EMWMF reaches capacity in 2022, whereas this analysis predicts that date is 2024 due to the overlap of available disposal (e.g., with EMDF accepting waste beginning in 2022, the life of EMWMF is extended).

**Table 2-4. Uncertainty (Contingency) and Corresponding Projected Disposal Capacity Need**

| Contingency | Projected Disposal Capacity Need ($yd^3$) | Description | EMDF Cells Needed per Conceptual Design |
|---|---|---|---|
| 0 | 1,746,430 | As-disposed waste volume estimate, no uncertainty | Cells 1-4 (1.77M $yd^3$) |
| 25% | 2,183,037 | As-disposed waste volume estimate plus 25% contingency to accommodate volume uncertainty | Cells 1-5 (2.18M $yd^3$) |
| 15% | 2,500,000 | Conceptual design facility capacity; will be adjusted in final design | Cells 1-6 (2.5M $yd^3$) |

If the On-site Disposal Alternative is selected as the remedy, the capacity will be further optimized for efficiency and land utilization considering topographic and hydrogeologic features in the detailed design. A phased construction of the landfill would allow adjustment of cell construction as needed to accommodate potential lower waste volumes (e.g., construction of Cell 6 could be eliminated if capacity is not needed).

Figure 2-3 shows the cumulative CERCLA waste capacity demand estimate through FY 2043 including the 25% uncertainty allowance for future volumes. Figure 2-3 also shows the maximum capacity of EMWMF (2.18 M $yd^3$) is estimated to be reached in FY 2024 based on 25% uncertainty in future volumes. A cumulative volume graphic for the new facility alone is also shown (Figure 2-3[b]). Based on this estimate, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2022[9]. Details regarding the calculations may be found in Appendix A.

In addition to uncertainty in future waste volume estimates, other factors such as funding, project sequencing, and contracting can impact project implementation plans and the RI/FS waste volume estimates. For example, annual funding lower than the $420M funding scenario assumed (see Section 2.2.1) could delay EMWMF reaching maximum capacity and the operational start of a new facility. A higher funding scenario could result in EMWMF reaching capacity sooner.

### 2.2.3 Volume for Off-site Disposal Alternative

Completion of the Off-site Disposal Alternative analysis requires the total volume of waste to be shipped. This volume is the as-generated waste volume (see Table 2-2). In addition, those volumes are adjusted by the same uncertainty used in the On-site Disposal Alternative (e.g., 25%).

Table 2-5 gives the as-generated waste volumes with 25% uncertainty, which are then used in the Off-site Alternative Analysis.

[9] Operational start-up of a new facility is assumed to begin approximately two years prior to reaching capacity at EMWMF.

**Table 2-5. Post-EMWMF As-generated Waste Volume Estimate (FY 2022 - FY 2043) with Uncertainty**

| Material Type | Waste Type | | TOTAL by Material Type ($yd^3$) |
|---|---|---|---|
| | LLW (includes LLW/TSCA) | Mixed (LLW/RCRA, LLW/RCRA/TSCA) | |
| ***25% Uncertainty applied to As-generated Estimates*** | | | |
| Debris | 1,151,440 | 149,418 | 1,300,858 |
| Debris/Classified[a] | 35,612 | 4,621 | 40,233 |
| Soil | 540,115 | 67,353 | 607,468 |
| **Total** | **1,727,167** | **221,391** | **1,948,558** |

[a] Some percentage of debris waste is expected to be classified, but is currently not specified as such in the Waste Generation Forecast. Three percent of generated debris is assumed to be classified for purposes of off-site disposal evaluation (based on 3% of waste from ETTP considered classified in the WGF).

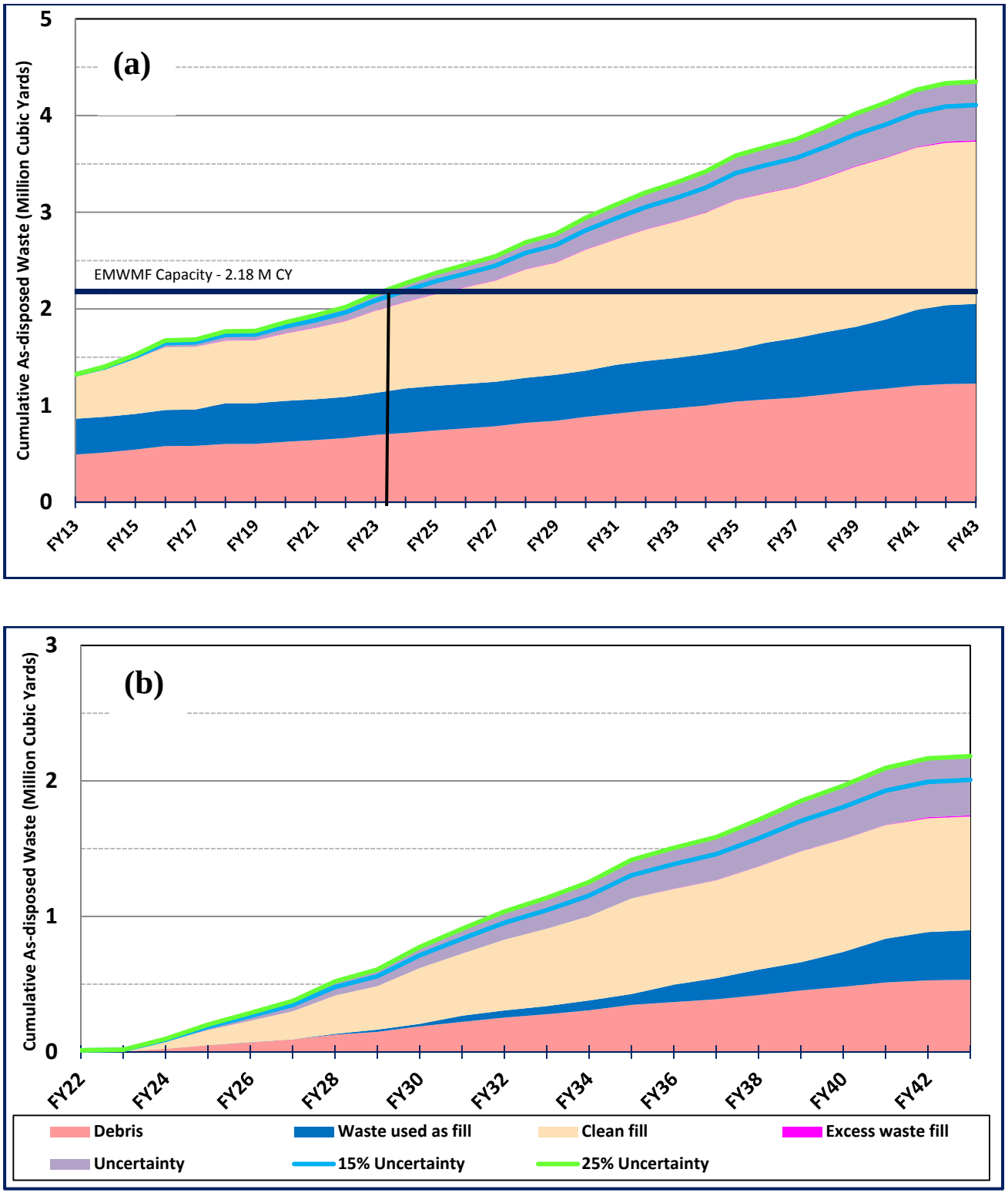



**Figure 2-3. (a) Cumulative CERCLA Waste Capacity Demand Estimate (b) Cumulative CERCLA Waste Capacity Demand Estimate for New EMDF**

## 2.3 RI/FS WASTE CHARACTERIZATION

This section discusses characterization of future generated CERCLA waste streams. Because detailed characterization data do not exist for many of the individual D&D and remediation projects, characterization of future waste streams is based on available data for waste disposed at EMWMF to establish contaminants of potential concern (COPCs) and estimate contaminant concentrations. This methodology relies on the assumption that available data for waste disposed at EMWMF approximately represent the waste characteristics of future waste streams. Use of characterization data for waste disposed at EMWMF is limited in the RI/FS to serving as a basis for the transportation risk and natural phenomena risk calculations. Additionally, these transportation and natural phenomenon risk analyses consider the risk posed by release of radioactively contaminated waste as far exceeding the risk posed to the public by any contained chemical hazards, and therefore only the radioactive portion of the waste is considered in those assessments.

The EMWMF waste characterization results were used to develop a derived data set of radionuclide contaminants as discussed in Section 2.3.1 below. The data set forms the basis for calculating transportation risk for the On- and Off-site Disposal Alternatives, and risk associated with natural phenomena (wind-borne [tornadic] contamination risk) for the On-site Disposal Alternative (see Table 2-1). Risk calculations are discussed in Appendix F. Because chemical contaminants contribute relatively minimal transportation and natural phenomenon risk, relevant non-radiological contaminant information provided in this RI/FS is limited to a discussion of the anticipated chemical constituents in Section 2.3.2.

PreWAC have been developed based on contaminant pathway analysis modeling for the proposed on-site disposal facility conceptual design. As shown in Table 2-1, the PreWAC evaluation is used to determine the following:

- Does the PreWAC allow most future CERCLA waste to be disposed?
- Does the proposed conceptual design provide adequate assurance that disposed contaminants would pose acceptable risks?

The projection that waste characteristics of future waste will be similar to waste disposed to date at the EMWMF is a key assumption in the analysis.

### 2.3.1 Radionuclide Characterization

The derived data set of radionuclide COPCs and estimated radionuclide contaminant concentrations are designed to provide a reasonable range of contaminant parameters for waste expected to be generated from future D&D and remedial action projects, especially as they are used only in a relative sense, to compare on-site and off-site alternative risks. It is recognized that radionuclide COPCs from future cleanup projects may differ in concentrations; however, the list of radionuclides received at EMWMF (includes waste received from all three ORR facilities) and on which this analysis is based is extensive and reflects the nuclides expected in future waste lots. The process used to develop the contaminant data set of mass-weighted average radionuclide concentrations for use in natural phenomenon risk and transportation risk evaluation consisted of the following steps:

- Data collection
- Data set development exceptions
- Development of data set used for risk evaluation

A summary of the process is provided below. A more detailed description of the process steps and calculations is provided in Appendix A.

#### 2.3.1.1 Data Collection

The data collection process is summarized as follows:

- Waste lots (WLs) for waste disposed at EMWMF were identified using a Waste Transportation Management System[10] EMWMF Disposition Summary Report.
- Radionuclide COPC concentration data for identified WLs were obtained from a Waste Acceptance Criteria Forecast Analysis Capability System[11] output report or waste profile data. The expected value concentrations of radionuclide COPCs reported in the individual waste WL data sets were identified.
- Net weight data for identified WLs were collected.

#### 2.3.1.2 Development of Data Set for Risk Evaluation

A mass-weighted average concentration for each radionuclide was derived for use as input for the transportation risk and natural phenomenon risk evaluation as summarized below:

- Calculate the activity in pCi of each radionuclide contaminant reported in each WL using the reported concentration of each radionuclide in the WL and the net weight of all shipments for the WL.
- Calculate the average concentration in pCi/g for each radionuclide contaminant in the WL data set by summing the activities calculated above and dividing by the sum of net weights of all shipments for all WL in the data set with a reported value for the radionuclide.

The mass-weighted average concentration in pCi/g calculated for each radionuclide contaminant shown in Table 2-6 forms the data set used for risk evaluation.

#### 2.3.1.3 Data Collection and Data Set Development Exceptions

Exceptions to the data collection and data set development process summarized above were made for WLs that were merged or split out from the original approved WL profile and therefore shipped under a different WL number. Details about the exceptions are provided in Appendix A.

### 2.3.2 Chemical Characterization

As stated previously, the chemical contaminants for future waste streams to be disposed at EMDF are assumed to be similar to those of waste disposed at the EMWMF. Because chemical contaminants contribute relatively minimal transportation and natural phenomenon risk, the chemical contaminant information provided in the RI/FS is not analyzed in those scenarios. The methodology explained for radionuclide data collection and average concentration calculations (Sections 2.3.1.1–2.3.1.2) was followed to obtain estimated chemical concentrations as well. A complete list of the chemical constituents identified in the EMWMF WAC and the chemical constituents which have historically been found in the waste disposed at EMWMF (BJC 2008) is provided in Table 2-7.

### 2.3.3 Mercury-contaminated Waste

One exception to the similarity in chemical contaminants for EMWMF waste compared to future CERCLA waste is mercury. Future Y-12 CERCLA waste will include media and debris generated during

[10] WTMS is a web-based tool that provides a central source for manually compiling and printing shipping documents required for the transport of waste and materials generated by the OREM contractor.

[11] Waste Acceptance Criteria Forecast Analysis Capability System is the primary tool used to ensure analytic WAC compliance at the EMWMF.

demolition and remediation of mercury-contaminated sources in the Y-12 main plant area. This mercury-contaminated waste will include debris and soils/sediments that are characteristically hazardous (carry the D009 hazardous waste code) due to elevated mercury levels based on the toxicity characteristic leaching procedure (TCLP) as well as waste that, although it contains mercury, passes TCLP and is therefore not hazardous. As the mercury concentrations in these future waste lots are expected to vary significantly, an average mercury concentration is not given in Table 2-7.

Past determinations have shown the mercury-contaminated waste, which will be generated upon demolition of the four Y-12 facilities and associated ancillary facilities, as well as the soils and sediments to be generated during remediation, would not carry the U-151 listed waste code (code for discarded elemental mercury product, off-specification metallic mercury product, and container or spill residues thereof). An extensive review of the subject was completed and communicated to regulators (DOE 2005), and the recent and thorough characterization work completed on the Alpha-5 facility also addressed this topic, confirming that the waste would not be U-151 listed (DOE 2012b).

According to RCRA LDRs[12], mercury -contaminated (D009) waste must be treated prior to land disposal unless another alternate regulatory approach is invoked. The proposed technical and regulatory approaches for management of the mercury-contaminated waste at the EMDF is described in Appendix C and Appendix G, respectively. All other RCRA hazardous waste that is disposed in an on-site facility will be required to meet LDRs prior to disposal, as is the practice at EMWMF per that facility's administrative WAC. The PreWAC analysis identifies additional risk- and dose-based chemical limits for constituents which may be present in the waste, and analytic WAC will be finalized for a future facility (see Appendix H).

[12] The purpose of LDR requirements is to reduce the toxicity and/or the mobility of the hazardous constituents in the environment. In particular, LDRs are aimed at reducing the likelihood that hazardous constituents will leach into groundwater and/or surface water. Under LDRs, specific constituent levels (i.e., treatment standards) must be achieved before the hazardous waste can be land disposed. Alternate regulatory approaches that achieve certain criteria may be used if approved by regulators.

**Table 2-6. Data Set for Natural Phenomena and Transportation Risk Evaluation**

| Isotope | Mass Weighted Average (pCi/g) | Isotope | Mass Weighted Average (pCi/g) | Isotope | Mass Weighted Average (pCi/g) |
|---|---|---|---|---|---|
| Ag-110m | 4.76E-01 | F-59 | 1.49E+00 | Pu-244 | 3.22E-02 |
| Am-241 | 9.18E+00 | H-3 | 1.91E+02 | Ra-226 | 9.10E-01 |
| Am-243 | 5.77E-01 | I-129 | 1.79E+00 | Ra-228 | 7.95E-01 |
| Bi-214 | 3.89E-01 | K-40 | 4.21E+00 | Ru-106 | 6.27E+04 |
| C-14 | 2.91E+01 | Kr-85 | 1.04E+02 | Sr-90 | 9.73E+03 |
| Cm-242 | 1.63E-01 | Mn-54 | 8.47E-01 | Tc-99 | 3.67E+01 |
| Cm-243 | 6.69E+00 | Nb-94 | 7.93E-02 | Th-228 | 4.27E-01 |
| Cm-244 | 1.14E+04 | Ni-59 | 4.04E+01 | Th-229 | 4.00E-03 |
| Cm-245 | 1.39E-01 | Ni-63 | 1.05E+02 | Th-230 | 1.55E+00 |
| Cm-246 | 5.41E+00 | Np-237 | 2.91E-01 | Th-232 | 1.69E+00 |
| Cm-247 | 9.55E-03 | Pb-210 | 2.50E+00 | U-232 | 1.65E+00 |
| Co-57 | 1.48E-01 | Pb-214 | 4.02E-01 | U-233 | 8.13E+01 |
| Co-60 | 5.05E+02 | Pm-147 | 1.00E+01 | U-234 | 2.69E+02 |
| Cs-134 | 2.48E+04 | Pu-238 | 5.69E+01 | U-235 | 1.63E+01 |
| Cs-137 | 5.83E+03 | Pu-239 | 1.17E+01 | U-236 | 1.14E+01 |
| Eu-152 | 6.43E+03 | Pu-240 | 1.74E+02 | U-238 | 1.60E+02 |
| Eu-154 | 4.85E+03 | Pu-241 | 2.01E+02 | Zn-65 | 1.46E+00 |
| Eu-155 | 1.41E+03 | Pu-242 | 3.79E-01 | | |

**Table 2-7. Chemical Constituents**

| Chemical | CASN | Mass-average (mg/kg) | Chemical | CASN | Mass-average (mg/kg) |
|---|---|---|---|---|---|
| (1,1-Dimethylethyl)benzene | 98-06-6 | | 4,6-Dinitro-2-methylphenol | 534-52-1 | |
| (1-Methylpropyl)benzene | 135-98-8 | 0.0 | 4-Chloro-3-Methylphenol | 59-50-7 | |
| 1,1,1-Trichloroethane | 71-55-6 | | 4-Methyl-2-Pentanone (MIBK) | 108-10-1 | |
| 1,1-Dichloroethane | 75-34-3 | | 4-methylphenol (p-cresol) | 106-44-5 | |
| 1,1-Dichloroethene (Dichloroethylene) | 75-35-4 | | Acenaphthene | 83-32-9 | 26.41 |
| 1,1,2-Trichloroethane | 79-00-5 | | Acenaphthylene | 208-96-8 | 0.55 |
| 1,1,2-Trichloro-1,2,2-Trifloroethane | 76-13-1 | | Acetone | 67-64-1 | 0.44 |
| 1,2,4-Trichlorobenzene | 120-82-1 | | Acetophenone | 98-86-2 | 0.1 |
| 1,2,4-Trimethylbenzene | 95-63-6 | 0.03 | Aldrin | 309-00-2 | 0.09 |
| 1,2-Dichlorobenzene | 95-50-1 | 0.0 | Alpha-BHC | 319-84-6 | 0.0 |
| 1,2-Dimethylbenzene | 95-47-6 | 0.01 | alpha-Chlordane | 5103-71-9 | |
| 1,2-Dichloroethane | 107-06-2 | | Aluminum | 7429-90-5 | |
| 1,2-Dichloroethene | 156-59-2 | | Anthracene | 120-12-7 | |
| 1,3,5-Trimethylbenzene | 108-67-8 | | Antimony | 7440-36-0 | 12.1 |
| 1,3-Dichlorobenzene | 541-73-1 | 0.0 | Arsenic | 7440-38-2 | |
| 1,4-Dichlorobenzene | 106-46-7 | 0.0 | Asbestos | 1332-21-4 | |
| 1-Methyl-4-(1-methylethyl)benzene | 99-87-6 | | Barium | 7440-39-3 | 256.3 |
| 2,3,4,6-Tetrachlorophenol | 58-90-2 | 0.23 | Benzo(a)anthracene | 56-55-3 | |
| 2,3,7,8-Tetrachlorodibenzo-p-dioxin | 1746-01-6 | | Benzene | 71-43-2 | 0.0 |
| 2,4-Dimethylphenol | 105-67-9 | 0.01 | Benzenemethanol | 100-51-6 | |
| 2,4-Dinitrophenol | 51-28-5 | | Benzo(a)pyrene | 50-32-8 | |
| 2,4,5-Trichlorophenol | 95-95-4 | | Benzo(b)fluranthene | 205-99-2 | |
| 2-Butanone (also known as Methyl Ethyl Ketone) | 78-93-3 | | Benzo(g,h,i)perylene | 191-24-2 | |
| 2-Chlorophenol | 95-57-8 | | Benzo(k)fluoranthene | 207-08-9 | |
| 2-Chloronaphthalene | 91-58-7 | | Benzoic Acid | 65-85-0 | 24.3 |
| 2-Hexanone | 591-78-6 | | Beryllium | 7440-41-7 | |
| 2-Methylnaphthalene | 91-57-6 | | Beta-BHC | 319-85-7 | 0.0 |
| 2-methylphenol (o-cresol) | 95-48-7 | | Bis(2-ethylhexyl)phthalate | 117-81-7 | |
| 3-3'-Dichlorobenzidine | 91-94-1 | | Boron | 7440-42-8 | 30.82 |
| 3-methylphenol (m-cresol) | 108-39-4 | | Butylbenzylphthalate | 85-68-7 | |
| 2-Nitroaniline (O-Nitroaniline) IP-Nitroaniline) | 88-74-4 | | Cadmium | 7440-43-9 | |
| 4,4'-DDD | 53-19-0 | 0.2 | Calcium | 7440-70-2 | |
| 4,4'-DDE | 72-55-9 | 1.2 | Carbazole | 86-74-8 | 47.44 |

**Table 2-7. Chemical Constituents (Continued)**

| Chemical | CASN | Mass-average (mg/kg) |
|---|---|---|
| Carbon disulfide | 75-15-0 | 0.0 |
| Carbon tetrachloride | 56-23-5 | 0.0 |
| Chlordane | 57-74-9 | 0.04 |
| Chlorobenzene | 108-90-7 | 0.0 |
| Chloroethane | 75-00-3 | |
| Chloroform | 67-66-3 | 0.0 |
| Chromium | 7440-47-3 | 932 |
| Chrysene | 218-01-9 | |
| cis-1,2-Dichloroethene | 156-59-2 | |
| Cobalt | 7440-48-4 | |
| Copper | 7440-50-8 | |
| Cumene | 98-82-8 | 0.02 |
| Cyanide | 57-12-5 | 0.6 |
| Delta-BHC | 319-86-8 | 0.0 |
| Dibenz(a,h)anthracene | 53-70-3 | |
| Dibenzofuran | 132-64-9 | |
| Dieldrin | 60-57-1 | 0.18 |
| Diethylphthalate | 84-66-2 | 8.13 |
| Dimethylphthalate | 131-11-3 | 3.99 |
| Di-n-butyl phthalate | 84-74-2 | 5.02 |
| Di-n-octylphthalate | 117-84-0 | |
| Endosulfan I | 959-98-8 | 0.18 |
| Endosulfan II | 33213-65-9 | |
| Endosulfan Sulfate | 1031-07-8 | |
| Endrin | 72-20-8 | 0.18 |
| Endrin Aldehyde | 7421-93-4 | 0.18 |
| Ethylbenzene | 100-41-4 | 0.06 |
| Fluoranthene | 206-44-0 | |
| Fluorene | 86-73-7 | |
| gamma-Chlordane | 5103-74-2 | 0.04 |
| Heptachlor Epoxide | 1024-57-3 | 0.02 |
| Hexachlorobutadiene | 87-68-3 | 0.0 |
| Hydrogen fluoride (released from $UF_6$) | 7664-39-3 | |
| Indeno(1,2,3-cd)Pyrene | 193-39-5 | |
| Iron | 7439-89-6 | |
| Isophorone | 78-59-1 | 0.05 |

| Chemical | CASN | Mass-average (mg/kg) |
|---|---|---|
| Lead | 7439-92-1 | 637 |
| Lithium | 7439-93-2 | 0.0 |
| Magnesium | 7439-95-4 | |
| Manganese | 7439-96-5 | 38,143 |
| Mercury | 7439-97-6 | varies |
| Methoxychlor | 72-43-5 | |
| Methylcyclohexane | 108-87-2 | 0.0 |
| Methylene Chloride | 75-09-2 | 0.02 |
| Molybdenum | 7439-98-7 | 34.5 |
| n-Nitroso-di-n-propylamine | 621-64-7 | 0.0 |
| Naphthalene | 91-20-3 | 46.2 |
| Nickel | 7440-02-0 | |
| Polychlorinated biphenyl (PCB), Total | 1336-36-3 | |
| Pentachlorophenol | 87-86-5 | |
| Phenanthrene | 85-01-8 | |
| Phenol | 108-95-2 | 0.45 |
| Potassium | 7440-09-7 | |
| Propylbenzene | 103-65-1 | 0.0 |
| Pyrene | 129-00-0 | |
| Selenium | 7782-49-2 | 118 |
| Silver | 7440-22-4 | |
| Sodium | 7440-23-5 | |
| Strontium | 7440-24-6 | 178 |
| Tetrachloroethene (PCE) | 127-18-4 | 0.0 |
| Thallium | 7440-28-0 | |
| Tin | 7440-31-5 | 81.9 |
| Titanium | 7440-32-6 | |
| Toluene | 108-88-3 | 0.04 |
| Trichloroethene (TCE) | 79-01-6 | 0.02 |
| Uranium | 7440-61-1 | |
| Vanadium | 7440-62-2 | 39.9 |
| Vinyl Chloride | 75-01-4 | 0.0 |
| Xylenes | 1330-20-7 | 0.04 |
| Zinc | 7440-66-6 | |
| Zirconium | 7440-67-7 | |
| | | |

This page intentionally left blank.

# 3. RISK EVALUATIONS

This chapter discusses evaluations of risk for the three alternatives: no action, on-site disposal, and off-site disposal, considered in this RI/FS. These evaluations were prepared in general accordance with the principles outlined in Risk Assessment Guidance for Superfund Parts A and C (EPA 1989; EPA 1991a).

## 3.1 EVALUATION OF BASELINE RISK (NO ACTION ALTERNATIVE)

CERCLA requires that the No Action Alternative be considered as a baseline for comparison against action alternatives. For a typical CERCLA evaluation, the No Action Alternative is based on the assumption that no cleanup actions or other measures are taken to mitigate existing or potential future impacts to human health or the environment posed by a site. For a typical No Action Alternative:

- Current and future baseline risks are estimated to (1) determine whether remediation of a contaminated site is required and (2) evaluate risk reduction that would result from implementation of remedial actions.
- Baseline Human Health Risk Assessments (BHHRAs) are performed in accordance with EPA guidance to provide estimates for both carcinogenic (cancer) risk and systemic toxicity (non-carcinogenic effects) from contaminant exposure.
- The receptor scenario (e.g., residential, industrial, or recreational use) is determined by considering current and potential future land use.

Unlike an RI/FS for a typical remediation project, the purpose of this RI/FS is not to evaluate alternatives for cleaning up a contaminated site. The purpose of this RI/FS is to evaluate alternatives for disposal of CERCLA waste generated from cleanup of various contaminated sites on the ORR and associated sites. Decisions about cleaning up those sites have already been made in existing CERCLA decision documents or will be made in future CERCLA decision documents. Remediation of the sites is expected to generate radiological and hazardous wastes that will require disposal at an approved facility.

Remediation projects for contaminated sites are connected to the evaluation of disposal alternatives in this RI/FS only by the candidate waste streams to be generated that require disposal. The baseline risk evaluations for contaminated sites in existing and future CERCLA documents are otherwise separate and distinct from this CERCLA evaluation of disposal alternatives for waste streams. Likewise, remedial actions to be conducted at contaminated sites are determined by CERCLA decisions that are separate from this RI/FS evaluation.

For the remediation projects that will generate candidate waste streams evaluated in this RI/FS, Table 3-1 contains a list of the applicable existing CERCLA documents that contain risk evaluations (including BHHRAs) and corresponding existing CERCLA decision documents. Future remediation projects for which a CERCLA risk evaluation and decision document have yet to be completed are also identified.[13]

Unlike the No Action Alternative for a typical RI/FS which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative for this RI/FS is based on the assumption that disposal of future waste streams from site cleanup would be addressed at the project-specific level. No coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached. Section 6.1 provides further discussion of the No Action Alternative.

[13] For these future remediation projects, selected remedies and candidate waste streams have been assumed for planning purposes only and do not preclude the outcome of a future CERCLA evaluation process.

**Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects**

| Site | Subproject | Risk Evaluation Document | Decision Document* | Project |
|---|---|---|---|---|
| ETTP | Remaining Facilities D&D | *Engineering Evaluation/Cost Analysis for the K-25 Auxiliary Facilities Demolition Project Group II Buildings at East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-1765&D4)* | *Action Memorandum for the Remaining Facilities Demolition Project at East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2049&D2-R) | Central Neutralization Facility |
| | | | | K-1037 and K-1037-C |
| | | | | Poplar Creek Facilities |
| | | | | TSCA Incinerator Facilities |
| | Site Wide | *Final Sitewide Remedial Investigation and Feasibility Study for East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2279&D3) | **Record of Decision for Site Wide Remedial Actions** | Site Wide Remedial Actions |
| | Zone 2 | *Focused Feasibility Study for Zone 2 Soils and Buried Waste, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2079&D1/R1) | *Record of Decision for Soil, Buried Waste, and Subsurface Structure Actions in Zone 2, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2161&D2) | Zone 2 Remedial Actions |
| ORNL | Melton Valley (MV) | **To Be Determined** | **MV Reactors and Other Facilities Record of Decision** | EGCR Complex |
| | | | | HPRR Complex |
| | | | | MV LGWO Complex |
| | | | | MV Waste Storage Facilities |
| | | | | MV HRE Facility |
| | | | | TWPC Complex |

**Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects (Continued)**

| Site | Subproject | Risk Evaluation Document | Decision Document* | Project |
|---|---|---|---|---|
| ORNL (cont) | Bethel Valley (BV) | *Remedial Investigation/Feasibility Study for Bethel Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee, Volume 1. Main Text* (DOE/OR/01-1748&D3) | *Record of Decisions for Interim Actions in Bethel Valley, Oak Ridge, Tennessee* (DOE/OR/01-1862&D4) | BV Chemical Development Lab Facilities |
| | | | | BV Isotope Area Facilities |
| | | | | BV Reactor Area Facilities |
| | | | | BV Tank Area Facilities |
| | | | | BV Remaining Slabs and Soils |
| | | | | ORNL Non- Hydrofracture Well P&A |
| | | | | ORNL Remaining Non-Hydrofracture Well P&A |
| | | | | ORNL Soils and Sediments |
| | | | | BV Inactive Tanks and Pipelines |
| | | | | BV Remaining Inactive Tanks and Pipelines |
| | | | Notice of Non-Significant Change to the Record of Decision for Interim Actions in Bethel Valley: Addition of Hot Storage Garden (3597) | Hot Storage Garden |
| | | | Notice of Non-Significant Change to the Record of Decision for Interim Actions in Bethel Valley, Oak Ridge, Tennessee (IFDP and ARRA Buildings) | 2026 Complex |
| | | | | 2528 Complex |
| | | | | 3019A Complex |
| | | | | 3525 Complex |
| | | | | 3544 Complex |
| | | | | 3608 Complex |
| | | | | 4501/4505 Complex |
| | | | | 5505 Building |
| | | | | 6010 and East BV Complex |
| | | | | Central Stack East Hot Cell Complex |
| | | | | Central Stack West Hot Cell Complex |
| | | | | Fire Station Complex |
| | | | | LLLW Complex |

**Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects (Continued)**

| Site | Subproject | Risk Evaluation Document | Decision Document* | Project |
|---|---|---|---|---|
| **ORNL (cont)** | **Bethel Valley (cont)** | *Remedial Investigation/Feasibility Study for Bethel Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee, Volume 1. Main Text* (DOE/OR/01-1748&D3) | Notice of Non-Significant Change to the Record of Decision for Interim Actions in Bethel Valley, Oak Ridge, Tennessee (IFDP and ARRA Buildings) | Southeast Lab Support Complex |
| | | | | Southeast Services Group Complex |
| | | | | Sewage Treatment Plant Complex |
| **Y-12** | **Upper East Fork Poplar Creek (UEFPC)** | *Engineering Evaluation/Cost Analysis for the Y-12 Facilities Deactivation/Demolition Project, Oak Ridge, Tennessee* (DOE/OR/01-2424&D2) | *Action Memorandum for the Y-12 Facilities Deactivation/Demolition Project, Oak Ridge, Tennessee* (DOE/OR/01-2462&D1) | 9206 Complex |
| | | | | 9206 Complex LMD |
| | | | | 9212 Complex |
| | | | | 9212 Complex LMD |
| | | | | Alpha-2 Complex |
| | | | | Alpha-2 Complex LMD |
| | | | | Alpha-3 Complex |
| | | | | Alpha-3 Complex LMD |
| | | | | Alpha-4 Complex |
| | | | | Alpha-5 Complex |
| | | | | Beta-1 Complex |
| | | | | Beta-1 Complex LMD |
| | | | | Beta-3 Complex LMD |
| | | | | Beta-4 Complex |
| | | | | Biology Complex |
| | | | | Beta-3 Deactivation Only |
| | | | | 9731 LMD |
| | | | | Steam Plant Complex LMD |
| | | | | 9213 and 9401-2 Demolition |
| | | | | Tank Facilities Demolition |

**Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects (Continued)**

| Site | Subproject | Risk Evaluation Document | Decision Document* | Project |
|---|---|---|---|---|
| Y-12 (cont) | Upper East Fork Poplar Creek (cont) | *Remedial Investigation of the Upper East Fork Poplar Creek Characterization Area at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volume 1* (DOE/OR/01-1641/V1&D2) | *Record of Decision for Phase I Interim Source Control Actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee* (DOE/OR/01-1951&D3) | UEFPC Sediments - Streambed and Lake Reality |
| | | | *Record of Decision for Phase I Interim Source Control Actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee* (DOE/OR/01-1951&D3) | UEFPC Soils 81-10 Area |
| | | *Upper East Fork Poplar Creek Soil and Scrapyard Focused Feasibility Study* (DOE/OR/01-2083&D2) | *Record of Decision for Phase II Interim Remedial Actions for Contaminated Soils and Scrapyard in Upper East Fork Poplar Creek, Oak Ridge, Tennessee* (DOE/OR/01-2229&D3) | UEFPC Remaining Slabs and Soils |
| | | | | UEFPC Soils |
| | Bear Creek Valley (BCV) | **To Be Determined** | **Bear Creek Valley White Wing Scrap Yard Record of Decision** | BCV White Wing Scrap Yard Remedial Action |
| | | *Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volume 1* (DOE/OR/01-1455/V1&D2) | **Bear Creek Valley Burial Grounds (Phase II) Record of Decision** | BCV Burial Grounds Remedial Action |
| | | | *Record of Decision for the Phase I Activities in Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (DOE/OR/01-1750&D4) | BCV S-3 Ponds |
| | | | | BCV DARA Facility Remedial Action |

***Bold Red Text** Denotes a Future CERCLA Evaluation or Decision

BCV Bear Creek Valley
BV Bethel Valley
EGCR Experimental Gas Cooled Reactor
HPRR Health Physics Research Reactor
LGWO Liquid Gaseous Waste Operations
LMD Legacy Material Disposition
MV Melton Valley
P&A plugging and abandonment
TWPC Transuranic Waste Processing Center
UEFPC Upper East Fork Poplar Creek

## 3.2 EVALUATION OF RISK FOR THE ON-SITE ALTERNATIVE

Risks associated with the On-site Disposal Alternative include short-term risks (risk associated with transport of the waste to an on-site disposal facility as well as risk associated with construction and operation of the facility) and long-term risks (residual health risk posed by the disposed waste, and permanence – that is the ability of the alternative to ensure protectiveness over time) (EPA 1991a).

Short-term risks associated with the On-site Disposal Alternative are evaluated in Appendix F, and include morbidity (non-fatal) and mortality (fatal) risks posed by transporting the waste on-site. Risk arises from radiological exposure during routine and accident scenarios, to both the maximum exposed individual (MEI) and collective populations, as well as risk due to vehicular-related occurrences, which include those due to emissions and those due to the location/miles travelled. Other short-term risks include those posed to human health by occurrences of natural phenomena events, and risk to human health via possible fugitive dust emissions during construction activities. These short-term risks are summarized in Table 3-2 and evaluated for the on-site alternative as part of the CERCLA short-term effectiveness criteria discussed in Section 7.3.4. Detailed calculations and results are given in Appendix F.

**Table 3-2. Short-term Risks Associated with the On-site Disposal Alternative[a]**

| Scenario | | Morbidity (Non-fatal) | Mortality (Fatal) |
|---|---|---|---|
| **Transportation of Waste to EMDF** | | | |
| Radiological Exposure (due to routine travel and accidents) | MEI | 6.63E-04 to 1.08E-02 | 4.97E-04 to 8.10E-03 |
| | Collective population | 2.59E-08 to 1.28E-01 | 2.59E-08 to 9.59E-02 |
| Vehicular-related incidents (due to emissions and miles travelled) | | 7.94E-01 | 3.31E-02 |
| **Natural Phenomena Risk in On-site Disposal of Waste at EMDF** | | | |
| Aggregate human health risk due to tornado strike: 3.71E-07 | | | |
| **Fugitive Dust Emissions $PM_{10}$ Values During Construction of EMDF** | | | |
| Range from 102 to 144 for various construction activities | | | |

[a] See Appendix F for details and calculations.

For the On-site Disposal Alternative, long-term risk evaluation is a much more involved process. Residual risk can only be estimated in the early "feasibility" stage of this remedy, as the waste is not yet in place, and the types and amounts of contaminants are not yet fully known. As the remedy is further advanced through the design and eventually implementation and closure stages, a more quantitative approach to determining/verifying risk can be applied. Figure 3-1 is an illustration of the stages of this remedy with their associated inputs, processes applied, and resulting outputs.

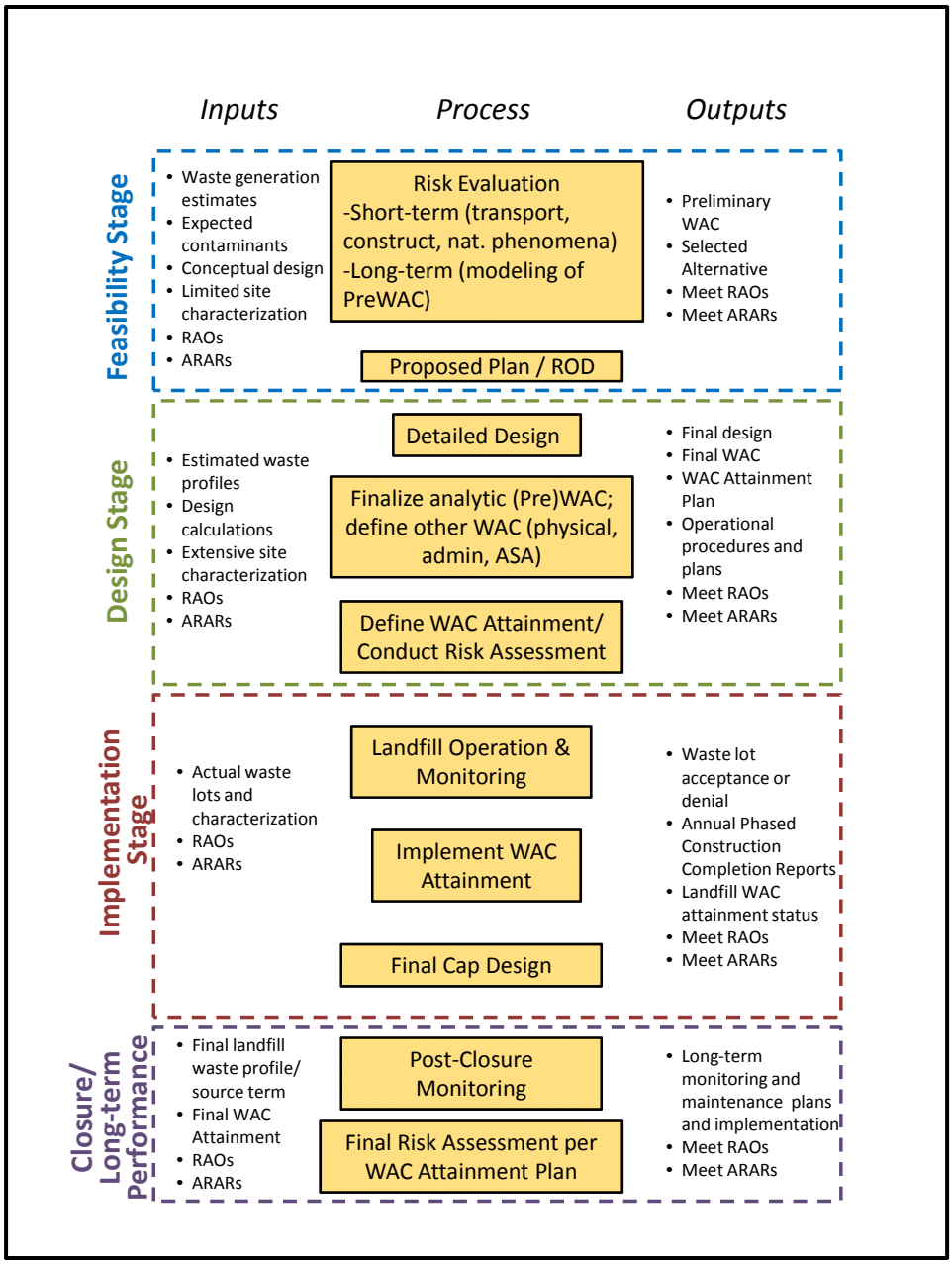



**Figure 3-1. Illustration of the Stages of an On-site Disposal Action and Resulting Risk Determinations**

As stated, residual risk is the human health risk posed by the waste disposed in the facility. At this RI/FS stage, (feasibility stage in the figure) that risk can only be estimated. Appendix H of this document provides an evaluation of contaminant concentration (upper) limits that would be applied to determine acceptance of the waste, the analytic PreWAC. As the figure illustrates, several inputs are required to determine the PreWAC, including the facility conceptual design, the waste generation estimate (volumes), expected contaminants, etc. PreWAC are determined based on meeting the RAOs that specify the acceptable risk, and meeting ARARs; for example, the maximum concentration limits (MCLs). PreWAC are comparable to CERCLA preliminary remediation goals. The modeling for PreWAC that is presented

in Appendix H is based on meeting defined risk goals and therefore serves as a risk evaluation. No changes are expected to the PreWAC/risk evaluation through the Proposed Plan and ROD processes.

During the second stage, the design stage, the WAC Attainment Plan, a primary FFA document, will be developed that will address the final analytic WAC as determined through the design processes, as well as other WAC (e.g., administrative, safety basis-controlled, and physical WAC, see Appendix H). Final analytic WAC will be determined as part of the WAC Attainment Plan development. Demonstration of final WAC attaining the prescribed risk goals (RAOs) and ARARs will be included in the WAC Attainment Plan.

The implementation (operating) stage of the on-site facility will focus on evaluating waste lot information, determining if waste lots are acceptable for disposal (per the WAC Attainment Plan), and continuing to meet RAOs and ARARs.

Completion of the remedy and closure of the on-site disposal facility would result in development of a final risk assessment, based on the final disposal facility inventory per the WAC attainment process. Additionally, long-term, post-closure monitoring is implemented and continues to ensure the protectiveness of the action.

## 3.3 EVALUATION OF RISK FOR THE OFF-SITE ALTERNATIVE

Risk associated with the Off-site Disposal Alternative includes only short-term risk, risks associated with transport of the waste to an off-site disposal facility. Short-term risks associated with the Off-site Disposal Alternative are evaluated in Appendix F, and include risk of injury (morbidity) and/or death (mortality) posed by transporting the waste off-site. These risks are summarized in Table 3-3 and evaluated for the off-site alternative as part of the CERCLA short-term effectiveness criteria discussed in Section 7.3.4. Note that Table 3-3 risks are for rail transport of wastes off-site, and that these risks increase by a factor of about ten if wastes are transported solely by truck.

Chapter 7 provides a detailed analysis of alternatives according to CERCLA evaluation criteria and NEPA values. Evaluations in Chapter 7 of overall protection of human health and the environment (a CERCLA threshold criterion), short-term effectiveness, and long-term effectiveness use risk assessment information from Appendix F and Appendix H.

**Table 3-3. Short-term Risks Associated with the Off-site Disposal Alternative[a]**

| Scenario | | Morbidity (Non-fatal) | Mortality (Fatal) |
|---|---|---|---|
| Radiological Exposure (due to routine travel and accidents) | MEIs | 1.03E-03 to 8.64E-02 | 7.75E-04 to 6.48E-02 |
| | Collective population | 1.61E-04 to 2.15E-01 | 1.21E-04 to 1.62E-01 |
| Vehicular-related incidents (emissions and miles travelled) | | 15.1 (NNSS destination)<br>4.2 (Energy*Solutions* destination) | 8.71 (NNSS destination)<br>2.5 (Energy*Solutions* destination) |

[a] See Appendix F for details and calculations.

# 4. REMEDIAL ACTION OBJECTIVES

CERCLA guidance defines RAOs as "medium-specific or operable-unit specific goals for protecting human health and the environment" (EPA 1988). According to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), (40 CFR 300.430[e][2][i]), RAOs should specify the media involved, contaminants of concern, potential exposure pathways, and remediation goals. The scope of this RI/FS is limited to evaluating alternatives for the disposition of future-generated CERCLA waste resulting from CERCLA cleanup actions on the ORR and associated sites after EMWMF capacity is reached. Remediation goals for those cleanup actions are established at the project-specific level in existing CERCLA decision documents, or will be made in future CERCLA decision documents. For this RI/FS, the actions being evaluated are designed to provide for the disposition and containment of various waste types, so rather than establishing remediation goals, goals are established for acceptance of waste (e.g., WAC, which is comparable to a remediation goal) and for containment of that waste (based on regulatory contaminant concentration limits, risk-based limits, and existing site background levels).

COPCs for the On-site Disposal and Off-site Disposal Alternatives include those present in various waste types derived from a wide range of sources and activities that would be disposed via either the On-site Disposal Alternative or the Off-site Disposal Alternative. A full description of those wastes and COPCs with estimated average concentrations based on wastes accepted at EMWMF to date (see Table 2-6 and Table 2-7) was given in Chapter 2.

As specified in Chapter 2, wastes that contain chemical contaminants that are RCRA hazardous must be treated to meet LDRs for either alternative (mercury-contaminated debris will require an interim waiver to LDR placement, but will ultimately meet LDR treatment standards, see Appendix C). These wastes will have therefore met the specific constituent treatment standards required for land disposal that ensure protectiveness in terms of toxicity and/or mobility of the particular in a land disposal environment. Those chemicals not addressed through LDRs, as well as radioactive COPCs, are addressed in this document through the establishment of PreWAC for the on-site facility, then through the application of the final WAC.

Four RAOs are defined for alternatives evaluated in this RI/FS:

1. Prevent direct or indirect exposure of a human receptor to future-generated CERCLA waste that exceeds a human health risk of $10^{-4}$ to $10^{-6}$ Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1 to 3.[14]
2. Prevent releases of future-generated CERCLA waste, or waste constituents that exceed a human health risk of $10^{-4}$ to $10^{-6}$ ELCR or an HI of 1 to 3,[14] or that do not meet ARARs for environmental media. This is accomplished through compliance with chemical specific ARARs, MCLs in waters that are current or potential sources of drinking water considering site-specific background levels, or risk-based levels for chemicals without ARARs.
3. Prevent ecological exposure to future-generated CERCLA waste.
4. Facilitate timely cleanup of ORR and associated facilities.

The On-Site Disposal Alternative involves the construction of a new on-site facility, the EMDF. For this alternative, the RAOs (ELCR of $10^{-4}$ to $10^{-6}$ and HI of 1 to 3) are demonstrated as achieved through the establishment of analytic PreWAC (waste acceptance goals) for COPCs to be disposed at the EMDF.

[14] Non-carcinogenic contaminant exposure is modeled to determine PreWAC limits based on an HI equal or less than 1.0 for up to 1,000 years. As the modeled time increases, prediction uncertainty increases and therefore the target HI is increased to 3.0 past 1,000 years. Likewise, an order of magnitude target ELCR increase (e.g., from $10^{-5}$ to $10^{-4}$) for the pre-1,000 year modeling to the post-1,000 year modeling is considered for carcinogenic contaminant modeling.

Analytic PreWAC limits establish bounds on waste acceptable at the disposal site from a perspective of mobility in the environment, given potential exposure pathways, and based on the conceptual design and site characteristics presented in this document. Development of the PreWAC is detailed in Appendix G, which lists the COPCs and describes the potential exposure pathways, receptors, fate and transport modeling, and risk and dose assessment procedures that were used. PreWAC are recognized as a preliminary data set, and serve as a starting point for final WAC. Other WAC (e.g., based on facility operating limits and administrative limits) will be determined as well, during development of operating procedures. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC (analytic among others) would require approval by all FFA parties for a new facility at the selected site, and would be documented in the primary document WAC Attainment Plan.

For the On-site Disposal Alternative, the containment goal (to achieve RAO for preventing releases exceeding human health risk of $10^{-4}$ to $10^{-6}$ ELCR or an HI of 1 to 3) is to prevent releases to the environment from a disposal cell that result in contaminant concentrations in potential drinking water sources that exceed MCLs, taking into consideration site background concentrations (cumulative contaminant concentrations and chemicals without ARARs to be determined as risk-based limits, as necessary) consistent with EPA guidance (EPA 1991b).

Under the Off-site Disposal Alternative, waste is shipped for permanent disposal at existing permitted off-site facilities. All off-site facilities presented and proposed for use under the Off-site Disposal Alternative in this RI/FS have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the NCP 40 CFR 300.440, and as such have been approved for disposal of CERCLA wastes.

As described in Chapter 3, the No Action Alternative provides no coordinated ORR effort to manage waste generated by future CERCLA actions after EMWMF capacity is reached; therefore, the first three RAOs are not directly applicable to the No Action Alternative. Overall protectiveness of human health and the environment and risk reduction would have to be addressed by CERCLA decisions at the individual sites without the benefit of a comprehensive disposal strategy.

The fourth RAO is directly applicable to the On-site Disposal and Off-site Disposal Alternatives as well as the No Action Alternative.

Evaluation of disposal alternatives for waste under the CERCLA process in this RI/FS will support DOE implementation of recent Oak Ridge Site Specific Advisory Board (ORSSAB) recommendations (ORSSAB 2011, ORSSAB 2014), including the following recommended actions:

- Evaluate and propose disposal capacity necessary to support current EM scope and potential additional cleanup waste streams.
- Analyze and compare the life-cycle costs and impacts of off-site disposal of expected waste streams versus those of a second on-site disposal cell.
- Reevaluate and update the original siting studies.
- Continue with planning for additional on-site disposal capacity for low-level radioactive and chemically hazardous contaminated waste, and continue ongoing efforts to minimize the need for additional on-site capacity.
- Ensure that the proposed new disposal facility will have sufficient capacity to accept all appropriate future generated waste from DOE activities through cleanup of the ORR.

This RI/FS evaluation will also support the DOE strategic plan for reducing the ORR's cold war legacy footprint and disposing of all resultant waste materials (DOE 2011c).

# 5. TECHNOLOGY SCREENING AND ALTERNATIVES ASSEMBLY

Technologies and process options are identified and screened in this chapter to determine representative process options that best support the disposal of candidate waste streams identified in Chapter 2. The representative process options are assembled into disposal alternatives that satisfy the RAOs developed in Chapter 4.

The selected disposal alternatives are further developed and evaluated against the CERCLA criteria to build a basis for choosing one that is the most likely to provide an effective, implementable, and economical solution. The alternatives are developed in detail in Chapter 6, and evaluated in Chapter 7.

## 5.1 IDENTIFICATION OF TECHNOLOGIES AND PROCESS OPTIONS

RAOs are met through implementation of general response actions, which are intended to protect human and ecological receptors from exposure to contamination in sources or environmental media. This section of the RI/FS draws from the general response actions, technology types, and process options that were presented in the EMWMF RI/FS and includes updates and modifications as necessary to address the present state of conditions. Applicable new information and lessons learned from construction and operation of the EMWMF are presented and applied throughout the screening process.

As specified in EPA RI/FS guidance (EPA 1988), a wide range of applicable technologies are evaluated to select a smaller number of process options for alternatives analysis. In the initial screening step, each process option is evaluated to determine its technical applicability to provide/support a potential solution. Next, the retained process options for each general response action and technology type are evaluated based on effectiveness, implementability, and relative cost to select final representative process options to retain for further development. Selection of representative process options for the development of alternatives does not eliminate other process options from future consideration.

The following general response actions apply to development of waste disposal alternatives for ORR CERCLA wastes:

- No action
- On-site disposal
- Off-site disposal
- Treatment of mercury-contaminated debris
- Volume reduction (VR)
- Waste packaging and transport
- Institutional controls

Potential applicable technology types and process options that apply to each general response action are identified, evaluated, and screened to narrow the selections to those that are most likely to be feasible. Following the initial screening, the process options retained are evaluated for relative effectiveness, implementability, and cost. Process options that best satisfy these criteria are carried forward as the representative process options that are assembled into remediation alternatives. Assembled remediation alternatives of the same technology type may use significantly different process options that could provide a unique advantage. In such a case, both alternatives of the same technology type may be carried forward for further development.

Selection of representative process options for the development of alternatives does not eliminate other process options from future consideration. Process options not retained may be reconsidered or new options may be added during development of the proposed plan, the ROD, or during the final design, equipment and vendor selection, or implementation.

Table 5-1 identifies and summarizes technologies and process options for each general response action, and identifies options that are retained or eliminated with comments regarding the basis for the screening decision. Process options are evaluated with respect to technical applicability and a smaller number of options are selected to retain for further study as recommended by EPA (EPA 1988). The evaluation process also documents the justification for eliminating options from further consideration. Process options or technology types that do not pass the initial screening step are not considered further. The following subsections provide general descriptions of process options considered for each of the seven general response actions.

### 5.1.1 No Action

The No Action Alternative is considered in accordance with CERCLA and NEPA requirements as required by the NCP as a basis for comparison with other general response actions. For this alternative, there would be no CERCLA action or work scope to consider for this project. Management of CERCLA waste after EMWMF capacity is reached would be addressed by the individual projects, rather than on an integrated ORR-wide basis.

Unlike the No Action Alternative for a typical feasibility study which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative in this case is based on the assumption that no coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached. No assumptions are made under this alternative regarding the implementation of remedial strategies or specific actions for the individual sites, or at the watershed or ORR program-wide level.

Project-specific remedial decisions, including those concerning on-site, off-site, or in-situ waste disposal, would be made under the No Action Alternative without the benefit of an ORR site-wide disposal strategy or infrastructure. While protective remedies would be implemented, the lack of a coordinated disposal program has potential cost and protectiveness impacts as discussed in Section 7.2.1 and Section 7.3.

### 5.1.2 On-site Disposal

On-site disposal technologies considered include new facilities and existing land disposal facilities. To be considered applicable, a facility would have to accept the anticipated candidate waste streams (unclassified or classified LLW and mixed solid waste types with RCRA and/or TSCA components). Facilities were screened out if they could not accept some or all of these wastes or are not acceptable for other reasons. Some candidate waste streams could be treated to remove or segregate contaminants and the uncontaminated portion of the waste stream could be disposed of in another approved manner.

#### 5.1.2.1 New Facilities

Concrete vaults: Concrete vaults are large, reinforced concrete, multi-celled structures constructed above- or below-grade facilities. The floors, ceilings, and exterior walls of concrete vaults may be up to 2 ft (0.6 m) thick. Concrete vaults are typically used to dispose of containerized LLW. Once these cells are filled with waste containers, the void spaces are filled with sand or grout and the filled vault is covered with a concrete lid. Vaults can be designed to allow for waste removal if necessary. Although vaults are structurally stable, concrete is more permeable than clay and as a result, disposal of leachable material within a vault would require an additional low-permeability lining of clay or other material for long-term containment of the waste. The requisite liners and multilayer cap can be used in conjunction with vaults for disposal of LLW and MLLW.

**Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options**

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Relative Cost | Selection |
|---|---|---|---|---|---|---|---|
| No Action | None | No actions | No coordinated CERCLA disposal capability is developed for the ORR. CERCLA cleanup projects arrange for disposal at the project level. | Ineffective as an ORR-wide disposal effort | Disposal is independently implemented by CERCLA cleanup projects. | Collective costs for project level waste management could be very high. | Retained as required by the NCP |
| On-site Disposal | New facilities | Below-grade facilities | Disposal of waste in silos, concrete vaults, engineered cells, or other facilities placed entirely below grade. | Effective for long-term disposal of LLW | Insufficient land available; groundwater is too shallow | Very High | Eliminated |
| | | Sanitary landfill | A sanitary or construction/demolition landfill similar to an engineered disposal facility but with fewer isolation features incorporated into design. | Ineffective due to insufficient waste isolation systems | Prohibited from receiving LLW or MLLW | Low | Eliminated |
| | | Unlined trenches landfill | A trench or excavation with no bottom liner and a simple vegetative cover. | Ineffective due to insufficient waste isolation systems | Prohibited from receiving LLW or MLLW | Low | Eliminated |
| | | Concrete vaults (above grade) | Large, reinforced, structurally stable, multi-celled structures designed for containerized waste. Allows for waste removal. Caps, liners, and leachate removal systems can be incorporated to meet requirements for LLW and mixed waste disposal. | Effective, but no more so than LLW landfill | Requires larger commitment of land than other new facility options | Very High | Eliminated |
| | | Engineered disposal facility (partially below grade) | Facility that is partially below grade and uses natural and man-made materials in embankments, cap, and liners. Caps, liners, and leachate removal system can be incorporated to meet requirements for LLW and mixed waste disposal. | Effective isolation of wastes; assumes treatment as required for land disposal | Superior: technology is mature and robust, materials, equipment, and contractors are available | Moderate | Retained |
| | | Tumulus facility | Waste placed in concrete containers on a concrete pad. Caps, liners, and leachate removal system can be incorporated to meet requirements for LLW and mixed waste disposal. | Effective, but no more so than LLW landfill | Increased design and construction requirements relative to LLW landfill | Moderate to High | Eliminated |

**Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)**

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Relative Cost | Selection |
|---|---|---|---|---|---|---|---|
| On-site Disposal (continued) | Existing facilities | Y-12 Industrial Landfill V | A Class II (TDEC) lined landfill designated to receive industrial, commercial, and institutional waste with little or no contamination. | Ineffective due to insufficient waste isolation systems | Prohibited from receiving LLW or MLLW | Low | Eliminated |
| | | Y-12 Construction/ Demolition Landfills VI/VII | Class IV (TDEC) unlined landfills designed to receive demolition wastes with little contamination for remodeling, repair, and construction. | Ineffective due to insufficient waste isolation systems | Prohibited from receiving LLW or MLLW | Low | Eliminated |
| | | Interim Waste Management Facility | Tumulus facility at SWSA 6 designed as a disposal facility for LLW generated at ORNL. | Not available | Closed under the Melton Valley Closure Project and not available for waste disposal | None | Eliminated |
| | | Long-term storage | Storage in containers in existing buildings until treatment or disposal capability is available. | Effective for limited waste volumes | May be used for interim storage of waste that may not meet disposal facility WAC, pending treatment and disposal options | Low | Retained as interim option |
| | | EMWMF | Facility is partially below grade and uses natural and man-made materials in embankments, cap, and liners. Caps, liners, and leachate removal system incorporated to meet requirements for LLW and RCRA waste disposal. | Effective isolation of wastes; includes limited treatment as required for land disposal | Projected to be at capacity and unavailable | Moderate | Retained Anticipated to be in use until 2024 timeframe |
| Off-site Disposal | New facilities | New off-ORR engineered facility | An above- or below-ground engineered cell, concrete vault, or tumulus facility at an off-site location designed to receive LLW and MLLW. | Effective | No known plan for a new facility. Adequately represented by existing permitted DOE and commercial facilities | Very High | Eliminated |
| | Existing LLW and mixed-waste facilities | Chem Nuclear | Commercial LLW disposal facility in Barnwell, South Carolina. | Effective | Availability is uncertain (state equity issues) | High | Eliminated |

**Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)**

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Relative Cost | Selection |
|---|---|---|---|---|---|---|---|
| Off-site Disposal (continued) | Existing LLW and mixed-waste facilities (continued) | Energy*Solutions* (formerly Envirocare) | Commercial LLW/mixed waste facility in Clive, Utah | Effective isolation of wastes; assumes treatment as required for land disposal. Treatment of LLW/RCRA waste to meet LDRs is available at facility | Available for non-classified LLW and MLLW. Incurs potential risk of transportation accident or shut-down | Very High due to transportation costs and disposal fees | Retained as representative commercial off-site disposal option for non-classified LLW and MLLW |
| | | DOE NNSS (formerly Nevada Test Site) | DOE disposal facility near Las Vegas, Nevada | Effective isolation of wastes; assumes treatment as required for land disposal. Treatment of LLW/RCRA waste to meet LDRs is available at facility | Available for non-classified and classified LLW and MLLW. Incurs potential risk of transportation accident or shut-down | Very High due to transportation costs | Retained as representative off-site disposal option for non-classified LLW and MLLW |
| | | DOE Hanford Reservation | DOE storage/disposal facility near Richland Washington | Effective for LLW disposal, but lacks MLLW disposal capability | Hanford's CERCLA ROD does not allow receipt of MLLW from out-of-state | Very High due to transportation costs | Eliminated |
| | | US Ecology-Hanford | Commercial LLW waste facility near Richland Washington | Effective for LLW disposal | Not available for ORR waste streams | Very High due to transportation costs | Eliminated |
| | | Waste Control Specialists (WCS) | Commercial LLW/mixed waste facility in Andrews, Texas | Effective for LLW and MLLW disposal; limited to receiving containerized debris waste (soil waste may be bulk) | DOE recently entered into a contract with WCS; however, WCS has limitations on volumes of waste that can be received due to its size (~ 1 M $yd^3$) | Very High due to limitations on waste receipt (containers and volumes) | Retained as representative commercial off-site disposal option for non-classified LLW and MLLW |
| | Existing RCRA/TSCA facilities | WMI-Emelle | Commercial RCRA-Hazardous and TSCA waste disposal facility in Emelle, Alabama | Effective for RCRA/TSCA, not currently capable of receiving DOE LLW or MLLW | Not currently on approved active TSDRF list for ORR cleanup | High to Very High | Eliminated |
| | | US Ecology-Beatty | Commercial RCRA-Hazardous and TSCA waste disposal facility in Beatty, Nevada | | | | Eliminated |
| | | Clean Harbors, Deer Park | Commercial RCRA-Hazardous and TSCA waste disposal facility in Deer Park, Texas | | | | Eliminated |
| | | Clean Harbors - Clive | Commercial RCRA-Hazardous and TSCA waste disposal facility in Clive, Utah | | | | Eliminated |

**Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)**

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Relative Cost | Selection |
|---|---|---|---|---|---|---|---|
| Treatment of mercury-contaminated debris[1] (details in Appendix C) | Immobilization | Macro-encapsulation at the demolition/ project site | Encapsulating material completely encapsulates debris and reduces leachability of final waste form; would be completed at demolition site | Effective on large waste volumes; demonstrated | Able to be implemented; has disadvantage of requiring transportation and placement of heavy waste forms | Moderate to high | Eliminated (see Appendix C) |
| | | Macro-encapsulation at disposal site | Encapsulating material completely encapsulates debris and reduces leachability of final waste form; would be completed at disposal facility | Effective on large waste volumes | Able to be implemented; requires variance | Moderate | Retained (see Appendix C) |
| | Thermal extraction | Retort or thermal desorption | Application of heat to vaporize mercury from waste matrix; vapor is captured and mercury can be recovered/disposed | Effective for very limited waste volumes | Existing facilities are not capable of treating estimated quantities of mixed mercury debris | Very High | Eliminated |
| | Chemical extraction | Chemical washing using chemical reagent | Washing of debris to remove mercury; generates secondary waste | Effective for very limited waste volumes and types | Not implementable on the scale needed for estimated quantities of mixed mercury debris | Very High | Eliminated |
| Volume Reduction (see Appendix B for detailed analyses) | Recycling and Reuse | Recycling/reuse | Recycle of commercially valuable materials | Effective for clean materials, but significant effort required for contaminated materials to render them suitable for recycle | Readily implemented for clean materials; difficult to implement for contaminated materials | Low for clean materials; high for contaminated materials | Eliminated; applicable at the Project level; assume all recycle completed prior to waste "entering" this RI/FS . DOE moratorium on recycling of CERCLA-generated scrap metal remains in force. |
| | | Sequencing | Schedule sequencing to make use of waste soil as fill material for landfill operations | Effective for on-site and off-site disposal | Readily implemented during planning phase; significant management effort required maintain effective project sequencing ; more difficult to implement of stockpiling is required | Very low if stockpiling of soils is not required; low if stockpiling is required | Retained as a common practice for all options at the Project level (see details in Appendix B) |
| | Segregation | Characterize and Separate | Separation of clean or lightly contaminated materials for Subtitle D landfill disposal | Effective for on-site and off-site disposal | Routinely implemented during CERCLA actions; extensive characterization may allow further segregation (see Appendix B) | Moderate due to the cost of characterization activities | Eliminated; applicable at the Project level; assume all segregation completed prior to waste "entering" this RI/FS . (see details in Appendix B) |

**Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)**

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Relative Cost | Selection |
|---|---|---|---|---|---|---|---|
| Volume Reduction (see Appendix B for detailed analyses) (continued) | Size Reduction | Excavator Attachments | Primary size reduction of debris to meet transportation, packaging, and landfill placement requirements | Effective for large debris items | Readily implemented during demolition operations | Moderate due to the additional equipment and effort required | Retained as a common practice for all options at the Project Level (see Appendix B) |
| | | Debris Processors | Additional size reduction using industrial processors to reduce debris void space | Effective for reducing off-site transportation costs for debris with low bulk density; not effective for on-site disposal (See Appendix B) | Complex and costly to implement | Costly to implement. Not cost effective for on-site disposal, but cost effective for off-site disposal (See Appendix B) | Retained for the Off-site Disposal Alternative only |
| Waste Packaging and Transport | Packaging | Small containers | Small containers such as drums, B-25 boxes, or over- packs can be used to accumulate, store, or transport waste | Effective for small quantities, but not appropriate for much of the anticipated ORR CERCLA waste stream | Implementable for small waste streams generated over long periods, but not suitable for large waste volumes or for large items | Moderate to High | Retained as process option for certain wastes |
| | | Large containers | Large containers such as roll-off bins, intermodal cargo or sealand containers can contain bulk waste or small containers | Effective and in current use for certain wastes; required for off-site transport | Intermodal containers are available. Intermodal containers are presently used for some off-site shipments originating on the ORR | Moderate | Retained for all waste streams as representative for comparative analysis of alternatives |
| | | Bulk containers | Bulk containers such as Supersacks can contain bulk soil-like waste | Effective for some classes of waste; less effective than intermodals in maintaining containment in the event of an accident | Currently routinely used for bulk materials and waste disposal | Low | Retained as process option for certain wastes |
| | Transport | Barge | Transportation of bulk or packaged waste to DOE Hanford Reservation by barge via Tennessee River, Mississippi River, Gulf of Mexico, Panama Canal, Pacific Coast, Columbia River | Effective for large quantity bulk wastes | Cannot be implemented because Hanford CERCLA landfill is restricted to receiving wastes only from Hanford facilities | Moderate | Eliminated |

**Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)**

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Relative Cost | Selection |
|---|---|---|---|---|---|---|---|
| Waste Packaging and Transport (continued) | Transport (continued) | Truck | Transportation of bulk waste on-site in dump trucks, or packaged waste to on-site and off-site disposal facilities by flatbed or other trucks | Effective for bulk and small-quantity waste packages (drums) | Implementable; roads, trucks, and contractors are available | Low to Moderate on a per ton/mile basis | Retained for off-site transportation of classified waste and for rail to truck transfer to NNSS<br>Retained as representative for all on-site transportation |
| | | Train | Transportation of bulk or packaged waste to off-site disposal facilities by railroad | Effective mode for off-site transportation of bulk wastes, intermodal containers, or small containers. | Implementable. A truck to train transfer facility is available at ETTP. Direct rail service is available from ETTP to ES in Clive, UT. NNSS can be accessed by using rail to truck transfer facility in Kingman, AZ, then truck transfer to NNSS. | Low to Moderate on a per ton/mile basis | Retained for off-site transportation of classified waste and for rail to truck transfer to NNSS, and for direct shipment of waste to ES |
| Institutional Controls | Access and use restrictions | Physical barriers | Security fences, signs, buffer zones, and other barriers installed around potentially contaminated areas to limit access | Effective while maintained | Implementable. Materials and contractors are available | Low | Retained |
| | | Administrative controls and security | Use of security (e.g., guards, surveillance, badges for access) or institutional requirements (e.g., training, standard operating procedures) to limit access to contaminated areas | Effective while maintained | Implementable | Low | Retained |
| | | Covenants and deed restrictions | Restrictions on land use by licensed agreements, regulatory permits, code, zoning, stipulations on property deeds | Effective | Implementable | Low | Retained |
| | Maintenance and monitoring | Surveillance and maintenance (S&M) | Inspection of engineered and remedial actions and performance of preventive and or corrective measures to ensure proper operation of engineered controls | Effective while maintained; improves overall reliability | Implementable and required | Low to Moderate | Retained |
| | | Environmental monitoring | Use of results from sampling and characterization of media before, during, and after remediation to predict and verify effectiveness of remedial actions | Effective while maintained; improves overall reliability | Implementable and required | Low to Moderate | Retained |

[1]Mercury-contaminated soil is assumed to be treated by individual remedial action projects and is therefore not considered part of the RI/FS remedy.

**Engineered Disposal Cell:** An engineered disposal cell can be designed to accommodate a wide range of solid waste streams. A partially below-grade or above-grade engineered cell typically consists of a multilayer liner beneath the waste, lined embankments, and a multilayer final cover to completely encapsulate the waste. Engineered cells are constructed to satisfy the design requirements appropriate to the type of waste they contain.

In a cell engineered for LLW, the waste is placed on a bottom clay layer designed to impede the percolation of free water from the cell into the ground. The waste is then covered with a cap that includes an impermeable layer, a drainage layer, and a vegetative layer. The cell makes extensive use of natural materials and can be engineered to isolate wastes for long periods.

RCRA-hazardous waste is disposed of according to the requirements of 40 CFR 264 and 268 and more stringent state requirements, as applicable. In a cell with design components similar to those specified in 40 CFR 264.301, the waste is placed on a bottom liner system consisting of two leachate collection/removal layers, each above a low-permeability liner with appropriate characteristics for retarding contaminant migration. The final (top) cover on this type of cell must be equally or less permeable than the bottom liner and meet other performance requirements.

TSCA waste must be disposed of according to the requirements of 40 CFR 761. A facility designed to receive TSCA waste (i.e., PCBs) would be required to meet the facility specifications in 40 CFR 761.75. The liner consists of 3 to 4 ft (0.9-1.2 m) of soil and may also use a synthetic membrane liner. The bottom liner of the cell must be 50 ft (15 m) above groundwater or provide equivalent or superior protection. A cell designed to accommodate LLW, RCRA, TSCA, and MLLW would incorporate design elements to meet all regulatory requirements. In general, landfills designed to meet RCRA requirements will meet or exceed TSCA requirements.

**Tumulus Facility:** A tumulus facility consists of an at-grade concrete pad, stabilized waste, and a cover designed to contain LLW. Concrete containers of stabilized waste are stacked on the pad. The concrete pad incorporates a leachate collection system; an impermeable liner may be added to contain other types of waste. Once the stabilized waste containers have been placed on the pad, a multilayer cap is placed over the stacked waste to limit the infiltration of water. Taken as a whole, the protective features of the containers, pad, liners, and cover allow the facility to receive LLW and MLLW.

#### 5.1.2.2 Existing Facilities

**EMWMF:** While capacity is currently available and suitable, projections are that the landfill will be at capacity by 2024**.**

**Interim Waste Management Facility:** This is a tumulus facility at Solid Waste Storage Area 6 that has been used to dispose of ORNL-generated LLW. Facility construction is similar to that described in the preceding paragraph.

**Long-term Storage:** Storage capacity in existing buildings on the ORR could accommodate some candidate waste streams. As with the existing wastes in storage, this is only an interim solution pending the availability of treatment or permanent disposal options.

### 5.1.3 Off-site Disposal

Evaluated off-site disposal technologies include new facilities, existing LLW and mixed waste facilities, and existing RCRA/TSCA facilities. Off-site disposal requires the same approach as on-site disposal with regard to the priority of recycle, reuse, and the use of Subtitle D landfills before considering disposal off-site. The process includes selection of an approved disposal site, development of generator certification documentation, development of waste profiles that meet the disposal site WAC, waste packaging, transportation, and disposal.

#### 5.1.3.1 Existing LLW and Mixed-Waste Facilities

**Energy*Solutions*:** Energy*Solutions* is a commercial waste disposal facility in Clive, Utah, that has previously received ORR waste. Energy*Solutions* can receive LLW and MLLW that meets their WAC. Energy*Solutions* also has facilities and permits necessary to process and stabilize untreated MLLW for disposal. Wastes are disposed of in an engineered disposal cell located in a remote arid environment.

**Nevada National Security Site:** NNSS is located in Nye County, Nevada 65 miles northwest of Las Vegas, Nevada. There is an ongoing DOE-EM mission at the NNSS that includes the Area 5 Radioactive Waste Management Complex (RWMC), a radioactive waste management and disposal facility where LLW and MLLW are safely and permanently disposed. The Area 5 RWMC is located in one of the most arid and least populated regions of the United States, which provides an ideal area for near-surface disposal of LLW. The NNSS has the unique capability of accepting U. S. Government classified waste materials for disposal.

The NNSS is authorized to receive DOE-generated LLW, as well as DOE-generated RCRA hazardous waste and RCRA MLLW (that meet LDRs). No treatment capability for mixed waste is provided at NNSS.

**DOE Hanford Reservation:** The DOE Hanford Reservation, near Richland, Washington, will accept out-of-state LLW for disposal, but cannot accept out-of-state MLLW for disposal.

**US Ecology-Hanford:** US Ecology operates a commercial LLW facility on the Hanford Reservation. US Ecology is currently accepting waste only from generators in the Northwest States waste compact.

**Waste Control Specialists:** WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, Texas. WCS offers management of radioactive waste, hazardous waste, and mixed waste.

#### 5.1.3.2 Existing RCRA/TSCA Facilities

There are a number of permitted commercial RCRA/TSCA disposal facilities available for ORR candidate waste streams. The following RCRA/TSCA facilities were considered in the technology screening process:

- WMI-Emelle in Emelle, Alabama
- US Ecology-Beatty in Beatty, Nevada
- Clean Harbors in Deer Park, Texas
- Clean Harbors in Clive, Utah

All of these facilities are similar in the types of waste that they receive for treatment and disposal and the services that they offer. The primary difference between them is transportation distance, with the WMI-Emelle facility the closest and US Ecology's Nevada facility the most distant. Off-site facilities in the western United States (e.g., Nevada, Utah, Texas, and Washington) tend to have more favorable hydrogeological conditions and lower local population densities than facilities in the more humid South (e.g., Alabama).

### 5.1.4 Treatment of Mercury-contaminated Debris

Mercury-contaminated (D009) waste will require treatment to render it non-hazardous and to meet LDRs. For soils contaminated with mercury, individual projects (remedial action projects) are assumed to provide this treatment (by sulfur polymer stabilization/solidification or similar process) prior to disposal (on-site or off-site), and therefore process option considerations for soils are not necessary in this RI/FS analysis. However, for debris, it can be cost effective to provide that treatment at an on-site facility as

opposed to providing it by/at the project/demolition site. Three process options are considered for debris treatment, stabilization, thermal extraction processes, and chemical extraction processes.

#### 5.1.4.1 Immobilization

Per 40 CFR 268.45, immobilization of D009 mercury-contaminated debris offers methods that consist of application of surface coating materials such as polymeric organics (e.g., resins and plastics) or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media; stabilization of the debris with reagents such as Portland cements so that the leachability of the hazardous contaminants is reduced; or application of an appropriate material which adheres tightly to the debris surface to avoid exposure of the surface to potential leaching media. Sealing materials include epoxy, silicone, and urethane compounds.

#### 5.1.4.2 Thermal and Chemical Extraction

Thermal and chemical extraction methods work by removing mercury from the waste, potentially permitting land disposal or reuse of some materials (e.g. valuable metals). Thermal treatment of mercury-contaminated soils, debris, and other solid wastes has been one of the most commonly applied technologies, in part owing to the potential for removal, recovery and reuse of elemental mercury. Thermal treatments utilize high temperatures and in some cases reduced atmospheric pressure to volatilize mercury from waste, coupled with extraction and condensation of the mercury vapor for reuse or further treatment and disposal. Chemical treatments reduce the mercury contaminant in the waste by chemical and/or physical means through washing/extracting the mercury. These methods would typically be used for waste streams that are significantly lower volumes than the debris waste expected from ORR cleanup of Y-12.

### 5.1.5 Volume Reduction

OREM follows a hierarchy for disposing of waste generated through cleanup projects to minimize disposition volumes and costs, and reduce needed landfill capacity. As shown in Figure 5-1, the foundation of the strategy is built on first evaluating waste materials for recycle or beneficial reuse. The second priority is to make use of onsite Subtitle D landfills for final disposal of waste. This RI/FS identifies process options for use after this step; that is, the recycle/reuse and use of ORR landfills through segregation is accomplished at the project level prior to waste entering consideration for management by the alternatives of this RI/FS; however, it is worth noting that these volume reduction methods are already part of the overall OREM strategy for waste management. This approach is common to all disposal actions. Size reduction processing requires additional evaluation to determine cost effectiveness and possible incorporation as a process option. Appendix B includes a detailed evaluation of volume reduction methods.

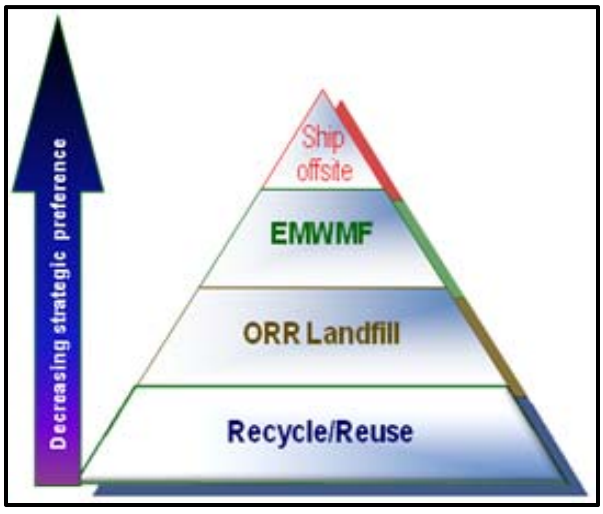



**Figure 5-1. OREM Hierarchy for Waste Disposition**

#### 5.1.5.1 Recycle/Reuse

Recycle involves identifying materials from CERCLA actions that have value within DOE or in the marketplace as a resource for construction or for manufacturing other products. Examples include recycle of structural steel for the automobile industry or recycle of masonry rubble and concrete as aggregate for road construction. CERCLA remedial action projects that generate waste soil are evaluated as a potential source of fill material for demolition debris with significant void fraction. As indicated above, CERCLA actions are evaluated at the project/program level for potential recycling and reuse.

#### 5.1.5.2 Segregation

Waste segregation is an important volume reduction option that is emphasized in planning of all DOE D&D projects. Significant effort and funding is provided for initial characterization activities in order to provide health and safety information for worker protection, to develop waste profile information for disposal, and to identify opportunities for separating clean and contaminated materials. Segregation involves the effort required to separate materials in order to divert suitable waste materials to a Subtitle D landfill such as the ORR Landfill. Again, while it is a pertinent element of OREM's waste disposition strategy, segregation is carried out at the project level. The possibility of more extensive characterization to enable more complete/extensive segregation is examined in Appendix B.

#### 5.1.5.3 Size Reduction Processing

Size reduction involves physical cutting, crushing, or compressing debris to reduce size for transporting, to meet physical criteria for landfill acceptance, and to reduce the void fraction of the material for disposal as well as ultimately reduce the volume of waste to be disposed. Reducing void space reduces the amount of fill material required to stabilize the landfill thus reducing overall size of the landfill, reduces pathways for water intrusion, and minimizes settling and associated damage to the final cover. The waste acceptance criteria for landfills includes physical criteria that will require size reduction actions be performed prior to placement in the landfill. An example of this is the EMWMF physical WAC that requires debris items to sized to dimensions less than 6 ft long, 4 ft wide, and 4 ft deep. This is usually accomplished using excavators with shearing and cracker jaw attachments. This primary size reduction would be required regardless of the disposal method (on-site or off-site) in order to fit the materials into containers or to meet disposal criteria. Additional size reduction beyond the primary requirement involves the use of processing equipment such as industrial shredders, crushers, and shears designed for high-volume production facilities. Debris void space can be reduced, which in turn reduces the volume of material necessary to fill voids and stabilize the landfill. If implemented effectively, size reduction can reduce the landfill footprint. However, the cost and complexity of size reduction must be considered to determine the net benefits of the process. Appendix B provides an evaluation of volume reduction options as applied to both on-site and off-site waste disposal.

### 5.1.6 Waste Packaging and Transport

Packaging technologies are used to ensure safe containment of waste during transport, storage, and disposal. Transport vehicles can be used in conjunction with packaging for relocation of waste to treatment or disposal facilities. Some transport vehicles can be equipped to provide containment without additional packaging.

#### 5.1.6.1 Packaging

**Small Containers:** A number of small containers such as lab packs, B-12 and B-25 boxes, drums, and overpacks are designed to contain various waste forms (e.g., debris, solid, liquid, sludge, granular) and types (e.g., LLW, RCRA-corrosive). Small containers would be applicable to certain specific candidate waste streams. Small containers are typically disposed of with the waste rather than emptied and reused.

**Large Containers:** Large containers include roll off bins, intermodal containers, and other container types with various weight and volume capacities, loading capabilities (top-, side-, or end-loaded), and handling characteristics. Some containers can be moved by forklift, some by crane, and some can be winched directly onto a truck bed. Some truck-mounted containers can be unloaded directly by dumping from the truck, while other containers must be removed and unloaded with additional equipment. A variety of waste forms and types can be loaded into the containers. Large containers can usually be decontaminated and reused. Dedicated containers can be reused for similar waste streams with only external decontamination.

**Bulk Containers:** Bulk containers are single-use containers typically disposed of with the waste. A Supersack, a large reinforced bag, is an example of a bulk waste package that can be used to package soil-like waste material.

#### 5.1.6.2 Transport

**Truck:** Truck transport is applicable to both local and long-distance waste transport. Trucks can transport bulk wastes either in approved containers or in covered beds. Waste being shipped off site by rail has to be transferred from trucks to railcars at a transload facility. All off-site disposal facilities are configured to receive waste directly via truck.

**Rail:** Rail transport would be viable only for long-distance waste transport. Railcars could be loaded from trucks at a transload facility. An existing transload facility at ETTP could accommodate containerized waste; however, additional waste transfer facilities would be needed to allow handling of bulk waste. Energy*Solution*s and WCS are configured to receive direct rail shipments. Shipment to other off-site disposal facilities would require either transloading to trucks for the last leg of the trip or construction of a rail spur from the nearest rail line to the disposal facility.

### 5.1.7 Institutional Controls

Access and use restrictions and maintenance and monitoring are institutional control technologies that can reduce the potential for exposure to waste that remains at a remediation site or is placed in a disposal facility. These technologies and the associated process options would be used in conjunction with on-site waste handling, storage, and disposal process options.

#### 5.1.7.1 Access and Use Restrictions

**Physical barriers:** Fences, signs, buffer zones, or other barriers can be installed around potentially contaminated areas to limit access.

**Administrative Controls and Security:** Security (e.g., guards, surveillance, badges for access) or institutional requirements (e.g., training, standard operating procedures) can be used to limit access to contaminated areas.

**Covenants and Deed Restrictions**: License agreements, codes, zoning, or stipulations on a property deed can be used to prohibit unacceptable uses of a contaminated site that could put human or ecological receptors at risk.

#### 5.1.7.2 Maintenance and Monitoring

**Surveillance and Maintenance:** Scheduled and special inspections of engineered facilities and implementation of preventive or corrective measures can be used to ensure the proper operation of engineered components.

**Environmental Monitoring:** Results of the sampling and characterization of environmental media before, during, and after remediation can be used to predict and verify the effectiveness of remedial actions.

## 5.2 RETAINING/ELIMINATING PROCESS OPTIONS

### 5.2.1 No Action

The "no action" general response action is retained as required by the NCP to serve as a baseline for comparison to action-based alternatives. For this alternative, there would be no CERCLA action or work scope to consider for this project. Management of CERCLA waste after EMWMF capacity is reached would be addressed at the project level.

### 5.2.2 On-site Disposal

On-site disposal technology types considered include new and existing land disposal facilities. Three of the on-site disposal options were retained for further study based on effectiveness in isolation of the required waste types, the maturity of the technology, availability of commercial contracting capability, and moderate cost.

#### 5.2.2.1 New Facilities

Sanitary and unlined trench landfills were eliminated from consideration because they are not applicable or suitable for candidate waste streams. Below-grade facilities, concrete vaults, and tumulus facilities were all eliminated due to higher costs, more difficult implementation, and/or physical limitations at the ORR.

The final representative process option retained for on-site disposal is the partially below-grade engineered disposal facility. This option is a proven concept currently demonstrated at the EMWMF and is expected to meet future requirements. It was selected based on equivalent or superior effectiveness, relative ease of implementation, and reduced cost compared to other process options.

#### 5.2.2.2 Existing Facilities

With the exception of EMWMF and long-term interim storage facilities, existing facilities on the ORR were eliminated because none have WAC that allow for disposal of projected candidate waste streams. The EMWMF option is retained in order to provide effective near-term disposal capability. EMWMF is expected to be filled to capacity sometime in 2024. The long-term storage is retained as an interim option for waste that may not meet disposal facility WAC, pending identification of appropriate treatment and disposal options.

### 5.2.3 Off-site Disposal

Options considered for off-site disposal include new facilities, existing LLW and mixed waste facilities, and existing RCRA/TSCA facilities. Several of the existing off-site facilities would accommodate the anticipated waste volumes and types to be generated on the ORR; however, the cost of transportation is extremely high and the options incur the risk of transportation incidents with potential exposure of the general public to radiological hazards. Tipping fees at commercial facilities would also increase costs to the extent that these off-site facilities are used. Further, DOE would retain liability for remediation of these sites in the event that releases occur.

#### 5.2.3.1 New Facilities

Consideration of the use of a new off-ORR engineered facility would require a plan for a new facility to be at some level of development/implementation. Since there are no new facilities being planned, this

option was eliminated. However, there are existing permitted DOE and commercial off-site facilities that could adequately accommodate the ORR CERCLA waste types and volumes.

#### 5.2.3.2 Existing LLW and Mixed-Waste Facilities

LLW and MLLW disposal sites evaluated included Energy*Solutions* in Clive, Utah; NNSS in Nye County, Nevada; the DOE Hanford Reservation near Richland, Washington; U.S. Ecology-Hanford, and WCS in Andrews, Texas. All these sites would effectively isolate wastes that meet their respective WAC, but would incur high transportation/disposal costs as well as risk liabilities until waste reaches its destination. ORR wastes are currently being shipped to the Energy*Solutions* and NNSS facilities, and shipment and disposal at these sites is readily implementable. DOE Hanford and U.S. Ecology-Hanford were eliminated from consideration due to limited ability to accept ORR waste. WCS is a potential process modification to the Off-site Disposal Alternative (see Section 6.3.5.10.1) if in the future the receipt of debris waste in bulk form is allowed (currently WCS requires debris waste to be containerized); however, their facility is currently not large enough (at just under 1 M $yd^3$) to take a majority of the future CERCLA waste. WCS is an option for MLLW receipt.

Energy*Solutions* was retained for disposal of non-classified LLW and MLLW. Treatment of MLLW waste to meet LDRs is also available at the Energy*Solutions* facility. The NNSS facility is retained for unclassified and classified LLW and MLLW disposal. However, treatment of LLW/RCRA waste prior to disposal is not available at NNSS. WCS is retained as a destination for MLLW, as they provide treatment to meet LDRs.

#### 5.2.3.3 Existing RCRA/TSCA Facilities

The Waste Management, Inc. (WMI)-Emelle (Emelle, Alabama), US Ecology-Beatty (Beatty, Nevada), Clean Harbors (Deer Park, Texas), and Clean Harbors (Clive, Utah) facilities were identified as existing RCRA/TSCA facilities. All of the facilities are eliminated because the facilities are no longer on the approved active treatment, storage, disposal, and recycling facilities (TSDRFs) list for ORR cleanup. Non-radioactive RCRA/TSCA waste is a small percentage of CERCLA waste generated that does not meet the EMWMF WAC and is not a differentiator for the On-site and Off-site Disposal Alternatives. Non-radioactive RCRA/TSCA waste and other waste that would not meet an on-site disposal facility WAC are not included as candidate waste streams for quantitative analysis (see Section 2.1.3).

### 5.2.4 Volume Reduction

Recycle/reuse as a volume reduction process option is eliminated because it is performed at the project level prior to the waste being considered in this RI/FS (see explanation of OREM waste disposal strategy shown in Figure 5-1; additionally clean, recyclable material is not acceptable at an on-site disposal facility – see exclusions under Section 2.1.1). Therefore, any waste that may be recycled should be recycled by the demolition project contractor, regardless of whether the CERCLA waste alternative for disposal is on-site or off-site. A more detailed analysis is presented in Appendix B, Section 5.1.

Project sequencing (in order to maximize the use of soil waste as void fill) was retained because it is very effective, low in cost, and is currently implemented for conserving the EMWMF disposal capacity.

Waste segregation was eliminated for the same reasons as recycle/reuse; waste that is capable of being disposed in ORR landfills should be disposed as such by the demolition project contractor, regardless of the CERCLA waste alternatives reviewed under this RI/FS analysis. However, a more detailed analysis is considered in Appendix B, and project-level cost benefit analyses of more detailed characterization to allow for further segregation are suggested (see Section 5.3 in Appendix B). Waste segregation is a current practice for CERCLA actions at the project level, and is effective in diverting clean materials from the EMWMF.

The cost and benefits of size reduction processing were evaluated in detail in Appendix B, and it was determined not to be cost effective for the On-site Disposal Alternative. However size reduction was retained for the Off-site Disposal Alternative because it reduces transportation and disposal costs (fewer shipments) by increasing bulk density and the mass of waste material per shipment.

### 5.2.5 Treatment of Mercury-contaminated Debris

Treatment of mercury-contaminated debris may be accomplished by several processes. However, the volume of mercury-contaminated debris to be generated on the ORR, by demolition of facilities at Y-12, is such that thermal extraction and chemical extraction options are impractical and so high in cost that remediation would be discouraged. Therefore these options were eliminated. More detailed information is developed in Appendix C.

Macroencapsulation of mercury-contaminated debris is the most effective way to treat the volumes of debris expected, regardless of on-site or off-site disposal. Therefore, this process option was retained. Appendix C evaluates the cost effectiveness and risk involved with performing the operation at the disposal facility versus at the demolition/project site. The option to treat at the disposal facility was selected as the more cost effective and practical option in Appendix C.

### 5.2.6 Waste Packaging and Transport

Packaging technologies are used to ensure safe containment of waste during transport, storage, and/or disposal. Transport vehicles can be used in conjunction with packaging for relocation of waste to treatment and disposal facilities. Some transport vehicles can be equipped to provide containment without additional packaging.

#### 5.2.6.1 Packaging

The use of small containers (e.g., B-12 and B-25 boxes, drums, and over-packs) is retained because they are effective and implementable for specific candidate waste streams. They are typically disposed of with the waste rather than emptied and reused, and they can be placed in large containers for ease of shipment.

Use of large containers (e.g., roll-off bins, intermodal/sealand containers) for bulk waste and over-packs containing small containers are effective and implementable. They are commonly used on the ORR in a variety of sizes and configurations that provide for diverse loading and unloading scenarios. Large containers are retained for all waste streams as a necessary component of On-site and Off-site Disposal Alternatives.

Bulk containers such as Super Sacks® are inexpensive, single-use containers typically disposed of with the waste. Large volumes of waste in bulk containers can be transported on-site by truck. Some bulk waste can be transported off-site by truck or train, depending on the waste characteristics and the receiving facility's waste handling capabilities. Bulk waste containers can also be placed in large containers to minimize large container decontamination costs. Bulk containers are retained as a process option because they can be suitable for certain on-site wastes, such as asbestos.

#### 5.2.6.2 Transport

Truck transport is applicable, effective, and implementable for both local and long-distance waste transport. Though the cost for long-distance transport is high, this process option is routinely used on the ORR for waste materials, and it is retained as a potential alternative.

Rail transport is retained as a viable long-distance waste transport method that could be more cost effective than truck transport for off-site disposal. An existing transload facility at ETTP can effectively accommodate transfer of containerized waste from truck to train for the expected waste volumes.

Energy*Solutions* in Utah is configured to receive rail shipments of LLW and MLLW. Transport by rail to NNSS in Nevada currently requires transfer of the waste from railcars to trucks at a transload facility (assumed as Kingman, Arizona) for the last leg of the trip. The cost for rail transport, including the cost of transloading, would be lower than truck transport for very large waste volumes.

### 5.2.7 Institutional Controls

As shown in Table 5-1, all institutional controls process options were retained to be used in conjunction with other actions to ensure adequate security and long-term protectiveness.

## 5.3 ASSEMBLY OF ALTERNATIVES AND ABILITY TO MEET REMEDIAL ACTION OBJECTIVES

The general response actions, technology types, and representative process options carried forward for alternative development are shown in Table 5-2 where they have been assembled into three disposal alternatives: the No Action Alternative, the On-site Disposal Alternative, and the Off-site Disposal Alternative. A hybrid alternative, combined on-site disposal and off-site disposal, is presented in Section 5.4; however, it is not carried forward throughout this document as the On-site Disposal Alternative adequately encompasses an off-site disposal element, as noted in sub-bullet 1, below, and RI/FS Chapter 2. The alternatives presented in Table 5-2 are described in detail in Chapter 6 and fully evaluated in Chapter 7. Each alternative includes the necessary characteristics that satisfy RAOs for CERCLA waste disposal.

The On-site and Off-site Disposal Alternatives satisfy the RAOs as described in the following:

- Prevent exposure of a human receptor to future-generated CERCLA waste that exceeds a human health risk of $10^{-4}$ to $10^{-6}$ ELCR or HI of 1 to 3.
  - **On-site Disposal Alternative:** The on-site disposal facility would meet this RAO by isolating the waste using appropriate engineered features and establishing a facility WAC for constituents of concern given the potential exposure pathways based on the conceptual design. If on-site disposal is the selected remedy, the final WAC would require approval by all regulatory parties. Waste not meeting the on-site disposal facility WAC would be shipped to appropriate off-site disposal facilities or placed in interim storage with adequate waste isolation features and institutional controls pending the development of treatment or disposal capabilities. Section 5.4 discusses scenarios that consider combined on-site and off-site disposal.
  - Appropriate controls at an on-site facility, including compliance with regulations and health and safety plans, would ensure that workers would not be exposed to the waste during handling, transport, or disposal operations.
  - Isolation features at the on-site disposal facility would be maintained after closure for an indefinite period. Such isolation would be regularly verified by the regulatory agencies responsible for ensuring proper design and compliance with long-term closure, monitoring, and maintenance requirements. The containment afforded by the facility's design, as well as permanent restrictions (e.g., ROD land use controls) on land and groundwater use, would ensure long-term protection of workers and the public.
  - **Off-site Disposal Alternative:** The off-site facilities proposed for use under the Off-site Disposal Alternative have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the NCP [40 CFR 300.440], and have been approved for disposal of CERCLA wastes. As a result, this RAO is met through facility design and operating conditions for off-site facilities and compliance with established WAC.

- Prevent releases of future-generated CERCLA waste or waste constituents that do not meet ARARs for environmental media.
  - **On-site Disposal Alternative:** The engineered isolation features of an on-site disposal facility would be designed to meet ARARs for protection of ecological receptors from contact with or exposure to the waste or waste constituents. Candidate wastes would be contained during transport and disposal to prevent exposure to ecological receptors.
  - **Off-site Disposal Alternative:** The off-site facilities proposed for use under the Off-site Disposal Alternative have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the NCP [40 CFR 300.440], and have been approved for disposal of CERCLA wastes. As a result, this RAO is met through facility design and operating conditions for off-site facilities and compliance with established WAC.
- Prevent ecological exposure to future-generated CERCLA waste.
  - **On-site Disposal Alternative:** Through compliance with ARARs and sound design, the on-site engineered disposal cell would effectively isolate the wastes from the environment, minimizing release of contaminants, and reducing overall environmental impact. Compliance with the facility WAC would also ensure minimal ecological exposure.
  - **Off-site Disposal Alternative:** The off-site facilities proposed for use under the Off-site Disposal Alternative have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the NCP [40 CFR 300.440], and have been approved for disposal of CERCLA wastes. As a result, this RAO is met through facility design and operating conditions for off-site facilities and compliance with established WAC.
- Facilitate timely cleanup of ORR and associated facilities.
  - **No-Action Alternative:** This alternative does not ensure the RAO to facilitate timely cleanup of ORR sites is met. A centralized disposal facility on the ORR would not be constructed and there would be no coordinated ORR site-wide effort implemented to manage wastes generated by future CERCLA actions. Lack of a coordinated disposal option could result in increased management of waste in place and greater residual risk at individual sites.
  - **On-site Disposal Alternative:** The on-site disposal facility would facilitate timely cleanup of the ORR by providing sufficient disposal capacity in close proximity to the CERCLA cleanup activities, thus avoiding the uncertainty and risk associated with securing alternate disposal capability. The need to procure disposal services on a project-by-project basis could increase the time, effort, and cost required to complete remedial actions at individual sites.
  - **Off-site Disposal Alternative:** Off-site disposal would facilitate the ORR cleanup by providing readily available off-site disposal capability for candidate wastes. ORR site coordination and a broad waste certification program would be required to minimize duplication of effort among CERCLA project activities. The ETTP transload facility would become a key element of the effort as a centrally located hub of waste transportation activities.

**Table 5-2. Alternatives Assembly, RI/FS for CERCLA Waste Disposal**

| General Response Action | Technology Type | Representative Process Option | No Action Alternative | On-site Disposal Alternative | Off-site Disposal Alternative | Comments |
|---|---|---|---|---|---|---|
| No Action | None | No actions | X | | | No concerted CERCLA action or work scope to consider. Required by NCP. |
| On-site Disposal | New facilities | Engineered disposal cell (partially below grade) | | X | | Representative process option applicable only to on-site disposal. |
| | Existing facilities | Long-term storage | | X | X | Retained as interim option for waste that may not meet disposal facility WAC, pending treatment and disposal options. |
| Off-site Disposal | Existing LLW and mixed waste facilities | Energy*Solutions* Clive, Utah | | a | X | Energy*Solutions* and NNSS are used for off-site LLW and MLLW disposal. Energy*Solutions* and WCS are used for off-site MLLW treatment and disposal. All are applicable (with restrictions) for the Off-site Disposal Alternative. Classified waste must go to NNSS. |
| | | DOE NNSS | | a | X | |
| | | WCS, Texas | | a | X | |
| Volume Reduction | Recycle and reuse | Sequencing | | X | X | Applies to project sequencing to ensure that contaminated soil is available for use as fill material for debris. |
| | Size reduction processing | Excavator attachments | | X | X | Refers to primary size reduction as necessary to meet disposal site WAC. Completed at the Project level. |
| | | Industrial processors | | | X | Retained for size reduction of low-density debris to reduce off-site transportation costs. |
| Treatment for mercury-contaminated debris | Im-mobilization | Macro-encapsulation at disposal facility | | X | X | Retained; process option is most applicable to large volumes of debris expected. Operation at disposal facility is more cost effective than operation performed by individual projects. |
| Waste Packaging and Transport | Packaging | Large containers | | X | X | All types of waste packages can be used for on-site and off-site transport. The use of intermodal containers, commonly used at the ORR and disposal facilities, is assumed. |
| | Transport | Truck | | X | X | Truck transport is used for all transport within ORR and for classified waste shipments to NNSS. Rail will be used for non-classified waste for the Off-site Disposal Alternative with rail to truck transfer for shipments to NNSS. |
| | | Train | | | X | |
| Institutional Controls | Access and use restrictions | Physical barriers | | X | X | All institutional controls apply to both On-site and Off-site Disposal Alternatives. Institutional controls are required at off-site facilities and costs are assumed to be included in disposal fees. |
| | | Administrative controls and security | | X | X | |
| | Maintenance and monitoring | Surveillance and maintenance | | X | X | |
| | | Environmental monitoring | | X | X | |

[a] Off-site disposal facilities are used as necessary when CERCLA wastes do not meet the On-site Disposal Alternative WAC. See Section 5.4 for a discussion of on-site and off-site disposal alternatives combined.

## 5.4 COMBINED ON-SITE AND OFF-SITE DISPOSAL

This RI/FS discusses two disposal alternatives, on-site and off-site, essentially as either-or propositions. However, in terms of on-site disposal, off-site disposal is necessarily a definitive part of that alternative. The reality is that, even if the on-site alternative is the selected alternative going forward, there will always be some portion of CERCLA waste that does not meet the on-site facility's defined WAC and must therefore be disposed off-site. Experience on the ORR to date suggests that approximately 1% to 4% of wastes have not met the current on-site disposal WAC of the existing EMWMF and is therefore disposed at off-site facilities. While a PreWAC is developed in this RI/FS for the on-site alternative, the final WAC will be determined later. The final WAC will include analytic, auditable safety analysis, physical, and administrative WAC limitations, and will be the product of both numeric analyses and regulatory negotiations. In addition, the CERCLA waste to be generated during future cleanup actions will likely be somewhat different from the CERCLA waste generated to date, given that both Y-12 and ORNL sites will be the sources of this waste, whereas ETTP has been the major source of CERCLA waste to this point in time. Given the uncertainty in the final WAC limits and the uncertainty in the future waste characterization, the amounts of waste acceptable for on-site disposal, and therefore the portion that must be disposed off-site, cannot yet be accurately known. This analysis considers various combinations of waste volumes that could be directed to on-site and off-site disposal, and the resulting changes in cost and risk.

While disposal in off-site facilities shifts the risks associated with contaminant release to locations outside Tennessee (primarily the NNSS and Energy*Solutions* in Clive, Utah), there are other risks are associated with transportation of wastes over long distances. For example, the acceptable risk range for CERCLA cleanups is from $10^{-4}$ to $10^{-6}$ cancer incidents. In other words, one person in 10,000 through one person in 1,000,000 exposed to the released contaminants may contract some form of cancer. This is the range in which the on-site EMDF facility would be expected to perform. Transportation risk, however, is expressed in the estimated number of injuries or fatalities incurred during the operational phase of the project. These estimated injuries or fatalities are due directly to traffic accidents or exposure to spilled wastes.

Six scenarios are considered, ranging from all disposal occurring on-site, combined on-site and off-site disposal in 20% increments, and all wastes disposed off-site. The six scenarios considered are:

- All wastes disposed in an on-site landfill, with only *de minimus* (<5%) volumes disposed off-site (e.g., the On-site Disposal Alternative).
- 80% of wastes disposed in an on-site landfill, and 20% disposed off-site.
- 60% disposed in an on-site landfill, 40% disposed off-site.
- 40% disposed in two smaller on-site landfills, 60% disposed off-site.
- 20% disposed in an on-site landfill, 80% disposed off-site.
- All waste disposed off-site (e.g., the Off-site Alternative).

As illustrated in Figure 5-2, risk of injury and death increases in direct relation to the fraction of wastes disposed off-site. It is important to note that there is no scenario that does not result in some risk of injury and death. The cancer risk associated with most wastes being disposed of in an on-site landfill is orders of magnitude (at least 10,000 fold) lower than the risk associated with transportation of wastes over more than 2,000 miles of roads and railroads.

A similar comparison was made for costs associated with each of the same six on-site and off-site scenarios, and the results show that costs increase in direct proportion to the amount of waste shipped off-site. Figure 5-3 shows the trend.

Note that the 40% option includes two on-site landfills to be used in tandem with off-site disposal. The inclusion of two small landfills drives the on-site and total cost higher than if only one landfill had been considered.

The clear conclusion is that the trade-off between the very small human health risks ($10^{-4}$ – $10^{-6}$ risk of contracting a cancer) associated with potential releases from a new on-site landfill and the considerably higher transportation risks (injury and death from traffic incidents) associated with off-site disposal is a poor one. When the cost differentials are added, this trade-off is even worse.

Ultimately, however, it will be the WAC of the on-site disposal facility that will determine the amount of waste that can be disposed safely on-site, and the amount that must be shipped off-site for disposal. The volume of future CERCLA waste acceptable at an on-site facility is limited by the WAC of the facility. The remainder of the waste, which does not meet an on-site facility WAC, thus is directed to an off-site disposal option. Since current characterization of the future CERCLA waste is not sufficient to draw an absolute line between waste volumes to be handled on-site versus those that will require off-site disposal, nor have final on-site disposal WAC been defined against which that characterization can be measured, assumptions must made regarding the volume and composition of future CERCLA waste for on-site disposal. Thus the volume of waste assumed to be able to meet an on-site WAC is conservatively estimated to allow for a maximum on-site disposal footprint design. EMDF is planned to be constructed in phases over the lifetime of waste generation, which will allow for a smaller facility footprint if warranted (e.g., four cells construction versus six cells), as details regarding waste characterization and generation are realized.

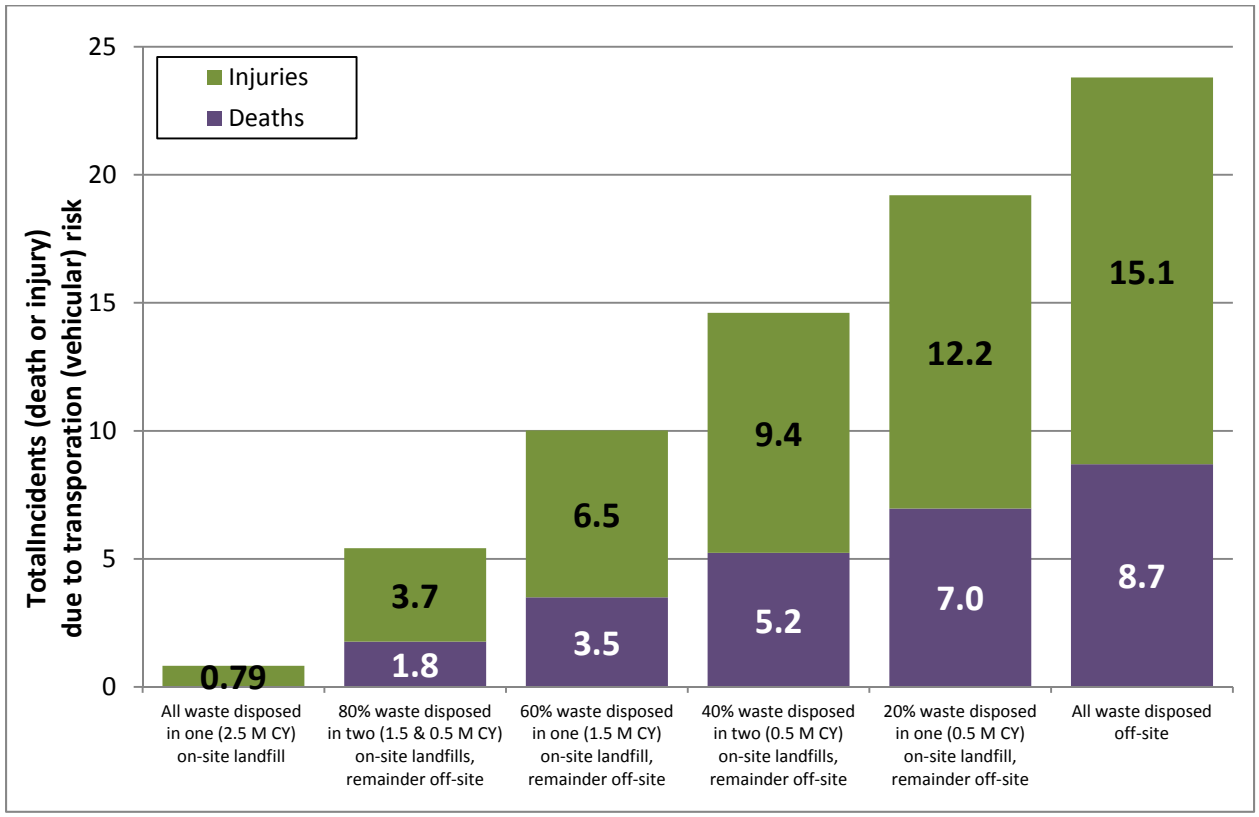
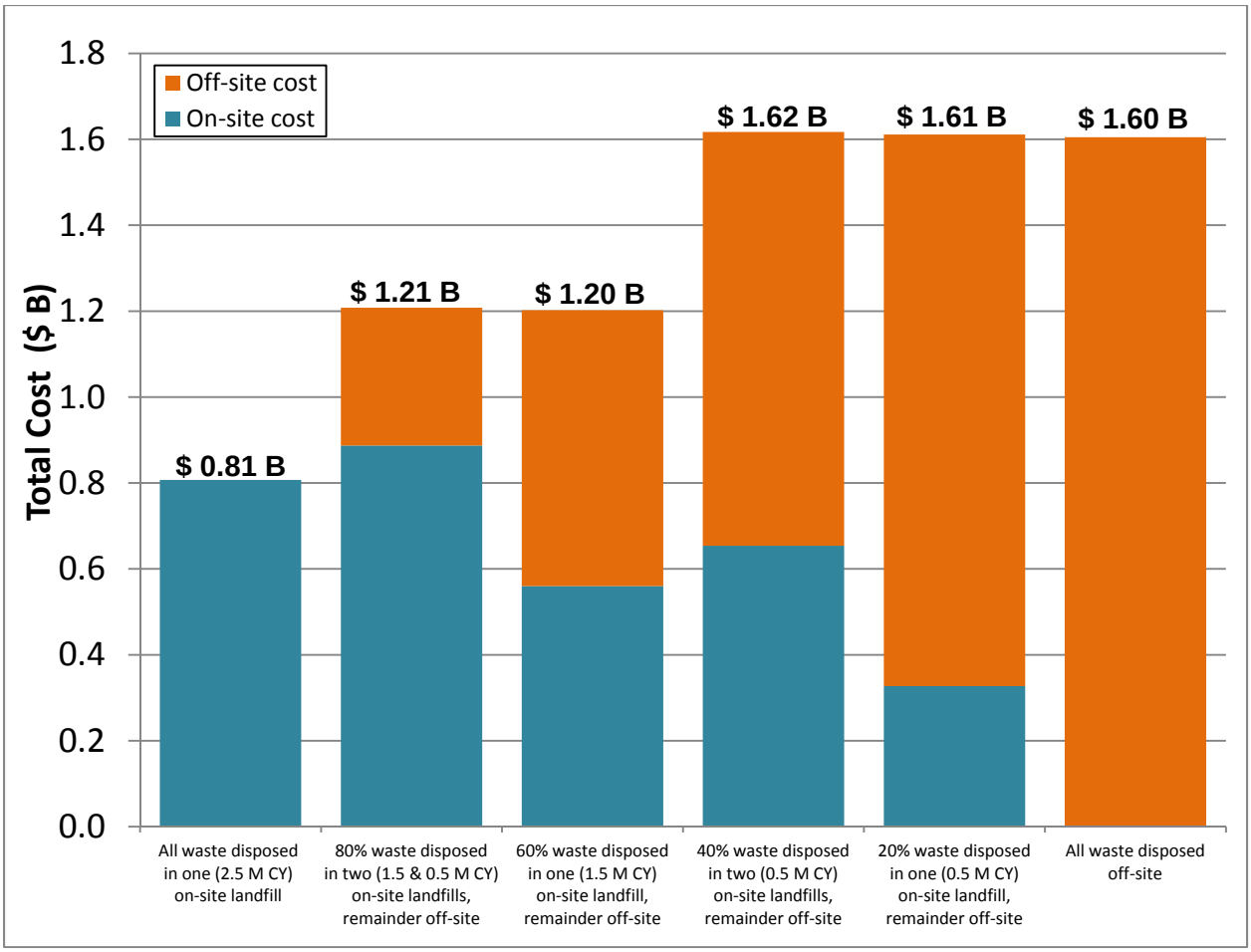



**Figure 5-2. Risks Associated with Transportation for Various On-site and Off-site Disposal Scenarios**




CY cubic yard

**Figure 5-3. Costs Associated with On-site and Off-site Disposal Scenarios**

# 6. ALTERNATIVE DESCRIPTIONS

This chapter provides detailed descriptions of the No Action Alternative and the On- and Off-site Disposal Alternatives for the candidate CERCLA waste streams identified in Chapter 2. The representative process options assembled in Chapter 5 have been used to develop conceptual designs and actions described in this chapter.

## 6.1 NO ACTION ALTERNATIVE

The No Action Alternative is considered in accordance with CERCLA and NEPA requirements to provide a baseline for comparison with other alternatives. For purposes of evaluation, the following assumptions are made for the No Action Alternative:

- A comprehensive, site-wide strategy to address the disposal of waste resulting from any future CERCLA remedial actions at the ORR and associated waste generator sites after EMWMF capacity is reached would not be implemented.
- A centralized disposal facility would not be constructed on the ORR to accommodate future generated CERCLA waste after EMWMF capacity is reached.
- Future waste streams from site cleanup that require disposal after EMWMF capacity is reached would be addressed at the project-specific level.

Unlike the No Action Alternative for a typical FS which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative in this case is based on the assumption that no coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached. No assumptions are made under this alternative regarding the implementation of remedial strategies or specific actions for the individual sites, or at the watershed or ORR program-wide level. No specific assumptions are made as part of the No Action Alternative regarding future institutional controls, either at the waste generator sites or at the ORR-wide level.

Project-specific remedial decisions, including those concerning on-site, off-site, or in-situ waste disposal, would be made under the No Action Alternative without the benefit of an ORR site-wide disposal strategy or infrastructure. While protective remedies would be implemented, the lack of a coordinated disposal program has potential cost and protectiveness impacts as discussed in Section 7.2.1 and Section 7.3.

## 6.2 ON-SITE DISPOSAL ALTERNATIVE

The On-site Disposal Alternative proposes consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, partially below-grade, engineered waste disposal facility (i.e., landfill) on ORR, referred to herein as the EMDF. Candidate wastes would include LLW and mixed waste with components of radiological and other regulated waste (LLW/RCRA, LLW/TSCA) as described in Chapter 2. Liquid wastes, RCRA-listed wastes, TRU wastes, spent nuclear fuel, and sanitary wastes are not candidate waste streams for the EMDF. Further exclusions are outlined in Section 2.1.1. Project level characterization and segregation efforts would identify uncontaminated or lightly contaminated waste generated during CERCLA remedial actions that can meet the WAC of existing Y-12 industrial or construction/demolition landfills (otherwise known as the ORR Landfill). These wastes can be disposed of at the ORR Landfill regardless of the selected alternative for future CERCLA disposal, and are outside the scope of this evaluation. Similarly, uncontaminated materials that are candidates for recycle would be identified during the CERCLA planning and characterization effort and separated for alternate beneficial purposes. Debris would be size reduced as necessary to meet the EMDF physical WAC using excavators equipped with cutting and crushing

attachments. Wastes not meeting the EMDF WAC would be transported to off-site disposal facilities or placed in interim storage until treatment or disposal capabilities become available.

Ultimately, the On-site Disposal Alternative is a combination of on-site and off-site disposal. The volume of future CERCLA waste acceptable at an on-site facility is limited by the WAC of the facility. The remainder of the waste, which does not meet an on-site facility WAC, thus is directed to an off-site disposal option. Since current characterization of the future CERCLA waste is not sufficient to draw an absolute line between waste volumes to be handled on-site versus those that will require off-site disposal, nor has a final on-site disposal WAC been defined to which that characterization can be measured against, assumptions must made regarding the volume and composition of future CERCLA waste for on-site disposal. Thus, the volume of waste assumed to be able to meet an on-site WAC is conservatively estimated to allow for a maximum on-site disposal footprint design. The construction of the facility is planned to be conducted in phases over the lifetime of waste generation, which will allow for a smaller facility footprint to be constructed if warranted (e.g., four cells construction versus six cells), as details regarding waste characterization and generation are realized.

The On-site Disposal Alternative only addresses disposition of CERCLA waste. It includes designing and constructing the landfill, support facilities, and roadways; developing plans and procedures, personnel training and supervision; receiving waste that meets the WAC; unloading and placing waste into the landfill; surveying and decontaminating as needed any containers, equipment, or vehicles leaving the site; and managing the waste and the landfill during the construction, operations, closure, and post-closure periods.

Disposal facility elements that are critical to ensuring adequate long-term protection of human health and the environment include the following:

- Location of the EMDF (Section 6.2.1)
- Design of the facility's waste containment features (Section 6.2.2)
- Characteristics of the waste placed in the EMDF (Section 6.2.3)
- Facility construction, operations, and operational monitoring (Section 6.2.4 through 6.2.6)
- Management of waste exceeding WAC (Section 6.2.7)
- Facility closure and post-closure care, including institutional controls (Section 6.2.8 and 6.2.9)
- Lessons learned, from design through operation of the EMWMF (Section 6.2.10)

### 6.2.1 EMDF Site

A proposed site in EBCV near EMWMF is evaluated as part of the On-site Disposal Alternative for development of the EMDF. This site was selected for detailed analysis based on the site screening process outlined in Appendix D. Figure 6-1 shows the location of the EMDF site relative to the ORR; the site plan for the EMDF is presented in Figure 6-2. The proposed EMDF site is located east of EMWMF on the ORR in the Bear Creek Valley (BCV) Watershed. The proximity of the site to EMWMF offers advantages through sharing existing infrastructure and by consolidating waste management areas (see Section 6.2.2.5).

The EMDF site in EBCV is located in the Zone 3 area designated for future DOE-Controlled Industrial Use in the BCV Phase I ROD (DOE 2000) as shown in Figure E-1 in Appendix E. Appendix D describes the screening process and selection of the EMDF site, which will remain under DOE control within DOE ORR boundaries for the foreseeable future. The nearest residence to the proposed EMDF site is 0.84 miles north, and is separated from the site by Pine Ridge.

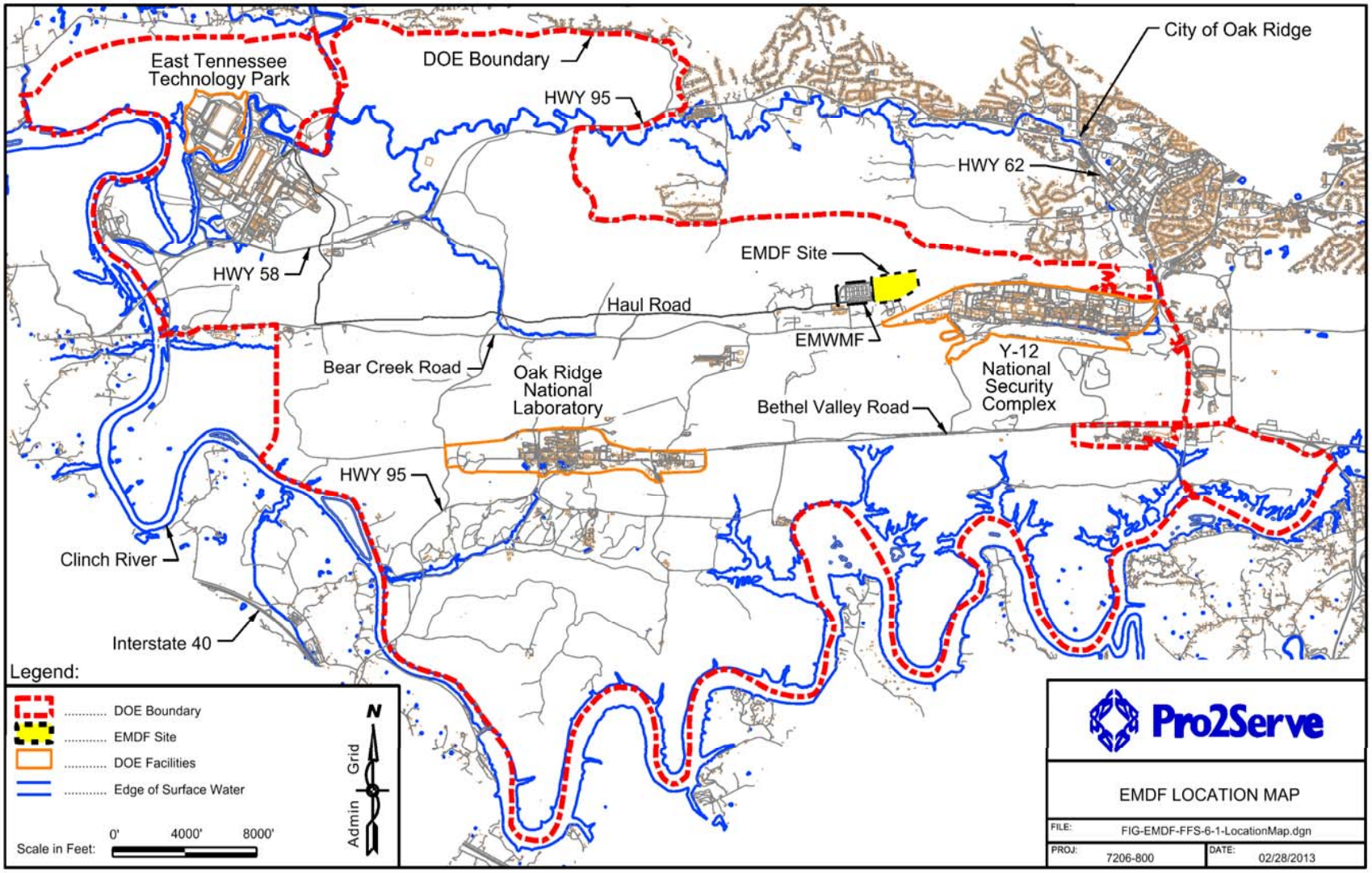



**Figure 6-1. EMDF Location Map**

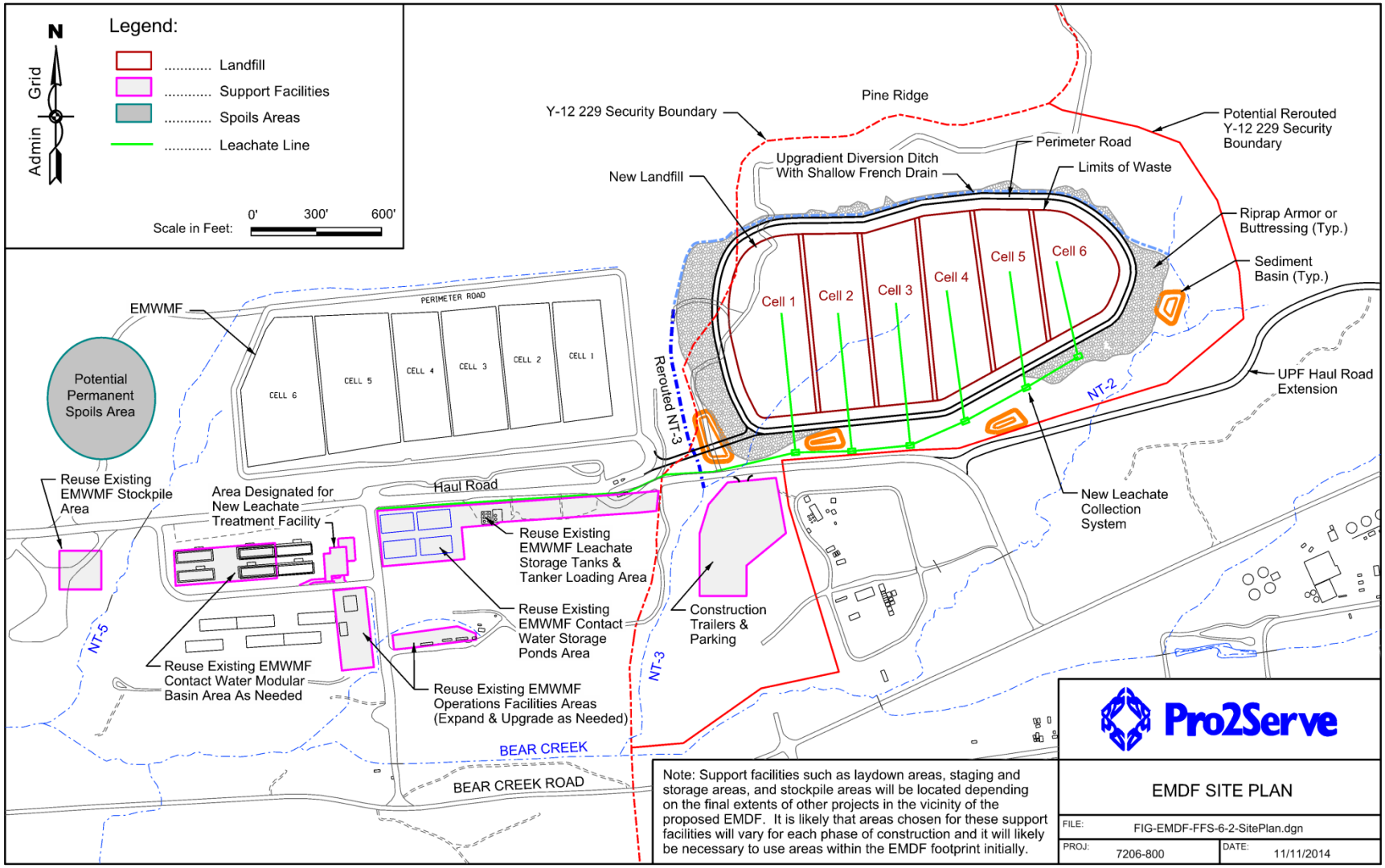



**Figure 6-2. EMDF Site Plan**

Construction of a disposal facility at the EMDF site may require moving the 229 Security Boundary for Y-12 as shown in Figure 6-2. This security boundary is designated pursuant to Section 229 of the Atomic Energy Act of 1954 as implemented by 10 CFR 860. The purpose of this security boundary is to prevent the unauthorized introduction of weapons or dangerous materials into Y-12. In order to revise this boundary, DOE would publish a notice of revision in the Federal Register. The need to redesignate the 229 Boundary is currently being evaluated by DOE and, while not costly, is a time consuming effort.

#### 6.2.1.1 EMDF Site Characteristics

The approximately 70-acre EMDF site is situated along the southern flank of Pine Ridge on undeveloped land immediately east of EMWMF. Based on process knowledge and a review of historical maps, the site is believed to be uncontaminated. The site is north of Bear Creek and is bounded by Haul Road to the south, Northern Tributary (NT)-3 to the west, the steep upper slope of Pine Ridge to the north, and NT-2 to the east. A portion of NT-3 would be rerouted to accommodate the western section of the landfill, and the footprint of the landfill will encompass a second branch of NT-3. The site is typically heavily wooded with most of the trees being deciduous. On May 19, 2013, severe weather in the area produced what the Weather Forecast Offices of Morristown later classified as a downburst. This storm event caused tree uprooting over several large swaths of land. Timber recovery efforts were later conducted leaving a large portion of the proposed EMDF footprint cleared. Site topography varies from a moderate slope in the southern part to a very steep slope along the northern portion where it meets Pine Ridge. The site is dissected by tributaries to Bear Creek and contains several deep ravines oriented in a generally north-south direction. The main channel of NT-3 crosses the central and western portions of the site in a southwesterly direction, and two small draws/ravines join the main channel just north of the Haul Road. Much of the flow in NT-3 and in the draws that drain into NT-3 is supported by springs and seeps. Two draws located in the southeastern portion of the site direct surface water to NT-2 in a southerly direction. The streams form a trellis drainage pattern typical of the Valley and Ridge Province of Tennessee. The site topography and geology are described and illustrated in Appendix E.

From south to north, the EMDF site is underlain by bedrock of the Maryville Limestone, Rogersville Shale, Rutledge Limestone, Pumpkin Valley Shale, and Rome Formations of Cambrian age. The lower units of the Maryville Limestone form a series of knolls south of and parallel to Pine Ridge.

The EMDF site soils are dominated by a thin mantle of alluvial and colluvial deposits and pedogenic soil underlain by saprolite and shales/siltstones of the previously mentioned formations. Pedogenic soil is formed in place by weathering and pedogenic alteration of the parent materials. Alluvial soil is soil that has been transported to its present location by running water. Shallow alluvial soil, generally less than 5 ft thick, but ranging up to about 10 ft thick near Bear Creek, may be present within the drainageways and along tributaries. Colluvial soil is soil that has been transported to its present location by gravity and includes slope wash at the base of slopes. Colluvium may be several feet thick at the base of some slopes. Typically, the depth to competent bedrock (i.e., as defined by auger refusal) varies from about 10 to 50 ft below ground surface and increases from south to north. Also, the depth to weathered rock is typically shallower in the incised drainageways and deep ravines than in the adjacent higher ground.

Ground water exists under the site in matrix pores, fractures, and possibly some cavities. Flow occurs mainly in the fractures, and the overall direction of flow is south with the slope of the ground water table; however, strike-parallel flow is also an important component of the ground water flow net. Based on the results of ground water measurements made immediately east and west of the site in a similar topographic and geologic setting, the depth to ground water varies from less than 3 ft below ground surface in the low areas along the tributaries in the southern portion of the site to more than 45 ft deep along the higher elevations of Pine Ridge. In the southern portion of the site ground water has an upward gradient and discharges to the tributaries. The tributaries and draws that drain to the tributaries are natural discharge areas for both shallow perched (stormflow zone) ground water and ground water upwelling from bedrock.

Shallow perched ground water moves laterally down slope where it discharges as "wet weather" seeps along the base of Pine Ridge. Numerous seeps and springs have been mapped within the site, including three seeps and springs which "daylight" near the contact of the Rome and Pumpkin Valley Shale Formations, forming the headwaters of NT-2 and NT-3.

Threatened and Endangered Species and Steam and Wetland Delineation Surveys were performed as part of the limited Phase I Site Characterization. Six wetland areas, totaling about 1.4 acres, have been delineated along NT-3 within and bordering the EMDF site (see Figure E-17 in Appendix E). A wetland area designated as Reference Area (RA)-5 encompasses wetlands known as the Temporary Quillwort Pond on NT-3 immediately north of the Haul Road. Wetlands on the east side of the EMDF site have been enlarged as part of the Uranium Processing Facility haul road extension, and are not included in this acreage figure. No known federal- or state-listed threatened or endangered species have been identified in the EMDF area. NT-3 is isolated from fish movement by the Haul Road culvert, and NT-2 tributaries are intermittent, and not populated by fish. An acoustic bat survey conducted by ORNL personnel did not detect any listed bats, such as the endangered Gray or Indiana bats. There are no known archeological or historical resources in or near the proposed EMDF site (DOE 1999; DuVall 1998; DuVall 1996; Fielder, et al. 1977).

Soil and ground water contamination is present in several areas south of the site, including along NT-3 south of Haul Road. Contaminants originated from wastes disposed at the Oil Landfarm, Boneyard/Burnyard (BY/BY), Sanitary Landfill I, and Hazardous Chemical Disposal Area (HCDA) (B&W 2011; DOE 1997). Soils at these sites have been removed or isolated, but ground water has not been remediated. There is no indication that the EMDF site has been contaminated on the surface or by subsurface migration from other areas. To the extent practicable, site characterization studies will be completed prior to submittal of the ROD to the regulators for approval. The lack of site-specific characterization data was factored into the original conceptual design by making conservative estimates of site characteristics such as seasonal high ground water level and top of rock, based on subsurface information available immediately east and west of the site and DOE's extensive experience in similar geologic settings in BCV. As site-specific data has been collected and evaluated, it has been factored into the conceptual design of the landfill. Modeling results for predicted groundwater levels have been used to adjust the landfill bottom to ensure that it is feasible to maintain the appropriate buffer between the waste and the water table for the selected site. This process of collecting, analyzing, and applying site specific data will continue into the final design. Process knowledge and previous ground water modeling indicate the area selected for construction of the new landfill footprint is undeveloped and not contaminated; this area is upgradient of existing burial grounds and known contaminated ground water plumes. Field screening performed as part of the Phase I studies has indicated no evidence of any contamination (see Appendix E).

### 6.2.2 EMDF Conceptual Design

The EMDF feasibility-level conceptual design is used to provide a comparative analysis for the On-site Disposal Alternative siting option. If this alternative is the selected remedy in the ROD, the final design for the selected site may differ from this conceptual design and would require approval by regulatory agencies. The design is based primarily on the EMWMF design as described in the Remedial Design Report (RDR) for the EMWMF (DOE 2001a), which has been approved by EPA and TDEC, but draws on design elements of other CERCLA disposal facilities as well (e.g. those at the Fernald and Portsmouth DOE sites). With the exception of one TSCA hydrologic ARAR (for which a waiver is requested, see Section 4 in Appendix G), the conceptual design complies with ARARs and to-be-considered guidance identified for disposal of RCRA, TSCA, LLW, and mixed waste. An additional waiver is requested, which deals with mercury debris macroencapsulation operations. The subsequent sections describe common and site-specific features of the landfill and support facilities, as well as process modifications that could potentially improve the feasibility-level design.

The primary design elements of the EMDF are described in the following order:

- Remedial design
- Early actions
- Site development
- Disposal facility
- Support facilities
- Conceptual design approach
- Process modifications

The close proximity of the operating EMWMF disposal cells allows for a unique opportunity to examine the elements that worked or could use improvement in terms of the design, construction, and operations of a new CERCLA landfill in EBCV. The major lessons learned are briefly mentioned where applicable in each of the subsections that follow, and are then summarized in Section 6.2.10.

#### 6.2.2.1 Remedial Design

Remedial design would include preparation of the Remedial Design Work Plan, RDR and Remedial Action Work Plan (RAWP), operating plans, WAC Attainment Plan, Environmental Monitoring Plan, and application for requisite permits (if any). A fast-track design process may be used to expedite construction, as was done for the EMWMF. The fast-track design process involves sequentially designing project elements and proceeding with their implementation while other elements are still being planned and designed. Use of this process would require cooperative design/approval effort by project integration, design, construction, operations, and oversight contractors; DOE; and regulators.

A major lesson learned from the EMWMF RDR preparation was regarding the action leakage rate (ALR). This value is an estimate of the maximum allowable leachate discharge from the leak detection layer of the liner system. This allowable leachate discharge limit serves as a threshold value to mark when rates of leachate collected might indicate that there is an unacceptable accumulation of leachate within the secondary collection layer (leak detection layer) of the liner system. It is expected that there will always be a certain amount of secondary leachate generated due to the physical properties of geomembranes and imperfections of installation of landfill components. The ALR sets the value at which action must be taken to ensure that the landfill liner system is functioning properly. Response actions triggered by an ALR exceedance start with a written notification to the appropriate regulatory agencies, followed by an assessment of the conditions, additional discharge rate reporting, and remedial actions if deemed necessary. The method employed to calculate the ALR per cell for EMWMF used generic EPA values which resulted in an ALR estimate that was too low. This resulted in extra paper work and effort for the EMWMF management staff to report “exceedances” that are actually within normal ranges for landfills of this nature.

Another lesson learned from EMWMF operations is the need to improve project sequencing to ensure availability of contaminated soil for filling debris void spaces and for general waste placement. The EMWMF design assumed that contaminated soil remediation projects would be sequenced to ensure full utilization of waste soil to replace clean fill during placement of debris waste. However, sequencing has not been executed efficiently to date and unanticipated quantities of clean fill have been necessary, which has added cost to landfill operations. Planning future project sequencing must be improved in order to minimize the need for clean fill and conserve landfill capacity. Current ORR Baseline scheduling has been organized to alternate D&D projects with RA projects as much as possible in order to maximize landfill capacity by minimizing the need for clean soil to be used to fill void spaces around debris. (D&D projects tend to produce debris wastes such as building rubble, piping, and equipment and the RA projects tend to produce soil wastes.)

Another related lesson regarding the use of soil fill at EMWMF stems from the initiation of the annual CARAR. Not only was it initially thought that no clean soil fill would be needed for EMWMF, the general ratio of soil waste required for debris waste was underestimated at 1:1 based on literature values reported by Benson, et. al. (2008). In 2004 the first CARAR was published to help apply historical data and set calculated density factors and ratios to improve waste disposal tracking and forecasting of future disposal volume needs. Current forecasts for EMDF utilize a soil-to-debris ratio of 2.26:1 based on the information established by the CARARs (now reported as part of the EMWMF annual PCCR). This should be factored into planning and cost estimating as soil-like waste will not always be available for use as void space fill within the landfill.

#### 6.2.2.2 Early Actions

It is necessary to perform certain remedial design activities early in the remedial design process. These activities are referred to as early actions and include: a baseline site topographic survey, wetlands delineation, field surveys to identify and map wetlands and threatened and endangered species, hydrogeological and geotechnical investigations, construction and upgrade of ground water monitoring wells, and baseline ground water monitoring. Early actions that have already been completed or are currently underway are noted within the following descriptions.

**Baseline Site Topographic Survey:** The EMDF site topography and surface features would be mapped using civil land surveying techniques. This information is needed to perform hydrogeological/ geotechnical investigations; establish locations, elevations, and depths for new ground water monitoring wells; map wetlands (in concert with a qualified wetlands delineator); and conduct landfill site design. Limited topographic survey information has been collected as part of the Phase I Site Characterization efforts in order to establish ground elevations of newly installed monitoring wells. A full-scale site survey will be performed as part of the Phase II Site Characterization.

**Wetlands Delineation:** A field wetlands delineation survey has been conducted by a qualified wetlands specialist to determine the areal extent of wetlands along streams and other low-lying portions of the landfill site and other areas, such as existing roadways where construction would take place. Wetland boundaries have been mapped using civil land surveying techniques. Results of the wetlands survey are included in Appendix E attachments. Potential wetland impacts during early actions (e.g., hydrogeological and geotechnical investigations), construction, operations, and/or closure of the landfill will be evaluated. Wetland protection considerations will be incorporated into planning and implementation, including mitigation of adverse impacts.

**Field Surveys for Threatened and Endangered Species:** Field surveys have been performed by qualified biologists to identify the presence of threatened and endangered species within areas of potential site disturbance. These surveys have been performed as part of the Phase I characterization; results are summarized in Appendix E attachments.

**Hydrogeological and Geotechnical Investigations:** The EMDF footprint and surrounding land would be investigated to determine surface hydrological, hydrogeological, and geotechnical conditions. No previous hydrogeological or geotechnical explorations are known to have been performed within the EMDF footprint. The investigations would evaluate areas selected for landfill support facilities, roadways, and on-site spoil/borrow areas. Off-site borrow areas may also be explored and characterized. Samples of soil, surface water, and ground water would be collected and analyzed to establish physical and chemical baseline conditions. This data/information would be used to develop the facility structural design and the ground water and surface water monitoring program. The hydrogeological and geotechnical investigations may be performed concurrently or in multiple phases.

**Construct New Ground Water Monitoring Wells and Surface Water Weirs:** Five ground water well pairs (deep and shallow) and three surface water weirs were installed in the proposed footprint as part of

Phase I characterization to determine baseline ground water and surface water hydrogeological conditions. This data supports PreWAC modeling efforts. Existing groundwater monitoring wells down gradient of the EMDF site would be used, where possible, and additional ground water monitoring wells would be installed as needed. Boring and well logs, geophysical data, hydraulic conductivity data, and groundwater flow data would be collected. It is estimated that approximately 19 new ground water monitoring wells and six surface water monitoring weirs would be required. However, these numbers of ground water monitoring wells and surface water monitoring weirs are estimates that have not been through the data quality objectives (DQO) process, but have been prepared solely for costing purposes. A formal DQO process will be followed to identify the objectives for pre-design investigation, and a sampling and analysis plan will be prepared for approval and implementation.

**Baseline Ground Water and Surface Water Monitoring:** As part of Phase II site characterization, ground water levels and surface water and ground water quality parameters (for example, specific conductivity, pH, temperature, dissolved oxygen and oxidation-reduction potential) would be monitored continuously for one year, if feasible, and contaminants [radionuclides, metals, volatile organic compounds, and polychlorinated biphenyls (PCBs)] would be monitored quarterly for one year, to establish a baseline. Ground water flow will be determined by down-hole measurements and surface water flow rates would be monitored by flume measurements for at least one year. These activities would be performed before construction of the landfill to establish pre-disposal baseline conditions, support design, and support WAC finalization.

Four major EMWMF lessons learned are applicable to Early Actions and emphasize the importance of performing thorough site characterization of the project footprint and selected borrow area(s). Items identified for improvement include the following:

- Overestimation of the availability of suitable low permeability clay from the ORR borrow site
- The quality of the background constituent characterization, especially in terms of statistical thoroughness and detection limits
- Underestimation of the amount of unusable spoils that would require hauling off-site
- Underestimation of the seasonal high ground water table

The complications that arose from these factors significantly slowed construction and increased construction and operating costs of the landfill. Fernald had similar landfill construction issues with unsuitable low-permeability clay from the borrow area selected for the project. Poor background characterization has caused issues in the course of routine environmental monitoring during operations at EMWMF.

#### 6.2.2.3 Site Development

The following development actions would prepare the site for construction of the EMDF:

- Installing initial sediment and erosion controls for site development activities. Initial erosion and sediment controls (e.g., silt fence, check dams, etc.) and storm water control structures (e.g., culverts) would be among the first site development protective measures installed. Standard erosion and sediment controls would be installed per best management practices (BMPs) as construction proceeds.
- Clearing and grubbing of the site.
- Constructing/upgrading access roads to the landfill site.
- Extending power lines, water lines, phone lines, and other utilities to the landfill site from existing infrastructure used for EMWMF (see Section 6.2.2.5).
- Preparing additional parking, laydown, and staging areas.

- Leveling and preparing areas for construction of leachate management support systems.
- Preparing on-site spoil/borrow areas for future construction activities.
  - A temporary spoils area would be prepared near the landfill for storage of materials excavated during clearing and grading that would be reused. Materials stored could include topsoil for establishing the vegetative cover on the landfill cap or other areas and excavated soil that meets the specifications for structural fill used to build roadways or the clean-fill dike. The area could also be used to store materials such as soil used for daily cover or filling of void spaces during operation of the landfill. Since the landfill would be constructed in phases, temporary spoils and staging areas may be established within the areas of future landfill cells.
  - A permanent spoils area would be established for disposal of excess or unsuitable cut materials (excavated to achieve design grade) that are not useable as fill during construction, expansion, operation, or closure. Excess fill would be placed and graded, and the area would be restored for appropriate future uses after landfill closure.
- Creating/expanding wetlands, as required, to mitigate impacts of proposed facility construction.
- Relocating the Y-12 Atomic Energy Act Section 229 Security Boundary, if required, and installing new guard stations and fencing.
- Upgrading the existing truck weigh scale and/or installing a new truck weigh scale.
- Setting up construction trailers.

#### 6.2.2.4 Disposal Facility

Key elements of the disposal facility would include a clean-fill dike to laterally contain the waste, a multilayer base liner system with a double leachate collection/detection system to isolate the waste from ground water and the geologic buffer, and multilayer cover to reduce infiltration and isolate the waste from human and environmental receptors, and a contouring layer installed over the waste to provide an even and stable base for installation of the cover system. The engineered disposal facility design basis incorporates the following:

- Attainment of RCRA, TSCA, and LLW regulatory design criteria.
- Effective protection of human health and the environment through waste isolation as defined by the remedial action objectives (see Chapter 4) and by DOE O 435.1, DOE O 458.1, and associated manuals and guidance.
- Protection against animal and plant intrusion, and minimization of the potential for human intrusion.
- Collection, treatment, and/or monitored discharge of landfill leachate.
- Reduction of potential for incremental and total settlement, and slope failure under static and seismic conditions, through proper design and waste placement techniques.

Design components of the disposal facility are described in the following paragraphs. Cross-sections and details of the conceptual design for the EMDF are provided in Figures 6-3 through 6-9.

##### *6.2.2.4.1 Clean-fill Dike*

A clean-fill dike would be constructed around the perimeter of the landfill in areas where there is insufficient excavation into the ground surface to provide lateral containment and stability to the waste (see Figure 6-3). The clean-fill dike would also protect against erosion, biointrusion, and inadvertent intrusion by humans. The clean-fill dike would be constructed of structural fill. (For this application, structural fill would consist of suitable earthen material used to create a strong, stable base for the landfill

and to construct portions of the clean-fill dike. Native soil excavated from the site may be deemed suitable for use as structural fill if it is free from large rocks and exhibits the appropriate compressibility and shear strength.) The inner slope of the dike would be covered by the liner system and possibly the geologic buffer. The top of the dike would anchor the liner components, tie into the cover system, and provide for drainage ditches and a perimeter access road. The outer slope would be armored with an 18 in. thick layer of durable rock riprap, to protect against erosion. It is anticipated the clean-fill dike would have a typical grade of 33% or lower (3H:1V or flatter), as will be determined by slope stability and erosion analyses in the final design phase. In order to maximize the waste disposal capacity of the landfill, the conceptual design shows the outer slopes of the clean-fill dike steepened to 2:1 in some areas to avoid encroachment on adjacent streams and wetlands. Side slopes steeper than 3:1 would include a 20 ft wide rock buttress for added stability and erosion resistance (see Figure 6-4). The viability of steepening the side slopes of the clean-fill dike to 2:1 would be further evaluated during the remedial design. Final design slopes for the clean-fill dike and details for rock buttressing would depend on the results of slope stability and erosion analyses.

#### *6.2.2.4.2 Upgradient Diversion Ditch with Shallow French Drain*

A geomembrane-lined drainage ditch with underlying shallow French drain would be constructed along the upper (i.e., northern) side of the landfill to intercept and divert upgradient storm water and shallow ground water away from the landfill (see Figure 6-5). The geomembrane liner would prevent surface water infiltration and recharge of ground water along the ditchline. The drainage ditch would be armored with durable rock riprap to prevent erosion. It is anticipated the French drain would extend about 10 ft below the ground surface and would be comprised of durable siliceous gravel wrapped with a geotextile filter fabric. The French drain would collect the uncontaminated shallow storm water flow, which could be discharged to the ground surface along the down gradient side of the landfill.

This diversion ditch/French drain would help divert a considerable volume of water that moves on and just below the ground surface in the upper few feet of soil during storm events, to minimize underflow towards the liner system, and reduce recharge to the ground water table in the vicinity of the landfill. A design requirement will be to evaluate the possibility of the upgradient ditches and drains failing. This evaluation would be conducted in order to demonstrate that the landfill will remain protective of the environment in the event these features fail. This evaluation will be conducted using site characterization data collected prior to the commencement of the final design process.

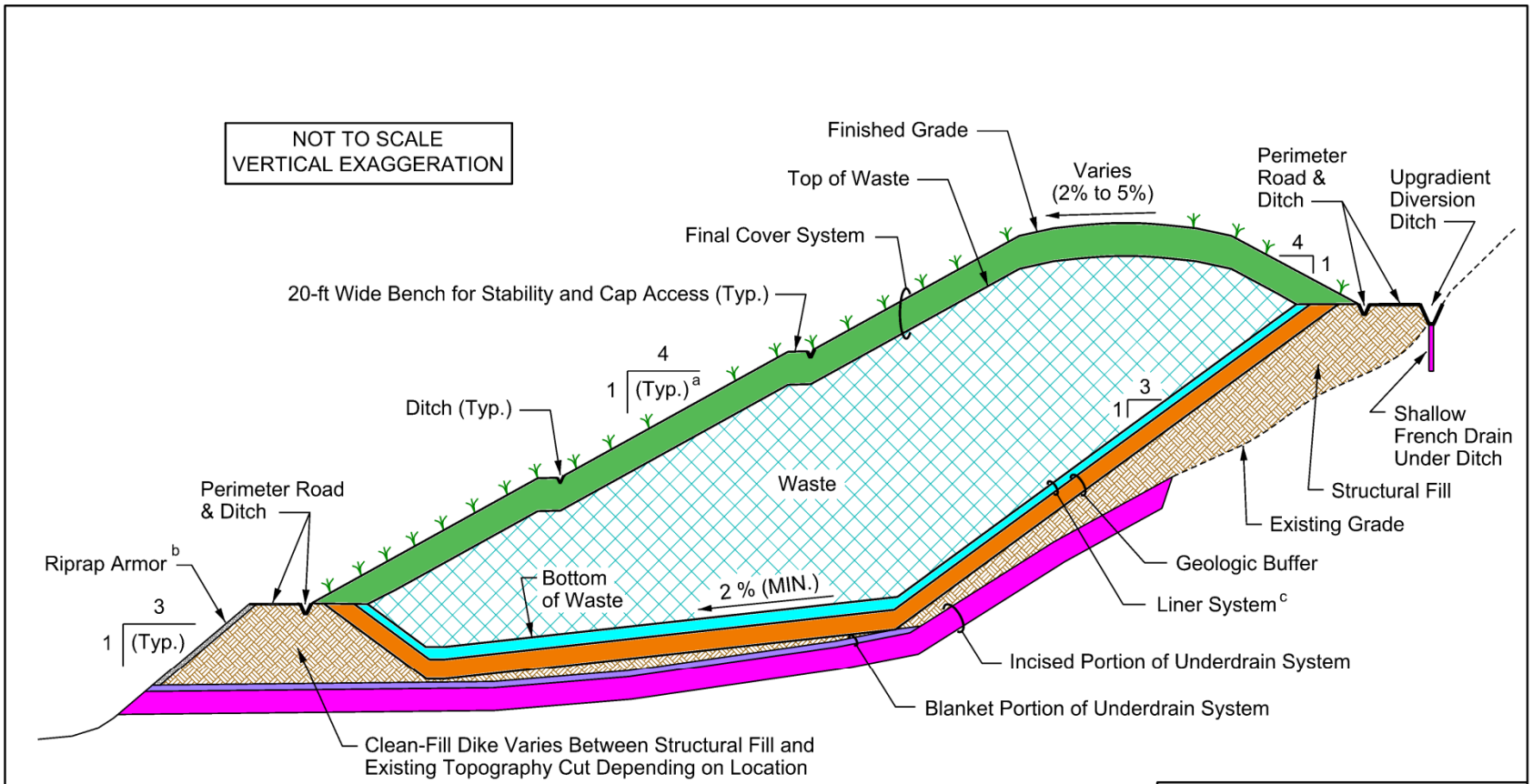



**Figure 6-3. Typical Cross-section of EMDF**

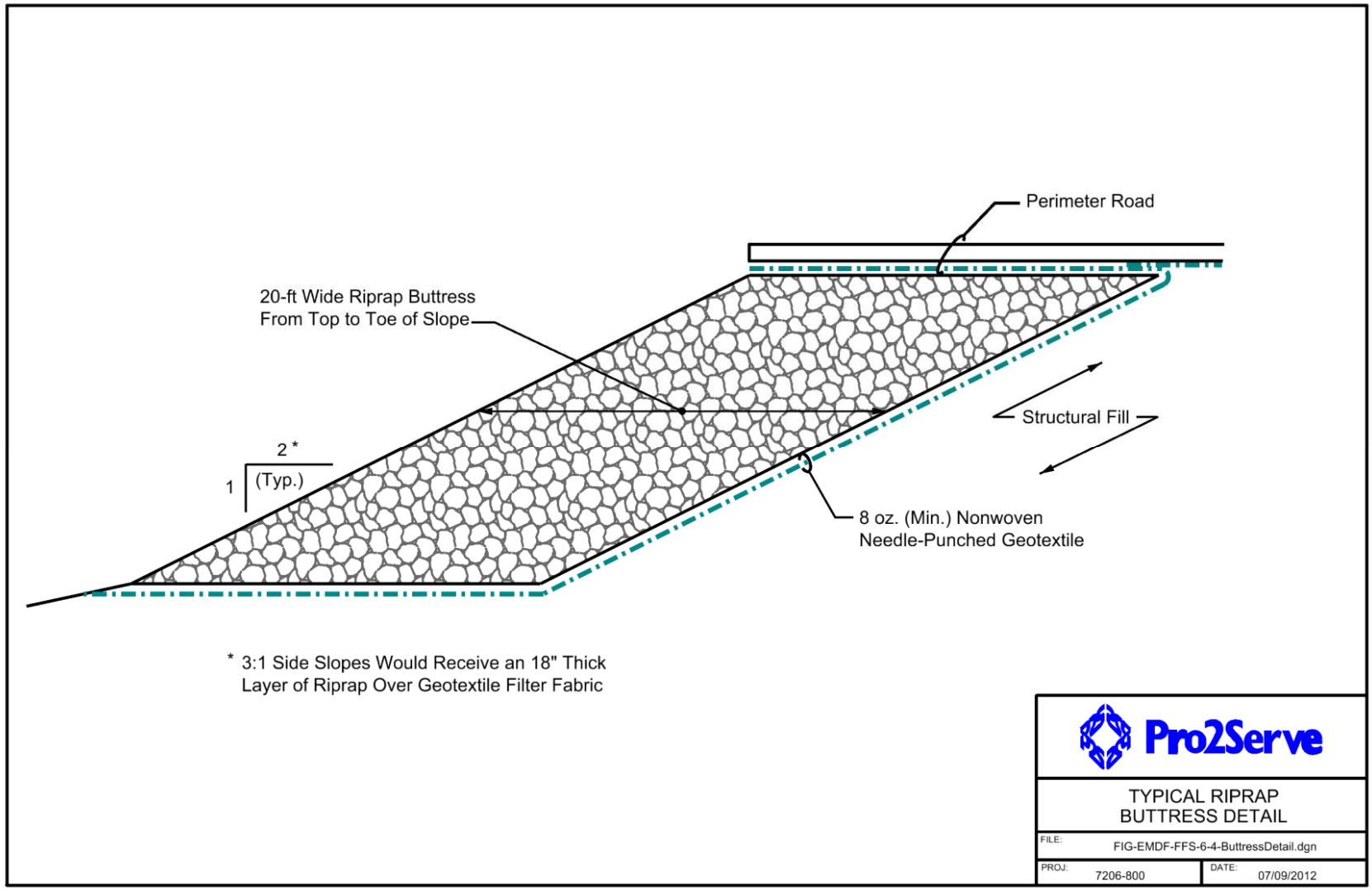



**Figure 6-4. Typical Riprap Buttress Detail**

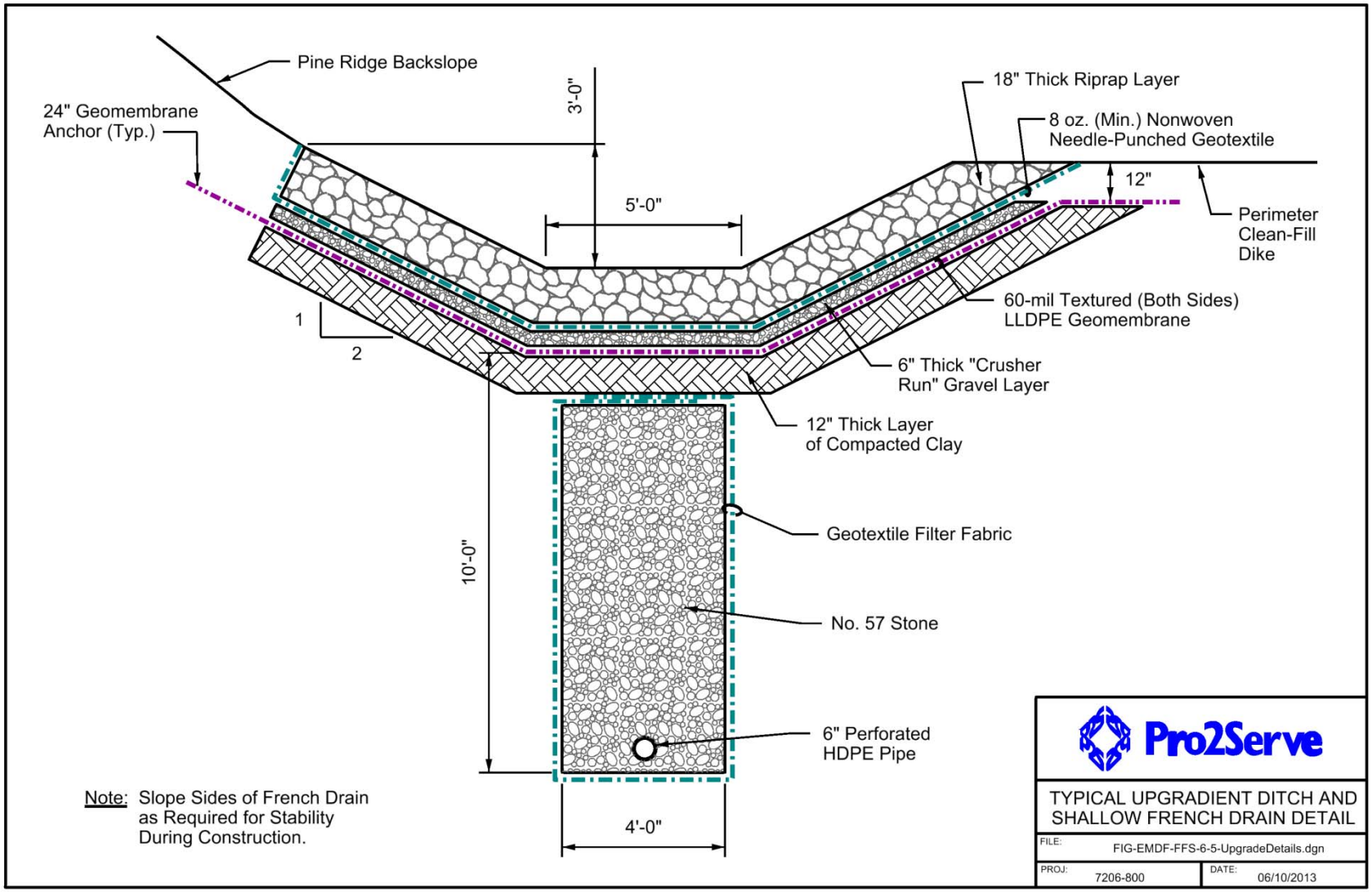



**Figure 6-5. Typical Upgradient Ditch and Shallow French Drain Detail**

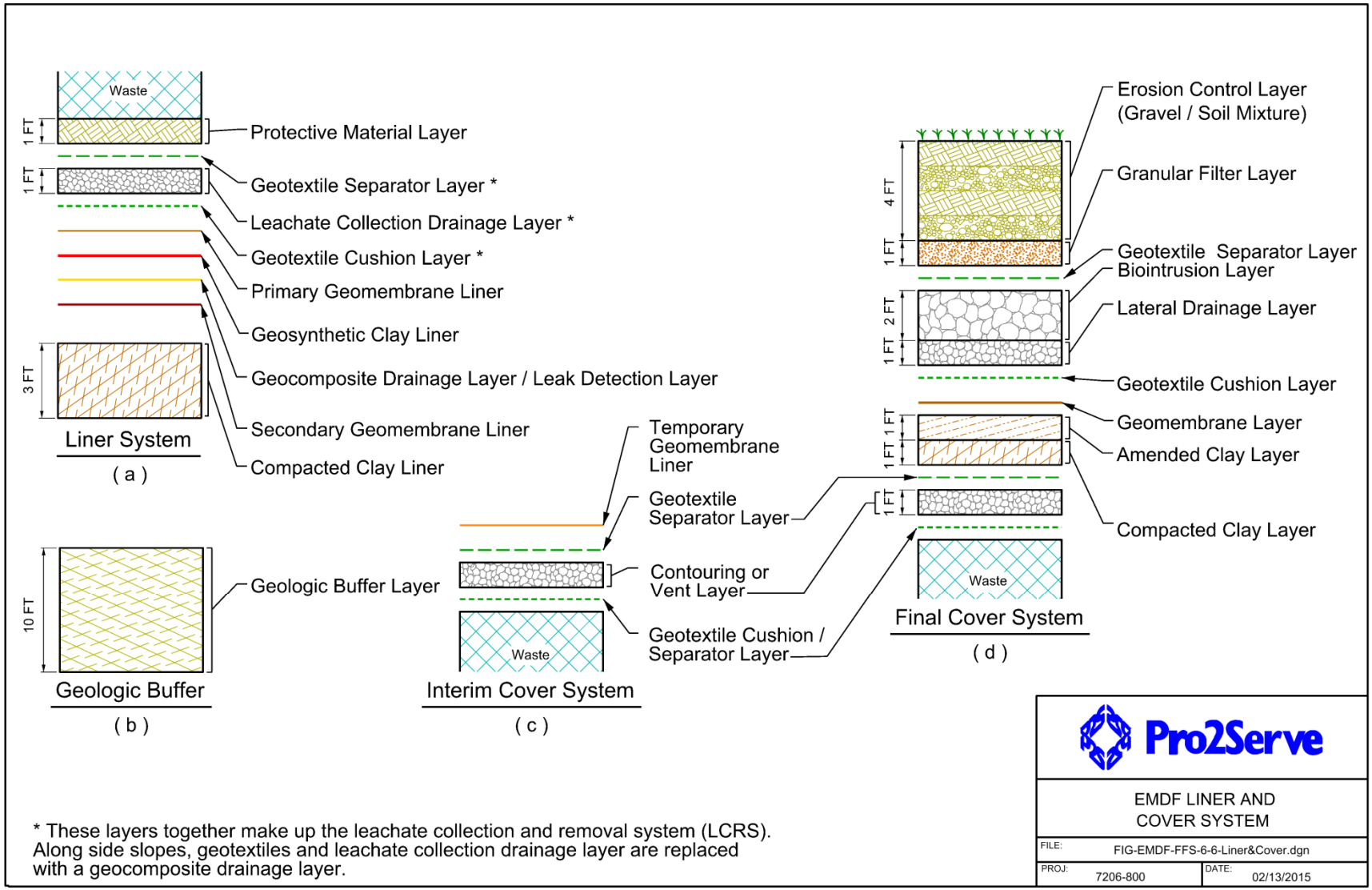



**Figure 6-6. EMDF Liner and Cover Layers**

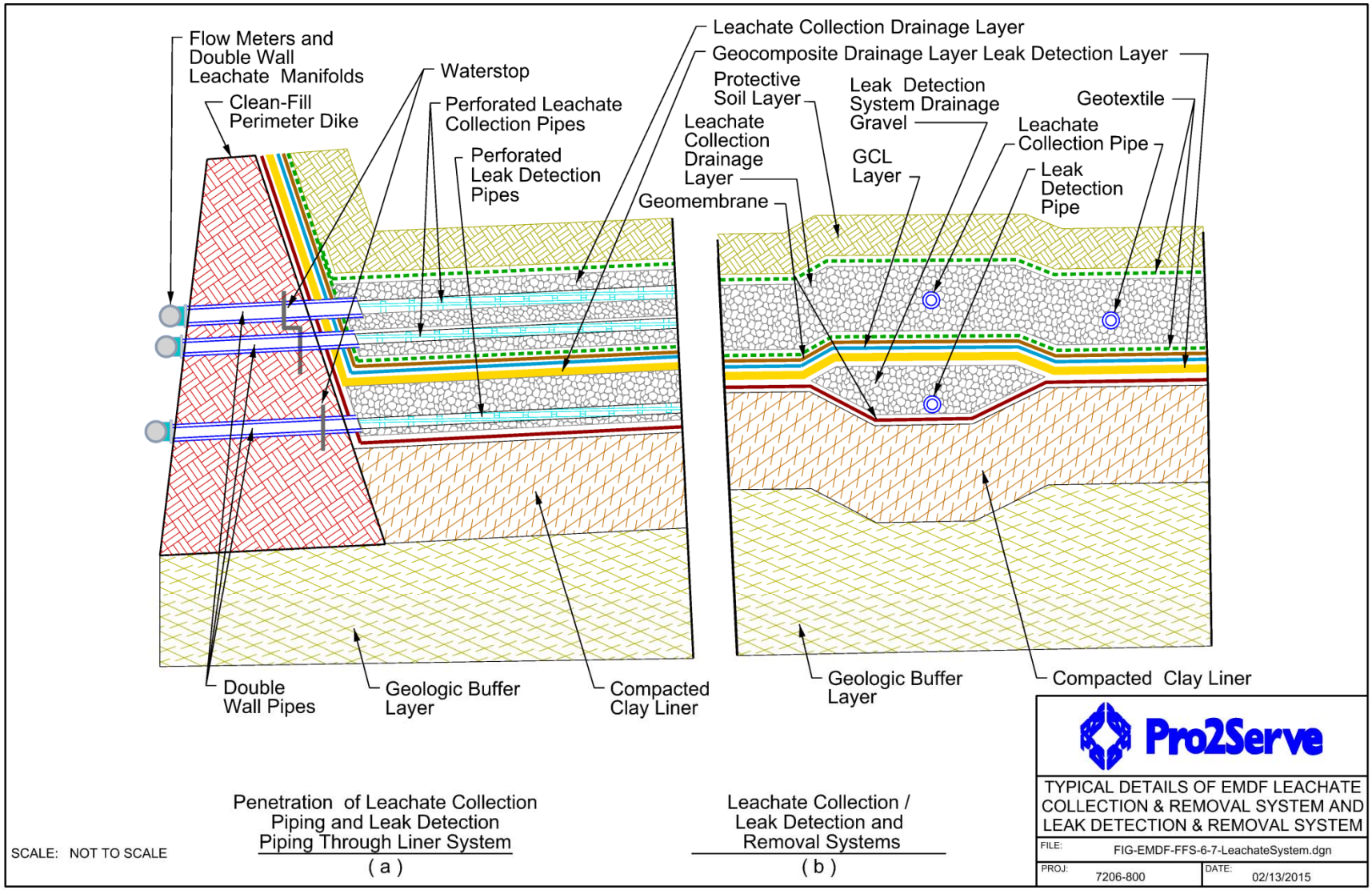



**Figure 6-7. Typical Details of EMDF Leachate Collection and Removal System and Leak Detection and Removal System**

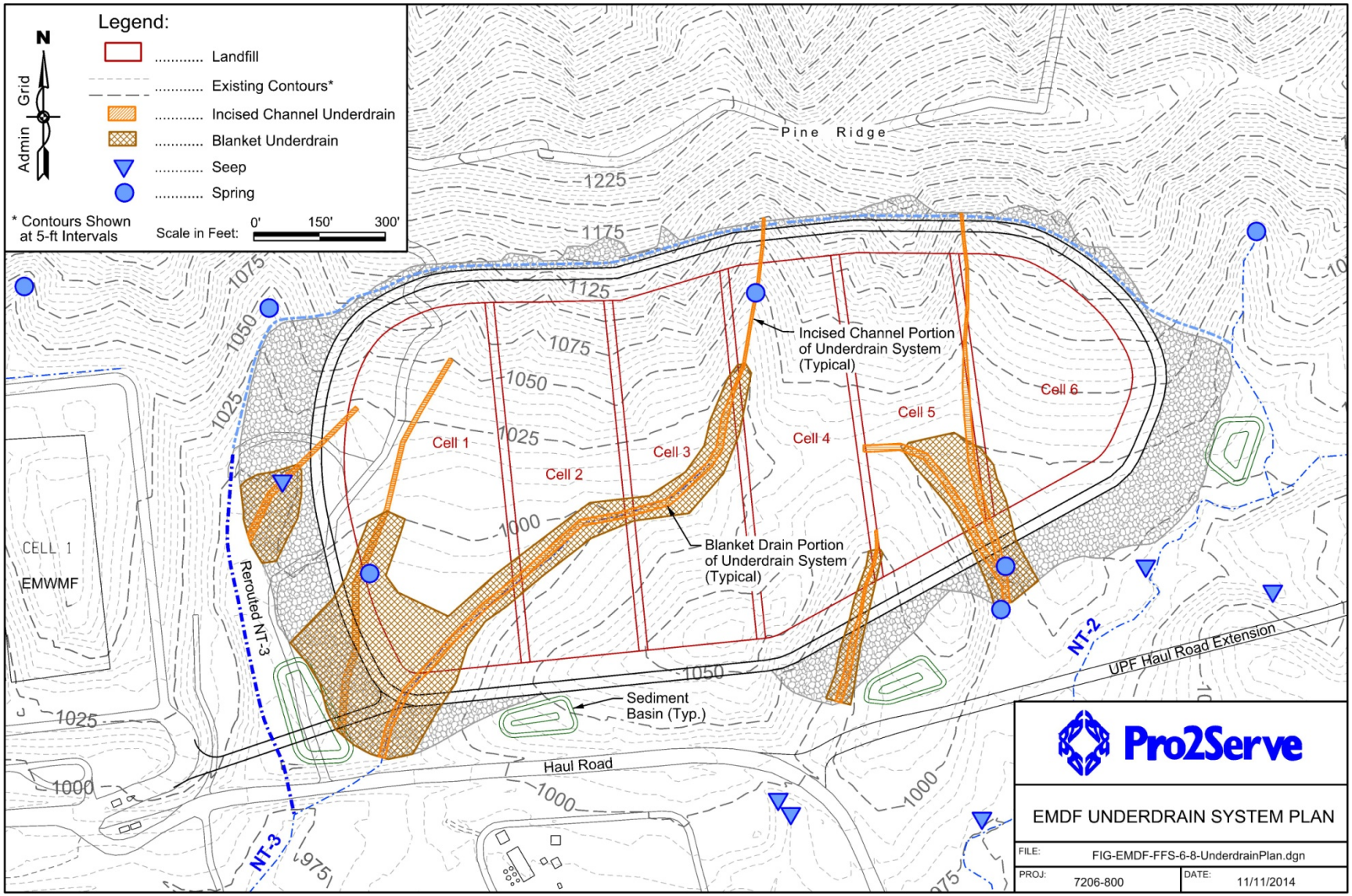



**Figure 6-8. EMDF Underdrain System Plan**

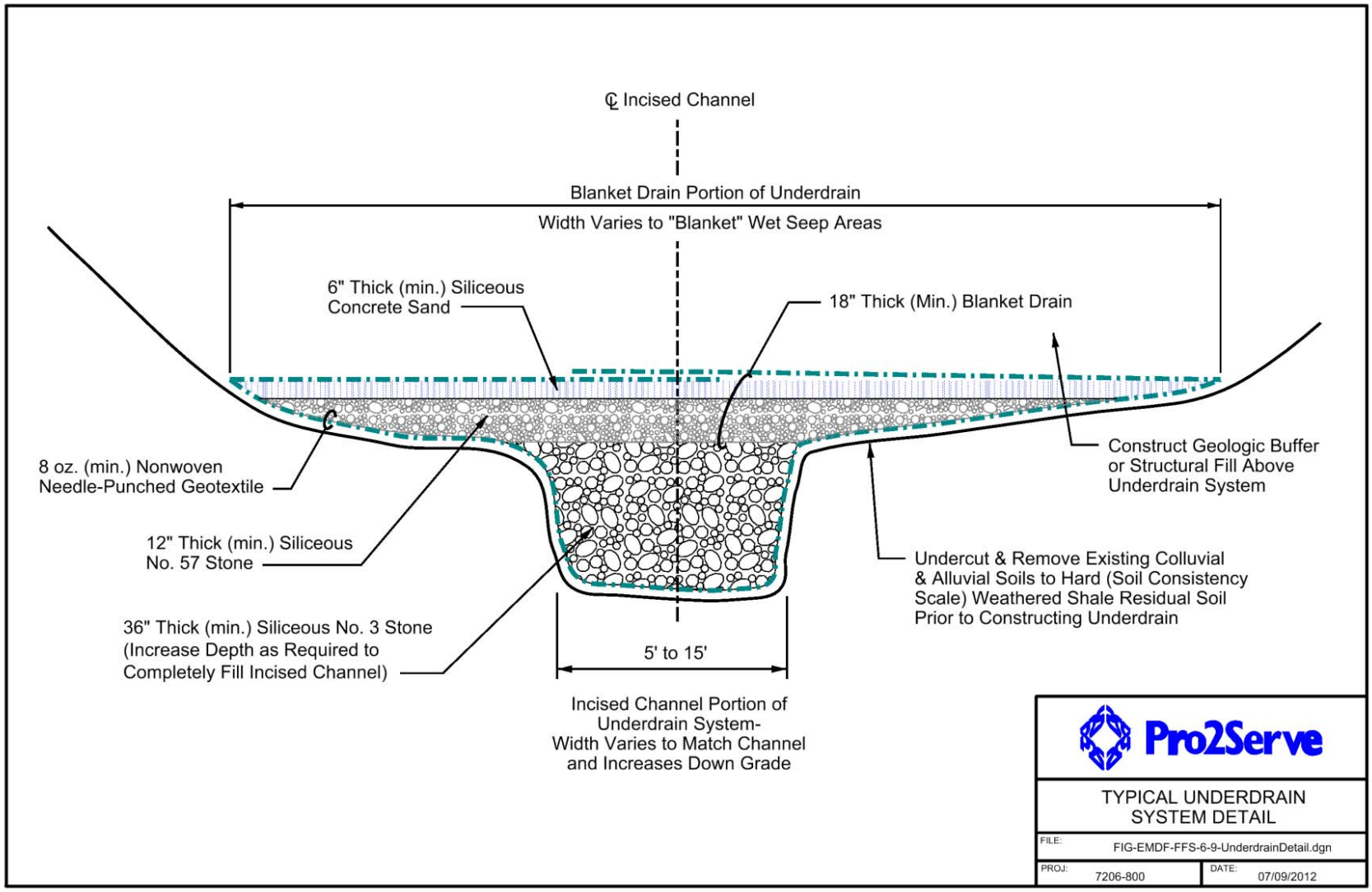



**Figure 6-9. Typical Underdrain System Detail**

#### *6.2.2.4.3 Liner System*

A multi-layer liner system will be installed to prevent leachate from migrating out of the disposal unit and impacting ground water. The liner system would be comprised of a double liner system with two leachate collection/detection and removal systems. In accordance with RCRA requirements, the top (primary) liner would be *". . . constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into such liner during the active life and post-closure care period."* The lower (secondary) component of the composite bottom liner would be designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the primary liner component were to occur.

The liner system would be comprised of multiple layers of synthetic and natural materials that would be compatible with the waste and resistant to degradation by chemical constituents expected to be present in the leachate. The layers of the liner system are depicted in Figures 6-6 and 6-7. The approximately 5 ft thick (approximately 4 ft thick on side slopes) liner system would be comprised of the following components from the bottom of waste downward:

- Protective Material Layer – typically a 12 in. thick (minimum) layer of native soil capable of supporting truck and operating equipment traffic during initial waste placement operations. The primary purpose of this layer is to protect the underlying components of the liner system from damage during waste placement during the operational life of the landfill. The thickness and composition of this layer may be variable and must consider the physical nature of the waste to be placed immediately above it, waste placement procedures, and water management operations within the disposal cell. For instance, a thicker and harder protective soil layer would be required for bulky structural steel debris than for soil-like waste materials.

  The design for EMWMF stipulated use of a protective soil layer with a hydraulic conductivity greater than the waste, but less than the leachate collection drainage layer so that during landfill operations runoff from the waste and unused portions of the disposal cell would pond temporarily above the protective soil layer. This liquid, referred to as contact water, was directed to the low area of the landfill cell where waste had not yet been placed. Temporary berms were constructed within the landfill cell to separate the waste from the contact water. This design feature allowed contact water to be collected and managed separately from the fluid collected within the LCRS, because it was anticipated that the contact water would be contaminated mostly with sediments from the protective soil itself and not from the waste. Actual operations of EMWMF have shown the difficulty of inhibiting the contact of storm water with the waste, and, therefore, the contact water collected in the cells has had to be managed as potentially contaminated liquid until it could be tested and deemed suitable for discharge. In most cases the contact water has met the facility discharge requirements, but in some instances the contact water has required shipment to the Process Waste Treatment Complex (PWTC) at ORNL for treatment prior to release.

  The EMDF conceptual design assumes a free-draining granular material as the protective layer within the cell low areas, essentially creating windows so that runoff collected there could more easily be managed within the leachate collection system. The free-draining granular material would be the same type of material used in the leachate collection drainage layer – a hard, durable, inert (non-limestone) material having a hydraulic conductivity of approximately $1\times10^{-2}$ cm per second. The majority of the protective layer within the cell would be a native soil material. Continuing to use a native soil material as the protective layer for the majority of the liner helps to balance cost (native soil material is less expensive than inert granular material) and helps to reduce the amount of water collected in the leachate system (soil material provides substantial temporary storage and evaporation for precipitation that falls within the cells).

- LCRS – in order to enhance slope stability and constructability, design components of the LCRS would be somewhat different on the floor of the landfill than on the side slopes.

Floor of Landfill

- Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per $yd^2$, and used to separate the protective soil layer and leachate collection drainage stone. The purpose of geotextile as separator layers is to provide a filter that restricts finer particles of a material on one side of the textile from traveling through to the other side in order to reduce the potential for clogging.
- Leachate Collection Drainage Layer – a 12 in. thick (minimum) layer of hard, durable, inert (siliceous) granular material, preferably rounded to subrounded, and having a hydraulic conductivity greater than or equal to $1\times10^{-2}$ cm per second. Perforated high-density polyethylene (HDPE) pipe (i.e., leachate collection piping) would be installed in this layer to collect and direct the leachate to manholes and lift stations. As was done for EMWMF (DOE 2001a), redundant collection piping would be installed at slightly higher levels than the primary collection piping to provide a secondary leachate collection route should the primary collection piping become blocked with sediment. This layer would serve as the primary leachate collection and removal layer.
- Geotextile Cushion Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 16 oz per $yd^2$, used as a cushion over the underlying geomembrane. The purpose of geotextiles as cushions layers is to provide protection of materials such as geomembranes by acting as a cushion to absorb impacts and potential sharp edges of neighboring materials.

Side Slopes

- Geocomposite drainage layer, consisting of an HDPE geonet core with nonwoven, needle-punched geotextiles thermally bonded to both sides. This layer would slope to drain to the leachate collection drainage layer.

- Primary Geomembrane Liner – a 60 mil thick HDPE geomembrane, textured on both sides to enhance sliding resistance. This layer would retard leachate migration out of the landfill and direct leachate into the primary leachate collection layer.
- Geosynthetic Clay Liner (GCL) – geocomposite layer consisting of sodium bentonite encapsulated between woven and non-woven geotextiles, which are needle-punched together to provide internal reinforcement and deter the shifting of the bentonite layer. This layer would be selected to achieve a saturated hydraulic conductivity less than or equal to $1\times10^{-9}$ cm per second. The purpose of this layer would be to help hydraulically isolate the leachate collection drainage layer from the leak detection drainage layer. This is a feature that was not part of the EMWMF design.. A GCL layer has been added beneath the geomembrane layer between the leachate collection and leak detection layers for the EMDF conceptual design to decrease leakage and create a composite primary liner. The use of a GCL layer between the leachate collection and leak detection drainage layers is consistent with the liner system that was used for Fernald, what is currently proposed for Portsmouth, and what is set forth in DOE guidance (SRNL 2014). Use of a GCL layer between the leachate collection layer and leak detection layer will aid in reducing the amount of fluid collected in the leak detection layer by serving to plug in holes that may be present or develop of time in the primary geomembrane liner.
- LDRS – geocomposite drainage layer consisting of an HDPE geonet core with nonwoven, needle-punched geotextiles thermally bonded to both sides would serve as the leak detection layer. The geocomposite drainage layer would be selected to achieve a long-term design transmissivity greater than or equal to that of a 1 ft thick layer of granular material with saturated hydraulic conductivity of $1\times10^{-2}$ cm per second. The geocomposite drainage layer would be sloped to drain to perforated HDPE pipe (i.e., leak detection piping). This layer would be used to detect and

remove any leachate that may leak through the primary geomembrane liner. Allowable leachate collection rates for this layer would be calculated based on site specific data in order to ensure that primary liner layers are functioning as intended.

- Secondary Geomembrane Liner – a 60 mil thick HDPE geomembrane, textured on both sides to enhance sliding resistance. This layer would provide secondary protection against leachate migrating out of the landfill and helps contain leachate within the leak detection layer.
- Compacted Clay Liner – 3 ft thick (minimum) layer of unamended, native clay soil or bentonite-amended soil compacted to produce an in-place hydraulic conductivity less than or equal to $1\times10^{-7}$ cm per second. This layer would further reduce the potential for leachate migrating out of the landfill. Compacted clay liner material would be selected on the basis of a borrow source assessment that would include performing a suite of geotechnical laboratory tests as recommended by EPA (1993). The choice of whether to use unamended native clay soil or bentonite-amended soil for this layer would depend on the results of the borrow source assessment, availability of low-permeability (i.e., hydraulic conductivity $\leq 1\times10^{-7}$ cm per second) unamended clay soil, and cost considerations.

#### *6.2.2.4.4 Geologic Buffer Layer*

TSCA, 40 CFR 761.75(b)(3), requires a 50 ft geologic buffer between the bottom of the landfill liner system and the historical high water table level. As discussed in Chapter 4 of Appendix G, it is anticipated that the depth to the historical high water table for the EMDF would be less than 50 ft below the bottom of the landfill liner system. Therefore, a waiver from the TSCA requirement would be requested from the regulators based on "equivalent protectiveness" per NCP guidelines (40 CFR 300.430[f][1][ii][C][4]). See Appendix G, Chapter 4 for a complete discussion of the waiver requested.

To provide equivalent protectiveness, the EMDF conceptual design includes at least a 10 ft thick geologic buffer between the landfill liner and ground water table per TDEC Rule 0400-11-01-.04(4)(a)(2). This ARAR is cited in Table G-4 in Appendix G. The thickness of the geologic buffer is measured from the bottom of the landfill liner to the top of the seasonal high water table of the uppermost unconfined aquifer, or to the top of the formation of a confined aquifer. The geologic buffer would consist of the geologic formation (i.e., in situ soil or rock) or an engineered structure (e.g., compacted native soil) meeting the following criteria:

- At least 10 ft thick with saturated hydraulic conductivity $\leq 1.0\times10^{-5}$ cm per second, or
- At least 5 ft thick with saturated hydraulic conductivity $\leq 1.0\times10^{-6}$ cm per second, or
- Other equivalent or superior protection.

The actual thickness and hydraulic conductivity of the geologic buffer would depend on subsurface conditions determined during the hydrogeological and geotechnical investigations for the EMDF. The geologic buffer could be comprised of compacted native soil or in situ fine-grained native soil, saprolite, or combinations of these geologic materials, depending on measured in situ hydraulic conductivity and layer thickness.

Further protection of ground water comes from the RCRA-compliant liner system. The liner system would extend up the sides of the clean-fill dikes, which would be constructed of structurally competent fill material. The dikes would surround the entire landfill, and intermediate dikes would be constructed in between cells.

#### *6.2.2.4.5 Facility Underdrain*

Landfill construction, operation, and long-term performance depend on maintaining the water table below the base of the landfill liner system. A lesson learned from the EMWMF underdrain construction is the

importance of planning for an underdrain system. Not only is it important to have a complete underdrain design that is part of the initial landfill design, that underdrain should not be depended upon as the sole measure to mitigate ground water intrusion. The EMDF underdrain would be designed to provide egress for any potential ground water discharge areas, but the landfill design would be based on the seasonally high ground water elevations. The landfill buffer elevations would be driven by these seasonally high ground water elevations. This buffer zone would be the primary defense against ground water intrusion. Two separate Engineering Feasibility Plans have been issued for EMWMF with respect to suspected ground water intrusion into the geologic buffer. The first of these was issued in August of 2003 and identified the need for the design and installation of the EMWMF underdrain due to ground water intrusion into the geologic buffer. The second plan was issued in October of 2013 in response to a period of consecutive readings from a pneumatic piezometer under EMWMF that indicated ground water intrusion into the upper 5 ft of the geologic buffer.

An extensive underdrain system (to be installed beneath the geologic buffer) would be required in order to provide a hydraulic break beneath the landfill within the portion of NT-3 to be back-filled, and beneath the geologic buffer where other low areas containing springs and seeps are presently located. The underdrain system would be located along the tributary channels to provide an enhanced natural flow path for ground water immediately below the landfill in order to prevent upwelling, as tributaries are natural discharge areas for ground water. Additional trenches and blanket underdrain areas would be added as required to capture any additional ground water seepage. The intent of this underdrain system would be to intercept potentially upwelling ground water and prevent it from rising up into the geologic buffer and liner system. The conceptual layout plan for the underdrain is shown in Figure 6-8. The underdrain system would extend from the spring and seep areas along the northern, upgradient side of the landfill to the perimeter of the clean-fill dike on the southern, down-gradient side of the landfill. In addition, underdrains would be constructed similarly within wet draws/ravines that drain to NT-2 and NT-3. Figure 6-9 shows a typical detail of an underdrain cross-section that could be used. The facility underdrain would be constructed either directly beneath the geologic buffer layer or under the structural fill layer that would then receive the geologic buffer layer, depending on the location of the underdrain section. It is anticipated the underdrain would consist of permeable layers of durable, inert, siliceous crushed stone or river gravel and sand, wrapped with filter fabric along the base of the landfill. Regulators have expressed dissatisfaction with the use of limestone materials to construct the existing EMWMF underdrain, as limestone is highly susceptible to dissolution over time, which may lead to clogging or the formation of voids. Review of design drawings from the Construction Quality Assurance Certification Report for the EMWMF underdrain indicate that the basal main drainage layer, approximately 5 ft thick, and the filter layers of the underdrain were constructed of siliceous rocks and not limestone materials. However, the structural backfill over the siliceous rock was comprised of manufactured limestone sand. The EMDF approach would be to construct the underdrain filter and drainage layers of inert, siliceous rocks and the structural backfill of non-calcareous soils in order to eliminate the potential for dissolution of those materials.

Once fitted with the underdrain system, the backfilled existing channels would behave hydraulically as underdrains to allow shallow ground water discharge preferably to surface water on the downgradient side of the landfill. The underdrain system would be designed with graded filtration to prevent clogging and would be conservatively sized to accommodate the flow rates of the intercepted ground water, based on maximum field measurements, storm flow calculations, and ground water modeling.

The underdrain would be installed at the level of native residual soil/weathered bedrock and would provide a pathway for ground water movement at a lower level than currently exists, and should consequently lower the water table. The upgradient shallow French drain would intercept and divert shallow, perched ground water (which flows down slope during storm events) around the landfill. Construction of the landfill components would eliminate ground water recharge within the footprint of the

landfill. Consequently, these measures would collectively lower ground water levels and reduce ground water fluctuations beneath the landfill.

The facility underdrain ensures the water table would not rise into the geologic buffer. However, the underdrain system could act as a preferred migration pathway for contaminant movement under some conditions if a failure in the liner system occurred. While leachate could percolate into the ground water system and migrate downgradient in the aquifer zone, some leachate would be captured in the underdrain system and discharge directly into surface water. Underdrain discharge points would be included as ground water sampling points in monitoring plans, as has been done at EMWMF. Modeling results of long-term facility conditions show the proposed conceptual design, which includes the underdrain system, would be protective for a hypothetical receptor near the facility (see Appendix H).

#### *6.2.2.4.6 Leachate Collection, Storage, and Transfer within Landfill Footprint*

As previously stated, the LCRS and LDRS would collect landfill leachate and detect leaks in the liner system. The perforated HDPE collection pipe that exits the landfill boundary would connect to solid double wall pipes that extend through the clean-fill perimeter dike. Redundant perforated collection piping in the LCRS would be installed at slightly higher levels than the primary collection piping to provide an alternate route for leachate drainage should the primary piping become obstructed with sediment. The collection piping would penetrate the liner, and would be sealed to the geosynthetic material using anti-seep collars and other fittings to prevent leakage around the penetrations. The solid double wall piping from the collection system and detection system in each cell would connect to manholes that flow to a main header that routes the leachate to a lift station for transfer to leachate storage tanks. Flow meters would be installed in manholes to measure the leachate volume from each cell collected during operations, cap construction, and during the long-term maintenance period following capping and closure. Leachate generated from the landfill would be properly collected, characterized, and treated as necessary to meet discharge ARARs or released if sample analysis indicated it meets discharge criteria (e.g., Managed Discharge, see Section 6.2.2.5.1 for more information).

#### *6.2.2.4.7 Cover Systems*

Cover systems consist of three different stages: (1) operational cover that represents a single "layer" used during daily operations to prevent spreading of waste temporarily, (2) interim cover that represents a cover system (multiple layers) used once a cell has been filled, as a temporary protection from infiltration of rainwater and to stabilize waste until final closure, and (3) final cover, the multi-layered system installed at closure of the landfill and all cells. A gas venting system, if necessary, is also considered part of the final cover system. These covers and the gas venting system are described in detail below.

- **Operational Cover:** Depending on the properties of the waste, it may be necessary to place a thin layer of clean soil over a lift of waste to prevent spreading of the waste by wind or other forces. This layer, referred to as daily cover or intermediate cover, may be removed and stockpiled for reuse prior to placement of subsequent layers of waste, as practicable, to conserve air space within the landfill.

After support systems are constructed and the liner and clean-fill dikes for each construction/disposal phase are completed, waste would be placed in the active cells as described in Section 6.2.5. After waste disposal is complete, an approximately 11 ft thick multilayer cover system (or cap) would be installed to prevent infiltration of precipitation into the waste. Note that some of the layers may be installed as an interim cover system to reduce the volume of leachate generated during active operations.

- **Interim Cover System:** An interim cover system, also referred to as an interim cap (see Figure 6-6), would be installed when waste has been placed to the final design grade over a large enough area of the landfill to allow practical construction. The primary requirements of the

interim cover system are to (1) minimize surface water infiltration into the waste, thus minimizing the volume of leachate generated prior to installation of the final cover system, (2) contain waste against wind dispersion, and (3) ensure no adverse impact to stability or other aspects of final cover performance. The design elements of the interim cover are as follows, from the top of waste upward:

- Geotextile Cushion/Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 16 oz per $yd^2$ used as a cushion and separator layer over the underlying waste.
- Contouring Layer – Standard sanitary landfill designs would require the layer between the waste and the final cover system to be a vent layer. This would typically consist of a 1 ft thick (minimum) layer of No. 57 stone to serve the dual function of contour fill layer and gas vent layer. This layer would provide a smooth, firm foundation for construction of the overlying cover layers, as well as a highly permeable layer for collection and venting of landfill gases. The venting layer is important in municipal settings where high volumes of organic wastes that are susceptible to decomposition and gas generation, also known as putrescible waste, might be expected. A vent layer coupled with vent mechanisms through the cap provide relief from excessive pressure build up within such a landfill. In the case of EMDF, however, careful consideration should be given to whether this layer would facilitate the release of radionuclides into the environment, whether the venting is even necessary considering the low quantities of organic waste, and whether the vent mechanisms would meet the life span needed for the cover system of this nature. These analyses will be performed during the final design. For the EMDF RI/FS this layer will be referred to as a contouring layer.
- Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per $yd^2$, used as a separator between the granular contour/vent layer and overlying temporary geomembrane layer (and permanent compacted clay layer).
- Temporary Geomembrane Layer – 30 mil thick polyvinyl chloride geomembrane. The geomembrane would be properly ballasted with sandbags, tires, or similar non-damaging objects of sufficient mass to prevent wind uplift.
- The geomembrane would be removed prior to construction of the final cover. The underlying layers would remain as part of the final cover system.

- **Final Cover System:** In accordance with RCRA requirements, the final cover system, also referred to as the final cap, would be designed and constructed to:
  - Minimize migration of liquids through the closed landfill over the long-term.
  - Promote efficient drainage while minimizing erosion or abrasion of the cover.
  - Control migration of gas generated by decomposition of organic materials and other chemical reactions occurring within the waste, if found to be necessary.
  - Accommodate settling and subsidence to maintain the cover integrity.
  - Provide a permeability less than or equal to the permeability of any bottom-liner system or natural subsoil present.
  - Resist inadvertent intrusion of humans, plants, and animals.
  - Function with little maintenance.

  The final cover would be sloped to facilitate runoff and would be placed over the waste and tie into the top of the perimeter clean-fill dike. It is anticipated the surface of the final cover system over the waste would be sloped at a grade of 2% to 5% and the sides would be sloped at a maximum grade of 25%. The conceptual design includes 20 ft wide horizontal benches spaced at maximum vertical intervals of 50 ft to reduce slope lengths, increase erosion resistance, and

enhance slope stability. Actual slopes may vary and would depend on slope stability and erosion analyses performed during remedial design. The approximately 11 ft thick, multilayer final cover system would be comprised of the following layers starting from the top of the waste and moving upward:

- Contouring Layer- It should be noted that this layer was discussed previously as one of the first three bullets under the Interim Cover System section. This layer, as part of the Interim Cover System, provides a working and contouring surface. It can then later function as a gas collection layer for the Final Cover System if deemed necessary. If used as a gas vent layer, it would be comprised of a 1 ft thick (minimum) layer of No. 57 stone sandwiched between a 16 oz per $yd^2$ geotextile cushion/separator layer below and 8 oz per $yd^2$ geotextile separator layer above. If a gas vent layer is not deemed to be appropriate, suitable structural fill would be contoured and compacted to provide a stable base for the landfill cover system. Remedial design efforts will include calculations to estimate possible off-gassing of buried waste and evaluate the need for a gas venting capability.
- Compacted Clay Layer – 1 ft thick (minimum) layer of native clay soil or amended soil compacted to produce an in-place hydraulic conductivity less than or equal to $1\times10^{-7}$ cm per second. This layer, in conjunction with the overlying amended clay layer and geomembrane layer, would function as a composite hydraulic barrier to infiltration. Similar to the compacted clay liner for the liner system, compacted clay layer material would be selected on the basis of a borrow source assessment that would include performing a suite of geotechnical laboratory tests as recommended by EPA (1993). The choice of whether to use native clay soil or bentonite-amended soil for this layer would depend on the results of the borrow source assessment, availability of low-permeability (i.e., hydraulic conductivity $\leq1\times10^{-7}$ cm per second) native clay soil, and cost considerations.
- Amended Clay Layer – 1 ft thick (minimum) layer of native soil amended with bentonite and compacted to produce an in-place hydraulic conductivity less than or equal to $1\times10^{-9}$ cm per second. It is necessary to amend native soil with bentonite for this layer to achieve the very low design hydraulic conductivity value less than or equal to $1\times10^{-9}$ cm per second.
- Geomembrane Layer – 40 mil thick HDPE geomembrane, textured on both sides to enhance sliding resistance.
- Geotextile Cushion Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 16 oz per $yd^2$, used as a cushion over the underlying geomembrane.
- Lateral Drainage Layer – 1 ft thick layer of hard, durable, free-draining, granular material (e.g., No. 57 stone) with sufficient transmissivity to drain the cover system and satisfy the requirements of the infiltration analysis.
- Biointrusion Layer – 2 ft thick layer of free-draining, siliceous coarse granular material (i.e., 4 in. to 12 in. diameter riprap) sized to prevent burrowing animals and plant root systems from penetrating the cover system and reduce the likelihood of inadvertent intrusion by humans by increasing the difficulty of digging or drilling into the landfill.
- Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per $yd^2$, used as a separator between the granular filter layer and biointrusion layer.
- Granular Filter Layer – 12 in. thick layer of granular material graded to act as a filter layer to prevent clogging of the biointrusion layer with soil from the overlying erosion control layer. The required gradation would depend on the particle size distributions of both the erosion control layer and biointrusion layer and would be calculated using standard soil filter design criteria once these properties have been established.

- Erosion Control Layer – 4 ft thick vegetated soil/rock matrix comprised of a mixture of crushed rock and native soil and constructed over the disposal facility to protect the underlying cover layers from the effects of frost penetration, and wind and water erosion. This layer would also provide a medium for growth of plant root systems and would include a surficial grass cover or other appropriate vegetation, with seed mix specially designed for this application.

The final cover system would tie into the top of the perimeter clean-fill dike. The drainage and overlying layers would discharge water into perimeter ditches that would carry runoff away from the landfill.

The overall effectiveness of the final cover system in reducing infiltration is a key long-term performance objective of the landfill. Cover technology is evolving and additional methods for reducing infiltration may be available at the time of final design. The overall goal is to reduce leachate generation through the reduction of infiltration.

- **Landfill Gas Collection and Venting System:** Wastes to be disposed of in the EMDF could include a small percentage of organic soils and biodegradable materials such as vegetation, trees, roots, and lumber which generate methane, carbon dioxide, and other gases during decomposition. As already mentioned the accumulation of these gases beneath the landfill cover could reduce the stability of the cover system and create a potentially explosive environment if unvented. However, it is recommended that the decision to implement a landfill gas venting system should be carefully evaluated and should consider the risk of radionuclide releases. Examination of forecasted waste types and resulting limitations on putrescible waste types could be implemented for the EMDF in order to minimize the likelihood that appreciable amounts of gas would be generated within the landfill. Construction/demolition debris, wood waste, and things such as yard waste are typically classified as "non-putrescible". The worst offenders for gas generation tend to be food wastes, which would not be disposed of within the EMDF landfill.

  If a gas vent a layer were deemed appropriate, it is anticipated that this system would be comprised of a gas vent layer consisting of free-draining crushed stone (e.g., No. 57 stone) wrapped with geotextile or a geocomposite drainage layer and vented through the cover using HDPE pipe extending approximately 5 ft above finished grade. It would serve the dual purpose of providing a contouring fill and gas vent layer. In either case, the contouring fill establishes uniform contours upon which to construct the overlying layers of the cover system.

#### 6.2.2.5 Support Facilities

Site layouts depicting proposed locations of the primary support facilities relative to the landfill footprint and surrounding existing and future facilities are shown in Figures 6-2 and 6-10. Locating the EMDF immediately east of EMWMF offers advantages relative to sharing existing EMWMF infrastructure and being in close-proximity to existing utilities.

Land suitable for development of new support facilities is very limited near the EMDF site (see Figure 6-10). The EMWMF landfill occupies the land to the west of NT-3. The slopes north of EMDF are too steep for construction of support facilities. Development east of the proposed EMDF would require crossing NT-2. Much of the land south of the existing haul road and south/southwest of the proposed EMDF is occupied by former waste disposal areas, existing EMWMF support facilities, and land planned for use by the Y-12 Uranium Processing Facility (UPF) Project (e.g., construction of a concrete batch plant, staging construction materials/equipment, parking for UPF construction workers, and wetland expansion/creation areas to offset wetlands impacted by the planned extension of the existing haul road to the Y-12 Plant). The former waste disposal areas (e.g., Oil Landfarm, Sanitary Landfill, BY/BY, and HCDA) have soil or RCRA-type covers, which limit potential use of these sites. With such limited space in the area, it is proposed to utilize the soil covered area of the BY/BY for construction trailers and parking areas. Care would need to be taken not to infringe on the riparian habitat that has been

established along NT-3 on the western edge of the BY/BY, not to infringe on the RCRA capped area (HCDA) in the southern extents of the BY/BY, and to avoid excavating for construction of support facilities.

For the conceptual design, it is assumed the design would utilize and upgrade, as necessary, the following support facilities and structures that are being used by the EMWMF:

- Operations/support trailers, staging/laydown areas, stockpile area, and parking areas
- Leachate storage tanks and truck loading stations
- Contact water tanks and basins
- Haul road
- Electrical, water, and communication utilities
- Truck weigh scale
- Guard station

The following new support facilities would be constructed:

- Wastewater management systems
- Wastewater storage
- Storm water management systems
- Parking areas
- Laydown/storage/staging areas
- Material stockpile area
- Spoils areas (temporary and permanent)
- Guard station

New support facilities are further discussed in the subsections below.

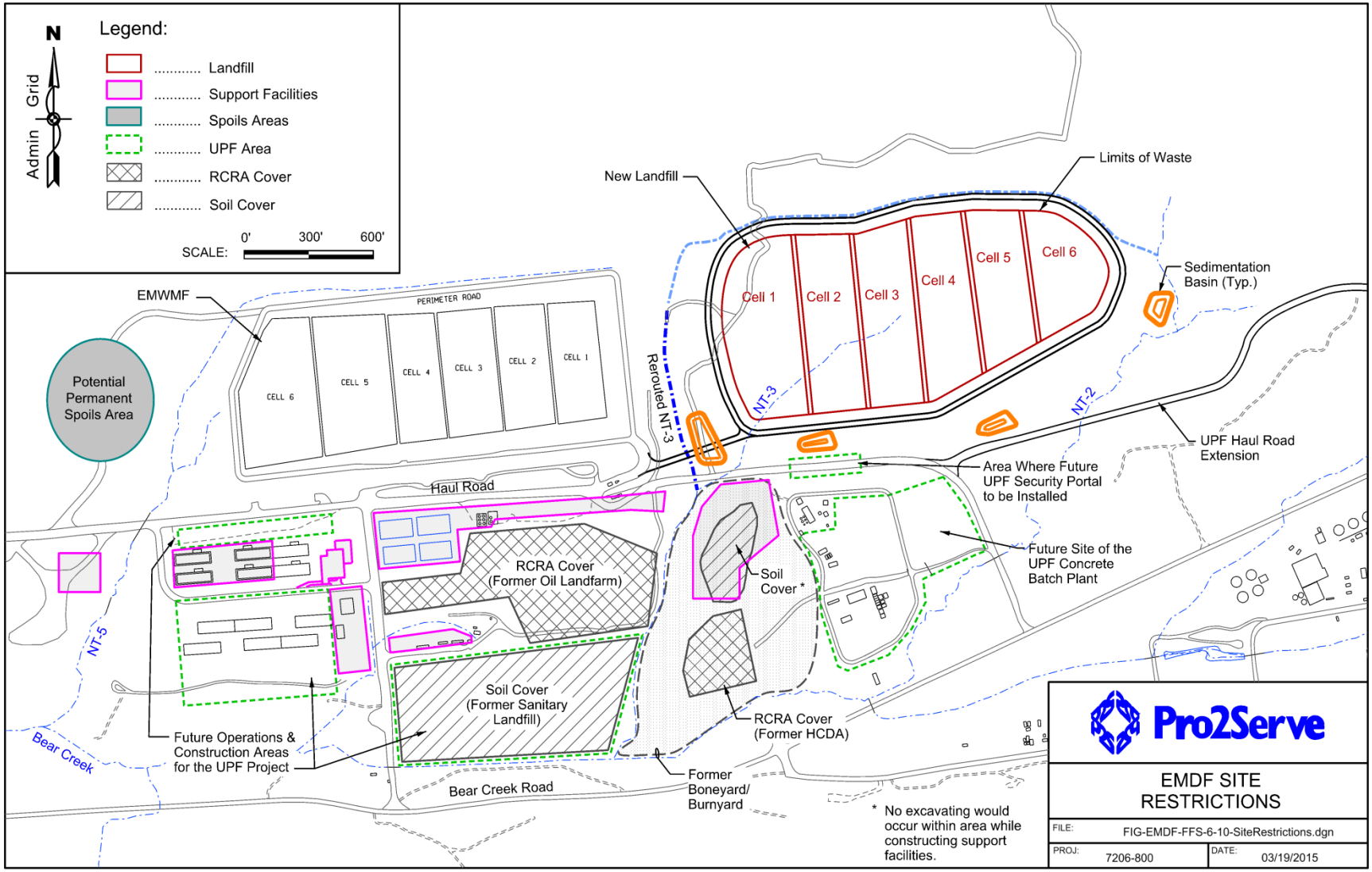



**Figure 6-10. EMDF Site and Surrounding Facilities**

#### *6.2.2.5.1 Wastewater Management Systems*

A companion CERCLA document to this RI/FS, the *Focused Feasibility Study for Water Management from the Disposal of CERCLA Waste on the Oak Ridge Reservation Oak Ridge*, DOE/OR/01-2664&D0 (Integrated Water Management Focused Feasibility Study [IWM FFS]), evaluates in detail the management of wastewater at both EMWMF and the proposed EMDF. The IWM FFS recommends treatment of wastewater that fails to meet discharge criteria, and "Managed Discharge" for wastewater that meets discharge criteria (e.g., sampling and discharge). Several treatment alternatives are examined in the document, including continuing to truck to the ORNL PWTC as EMWMF currently does; building a pipeline to transfer wastewater to the ORNL PWTC or to the future Outfall 200 Mercury Treatment Facility for treatment and discharge; or building a new on-site treatment facility. The selected alternative in the IWM FFS is a combination of Managed Discharge and an on-site (EMWMF/EMDF) treatment system. The potential site for constructing the treatment system would be the area adjacent and east of the existing EMWMF contact water tanks (see Figure 6-11).

The existing EMWMF leachate and contact water management systems (existing tanks) would be used for management of EMDF leachate. Due to the anticipated larger leachate volume for the combined EMWMF and EMDF leachate expected during the operational overlap of these two facilities, additional storage tanks would need to be provided with a total capacity of 1.5 M gallons. These tanks would be constructed in the area immediately east of the existing EMWMF leachate storage tanks. The leachate treatment system could be constructed in the area east of the existing contact water tanks. Proposed locations for these facilities are shown in Figure 6-11.

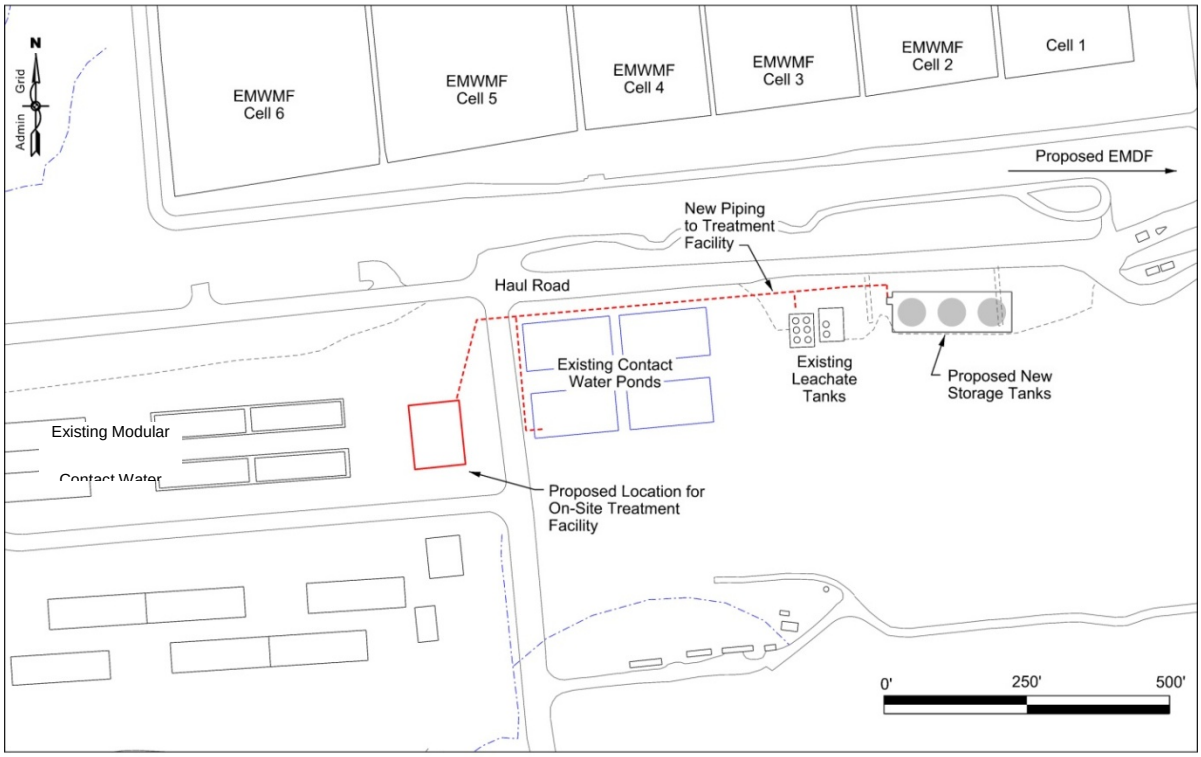



**Figure 6-11. Proposed Locations for Water Treatment Systems**

For details regarding the proposed treatment system and its operation, refer to the IWM FFS. ARARs associated with the IWM FFS are presented in that document. It is intended that complete merging of conclusions reached in the IWM FFS and this RI/FS are addressed at the Proposed Plan stage. A single ROD will address the integrated alternative, and include ARARs from both the RI/FS and the IWM FFS. This is done to avoid "double review/double updating" of the water management approach and ARARs. Therefore, necessarily, the coverage of the wastewater management in this RI/FS document is kept to a minimum. Costs, however, are entirely captured within the On-site Disposal Alternative in this RI/FS.

#### *6.2.2.5.2 Wastewater Storage*

Existing EMWMF leachate storage tanks and contact water basins and tanks will be used for collection and holding of leachate generated during operation of EMDF. These systems include transport tanker loading stations as a near-term or contingency measure for transporting wastewater to the ORNL PWTC for treatment and discharge (see Figure 6-2). In addition to EMWMF storage systems, additional tanks will be constructed for the EMDF leachate, providing 1.5 M gallon storage capacity to accommodate additional leachate flow expected when both the EMWMF and EMDF landfills are operating at the same time. As defined in 40 CFR 260.10, leachate is any liquid, including any suspended components in the liquid, which has percolated through or drained from hazardous waste. Landfill systems that collect and transfer leachate are described in Section 6.2.2.4. Leachate production is highly dependent on operational practices used to limit exposure of the waste to precipitation and weather conditions, with high volumes of leachate corresponding to periods of heavy rainfall. Leachate generation would be expected to increase as the volume of disposed waste increases and additional cells are opened; likewise, leachate generation would decrease with placement of interim covers. After capping and closure of the landfill, leachate volumes will significantly decrease because precipitation infiltration into the waste would be virtually eliminated. The capped landfill will dewater over time as leachate within the waste drains into the leachate collection system at a declining rate. Contact water and leachate storage tanks and basins would be removed over time as the leachate generation rate declines.

Leachate that has percolated through the waste and into the EMWMF LCRS is collected and stored separately in existing leachate storage tanks. The EMDF leachate collection system will be designed to provide a high permeability media near the bottom of the cell (referred to as "windows") that will allow water that falls into the cell to be collected in the EMDF LCRS. Temporary in-cell storage of water would still be available in emergency circumstances by closing valves that connect the lateral leachate transfer lines to the main leachate header. The EMDF leachate may be collected in existing EMWMF leachate storage tanks, existing basins, or new storage tanks constructed to increase leachate storage capacity. New leachate storage for the EMDF would be constructed to meet RCRA ARARs. When EMDF landfill operations begin, EMWMF and EMDF leachate and EMWMF contact water may be combined and managed as one stream.

#### *6.2.2.5.3 Storm Water Management*

Storm water runoff that does not come in contact with waste materials would be directed through ditches and culverts directly into the storm water detention basin(s) and discharged, provided sampling indicates discharge criteria are met. Design for the EMDF storm water runoff takes into consideration the need to manage multiple storm events and also considers that this is a more specialized construction project than what is typically being evaluated. The most important lesson learned from EMWMF regarding storm water management is in selecting an appropriate storm event during landfill operations for the design basis. The EMWMF design followed the typical requirements for sizing holding basins, the 25-year, 24-hour storm event, but during the first year of operations EMWMF experienced well above average amounts of precipitation. It was not typically a single event that proved to be the problem, but several occurrences back-to-back. During construction of Cells 1 and 2 of EMWMF the amount of total suspended solids contained within the site discharge that released from the sediment basin and into Bear

Creek drew attention of the state water quality regulators. The sediment basin was not providing the necessary time for the solids to settle out of the runoff. Problems were also seen once operations began. During the first year of EMWMF operations, May 2002 through May 2003, the total rainfall was 50% above average. This was compounded by precipitation that occurred over extended periods of time and as above average storm events. In calendar year 2003, EMWMF generated 7,570,000 liters of leachate. This was double what had been estimated as the annual quantity in the project design basis.

Footprint availability for sediment basins for the EMDF is a challenge. The EMDF conceptual design utilizes multiple smaller basins to meet the anticipated capacity required. This approach works well with the Phased construction approach of the landfill, but will need to consider longer term sampling needs. Accommodating a single large basin may be more appropriate from a monitoring standpoint.

#### *6.2.2.5.4 Other Support Facilities*

The Haul Road extension supporting the UPF project has impacted wetland areas in the vicinity of the proposed EMDF footprint. Mitigation of this loss has been achieved through expansion and/or creation of wetland acreage at several locations within the Bear Creek watershed (B&W 2010). The eastern part of the proposed EMDF footprint, if fully constructed, would impact two of the expanded wetlands identified in the Aquatic Resources Alteration Permit (ARAP) issued in June 2010 (TDEC 2010). If the On-site Disposal Alternative is selected, coordination of EMDF activities with planned UPF project activities, including a modification to the ARAP, would be required.

Earthwork spoil materials that can be reused in future landfill construction would be stored on-site, since construction of the landfill would be phased. Existing potable water/fire water, electrical, and communication lines used by EMWMF are in close proximity to the proposed landfill footprint and could be extended as needed for the new facility or brought on-site from Bear Creek Road lines. Water from showers and toilet facilities would be temporarily stored in a collection tank prior to transport for treatment at an off-site sanitary treatment facility as is currently the practice for EMWMF.

Waste operations would be conducted in the exclusion area, which would be assumed to be contaminated during operations. Any personnel, equipment, vehicles, or containers leaving the exclusion area would be monitored and, if necessary, decontaminated. Clothing worn in the exclusion area would be managed by an off-site contractor/facility. An enclosed decontamination facility with high-pressure water spray equipment, a collection sump, and pump would be available to inspect and decontaminate vehicles, equipment, and containers. It is anticipated wastewater from decontamination operations would be pumped to a temporary storage tank. The wastewater would be combined with leachate for treatment or used for dust control in the exclusion area.

An equipment storage, maintenance, and fueling area would be constructed in the exclusion area for use during operations. A waste staging area inside the exclusion area would serve as a temporary storage area for incoming waste. This area would be used if the rate of incoming waste deliveries exceeds the rate of waste placement in the disposal facility, as could occur during inclement weather. A covered storage area would be included in the staging area.

### 6.2.2.6 EMDF Conceptual Design Summary

A conceptual final cover grading plan for the EMDF landfill in EBCV is shown in Figure 6-12 and landfill cross-sections are depicted in Figure 6-13.

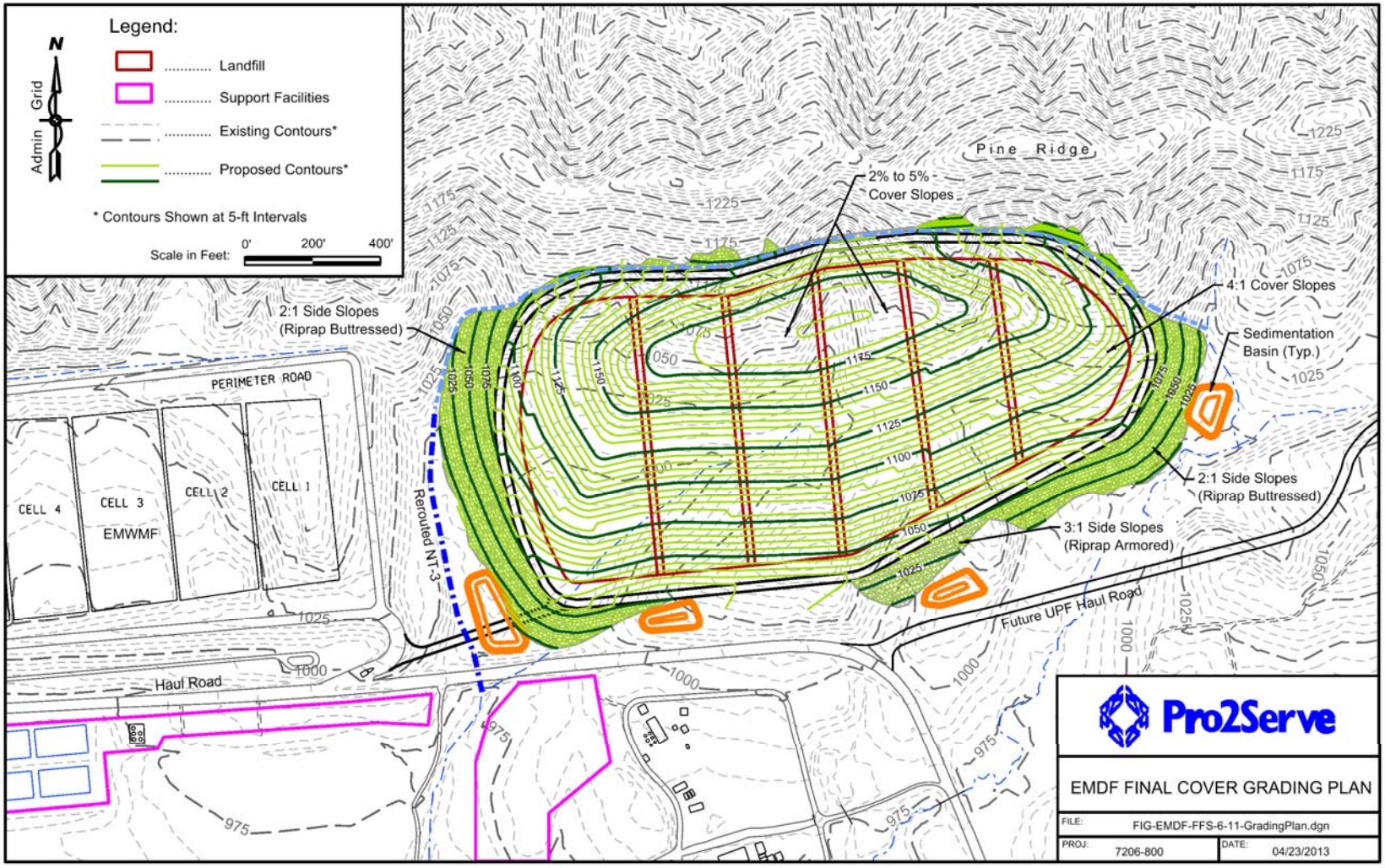
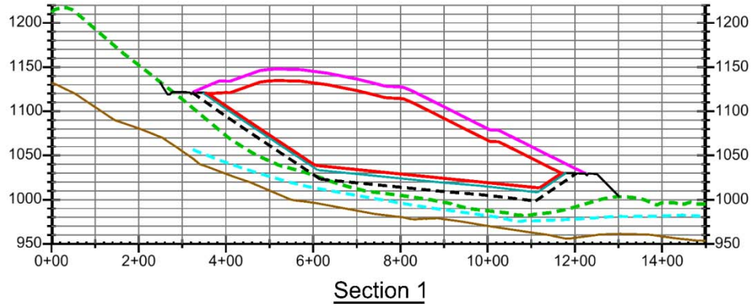
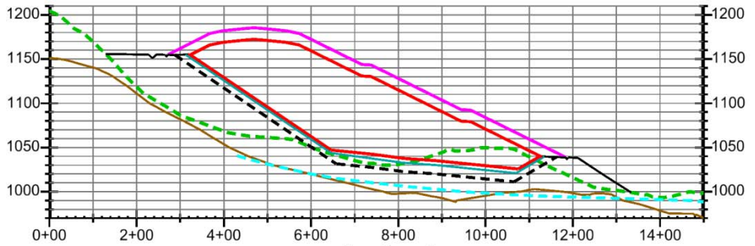


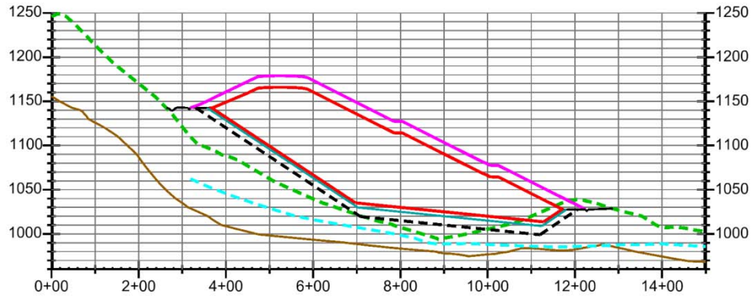

**Figure 6-12. EMDF Final Cover and Grading Plan**



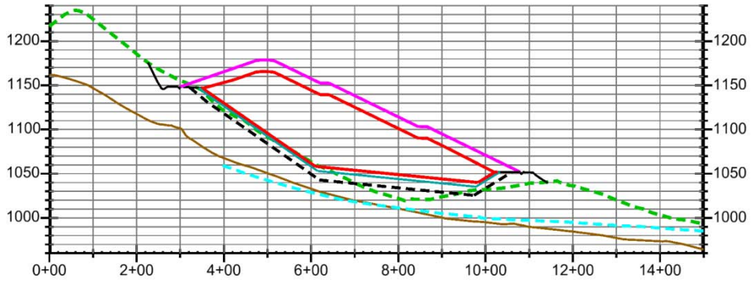

Section 1



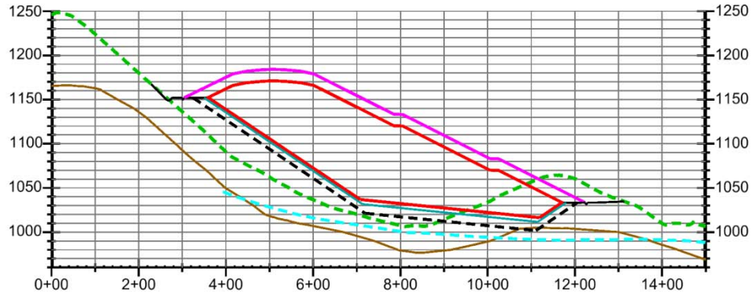

Section 4



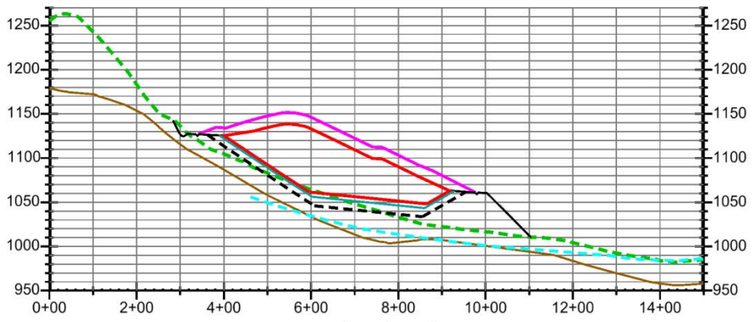

Section 2




Section 5



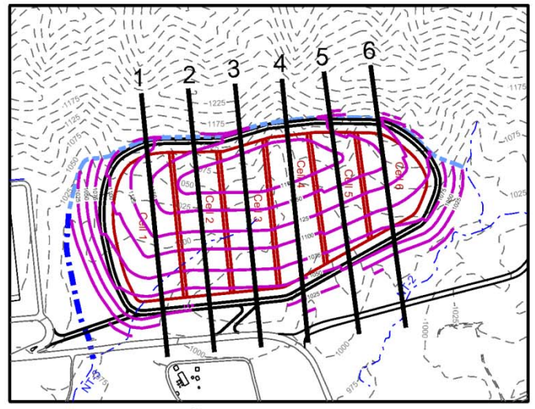

Section 3




Section 6

Legend:

- Existing Grade
- Model Predicted Post Construct Water Levels
- Estimated Top of Bedrock
- Top of Final Cap
- Limits of Waste
- Bottom of Liner System
- Bottom of Geologic Buffer




Plan View
Not to Scale

Veritcal Exaggerated 2x Horizontal

Horizontal Scale in Feet: 0' 200' 400' 600'

Vertical Scale in Feet: 0' 50' 100' 200' 300'

Pro2Serve

EMDF CROSS-SECTIONS

FILE: FIG-EMDF-FFS-6-12-TrueSections.dgn

PROJ: 7206-800

DATE: 03/19/2015

**Figure 6-13. EMDF Cross-sections**

This page intentionally left blank.

The conceptual design for EMDF would provide a disposal capacity of approximately 2.5 M $yd^3$ (see Chapter 2). With this layout, the 48-acre landfill footprint (computed to the outside edge of grading for perimeter clean-fill dike) would be roughly oriented east to west. The landfill would be somewhat rounded in shape to enhance geomorphic stability and more closely model the natural topography. The approximate total area of development, including temporary construction activities, existing and new support facilities, and spoils areas would be approximately 92 acres. Approximately 60 to 70 acres would remain committed to waste disposal post-closure. This committed area would consist of the landfill (as delineated by the limits of grading), roads for accessing the landfill, and leachate management areas (see Figures 6-2 and 6-10). The remaining 20 to 30 acres would provide for miscellaneous support facilities and spoils areas during active operations, and could be converted to meet other future project needs or be decommissioned and removed at landfill closure. The total area of disturbance at any point in time would be reduced by phased construction (only constructing 2 cells during each phase as opposed to all 6 cells as one phase allows use of the future cell face for spoils storage etc.), reuse of construction spoil, implementation of BMPs to manage sediment and erosion during construction activities, and other detailed design considerations. A new larger culvert would be constructed to carry NT-3 and runoff from the EMDF beneath Haul Road. Sediment basins would be constructed in phases along the southern side of the landfill. Depending on the outcome of detailed storm water calculations performed during remedial design, one or more sediment basins may be retained as permanent storm water detention basins. Also, consideration would be given to converting the sediment basins to wetlands.

Vehicle access to EMDF would be provided from the existing Haul Road. The landfill would share the existing access road and guard shack for the EMWMF, located southwest of EMDF. A secondary access road would be constructed along the southern side of EMDF to better accommodate concurrent construction and operations activities. As shown in Figure 6-2 and discussed in Section 6.2.2.5, existing and new support facilities would be located south of the existing Haul Road and south/southwest of EMDF.

Detailed analysis of the various components of the landfill is outside of the scope of the conceptual design. Thorough calculations and development of proactive procedures will be performed as part of the final design and operations work plans for the landfill to ensure a safe and effective system is put into place. Table 6-1 summarizes topics that are considered in final design along with major considerations and calculations that will be performed.

**Table 6-1. Final Design Topics and Considerations**

| Design Analysis Topic | Points of Consideration |
|---|---|
| Clean fill dike stability | • Incorporating site characterization data to set size and elevation of dike to maintain appropriate groundwater buffer requirements for landfill<br>• Calculating needed soil mass at landfill toe<br>• Calculating maximum allowable slopes<br>• Designing appropriate slope armoring<br>• Setting compaction and lift placement requirements |
| Waste mass failure (during operations) | • Placing waste at appropriate slopes<br>• Developing operational procedures and compaction requirements for filling voids<br>• Ensuring proper drainage of water within cells |

**Table 6-1. Final Design Topics and Considerations (Continued)**

| Design Analysis Topic | Points of Consideration |
|---|---|
| Liner stability | • Calculating maximum allowable slopes<br>• Selecting appropriate geosynthectics for predicted site conditions<br>• Following manufacturer's recommendations regarding design and installation<br>• Designing appropriate anchor systems at landfill perimeter |
| Liner leakage failures | • Conducting a thorough site characterization prior to design so that liner system is set at elevations to maintain appropriate groundwater buffer requirements for landfill<br>• Designing layer thicknesses, layer types, layer slopes, and collection piping so as to ensure appropriate liquid removal rates<br>• Designing system to prevent clogging (e.g., materials used)<br>• Design system using real data to supplement and validate model predictions<br>• Utilizing an independent QA/QC program during construction |
| Wastewater Management System Failure | • Calculating appropriate leachate collection piping sizes<br>• Calculating appropriate required on-site storage volumes<br>• Designing for severe precipitation scenarios<br>• Incorporating redundancy and contingency into design<br>• Incorporating operations practices that shed clean water away from contacting waste to reduce wastewater |
| Cap failure due to voids formation or differential settlement | • Calculating and designing appropriate cap layer thicknesses and slopes to ensure movement in waste can be tolerated by cap system without failing<br>• Developing operational procedures and compaction requirements for filling voids |
| Underdrain failure | • Conducting a thorough site characterization prior to design so drainage system can be properly designed<br>• Ensuring all seeps and springs are captured with drainage system<br>• Following natural surface water drainage flow paths with system<br>• Creating redundancy to minimize effects of clogging<br>• Using graded filtration to minimize effects of clogging<br>• Excavating and removing unsuitable residual materials within drainage paths prior to construction of system |
| Upgradient ditch failure | • Conducting a thorough site characterization prior to design so drainage system can be properly designed<br>• Lining of ditches to inhibit surface water from entering into ground as water is diverted around landfill<br>• Installing a shallow groundwater intercepting French drain system<br>• Allowing safety factors (sizing) groundwater intercepting French drain system<br>• Avoiding ditch bottom slopes that might lead to collection of water over time |
| Landfill failure due to earthquake | • Conducting a thorough site characterization prior to design to evaluate that geologic bedding planes are not earthquake sensitive<br>• Adhering to TDEC Earthquake Evaluation Guidance Document<br>• Evaluating the shear properties of landfill liner, landfill cap, and landfill waste mass |

#### 6.2.2.6.1 Layout Approach

A number of factors were considered when selecting and laying out the conceptual design of the EMDF landfill, including its location adjacent to legacy waste management (brownfield) areas, proximity to EMWMF, and the area available to feasibly construct a facility (see Appendix E). The proposed EMDF footprint would be constructed over a portion of NT-3. The approach used to set the extents of the landfill waste and perimeter features was based on maximizing the disposal capacity that could be achieved while minimizing impacts to existing features such as site infrastructure and natural resources. Layout constraints for the disposal facility are described below:

- A 200 ft buffer between the waste and NT-2 was maintained and was set as the eastern constraint. Note this preliminary distance was selected to avoid wetlands and low-lying areas and may be adjusted up or down during the design process depending, in part, on the results of site characterization studies and ground water modeling. Design ground water modeling will demonstrate the landfill is sited a sufficient distance away from NT-2 to protect human health and the environment. Post-construction ground water and surface water monitoring will confirm the design is protective of human health and the environment.
- The southern constraint was set by the existing Haul Road and avoiding any impact to that road and associated overhead high-voltage power line. Keeping the landfill footprint north of the existing Haul Road avoids shallower ground water, Bear Creek floodplains, and existing buried hazardous waste located to the south. It also avoids impact to areas designated for use by the planned UPF Project (see Figure 6-10).
- The western constraint was set by having an adequate drainage pathway between EMWMF and the new disposal facility to manage any surface water runoff around the two facilities, as this would become the rerouted location for NT-3. Final grading of the new landfill would divert some of the runoff that previously discharged to NT-3 over to NT-2.
- The northern constraint was set by the steep upper slopes of Pine Ridge which have typical slope ratios of two horizontal to one vertical (2:1) or steeper. Making cut slopes steeper than the natural slopes of Pine Ridge was avoided since it could cause the ridge slopes to become unstable. Also, it was necessary to somewhat match the existing slopes of Pine Ridge where the perimeter road and ditches would tie into existing grade along the north side of the landfill. Using a leveled backslope was undesirable since it would create an excessively high cut slope that would make it impossible to intersect any new grades to the existing grades near the crest of Pine Ridge. Another consideration for the north side of the landfill was to ensure the perimeter road that travels from the lower south side of the landfill up to the higher north side was not too steep for vehicles. A maximum roadway grade of 8% was set to control this and also controlled the elevation on Pine Ridge for the northern edge of the landfill.

#### 6.2.2.6.2 Phased Construction Approach

The EMDF conceptual design allows the ability to construct the landfill in phases. The landfill would have six cells and it is anticipated that each phase would construct two cells. This approach promotes using gravity drainage for piping systems and consolidates brownfield areas if later phases of the landfill construction are not needed.

Building over NT-3 would be an important consideration as part of the detailed design and phased construction approach. The conceptual design assumes that the entire NT-3 underdrain system would be constructed as part of Phase I (Cells 1 and 2). Phase I would then also include part of the rough grading that would be required to complete Phase 2 construction (Cells 3 & 4). The rough grading would direct surface water runoff away from Cells 1 & 2 and toward the NT-2 drainage area. Current thought is that the cells would be constructed from west to east, but there is flexibility in how the phases can be

executed. It may be advantageous to construct Cells 3 and 4 and associated underdrain first, followed by Cells 1 and 2 in the subsequent phase. As the design evolves, alternative phased approaches may prove to be more appropriate.

#### *6.2.2.6.3 Predicting Seasonal High Ground Water Elevations*

Existing ground water data for the new site is limited, and understanding expected seasonal high ground water levels is a key element to designing a landfill. The goal of the EMDF conceptual design was to establish a reasonable but conservative estimate for the seasonal ground water level in order to establish the lowest allowable elevation of the landfill. The lowest allowable elevation of the EMDF landfill bottom was established to leave a 10 ft buffer between the bottom of the liner system and the estimated seasonal high ground water elevations. Estimating seasonal high ground water elevations has been an iterative process.

The first iteration of the EMDF landfill conceptual design was based on a potentiometric surface estimated from a combination of data obtained from *The Y-12 Ground Water Protection Program Location Information Database* (B&W 2012) and data used to build the BCV hydrogeologic conceptual model for Bear Creek. Originally there were no wells or boring data within the proposed EMDF footprint; however, wells and ground water data in adjacent areas east, west, and south of the site were available. Seasonal high ground water contours were estimated based on maximum water elevations measured for wells near the site and elevations of existing seeps, springs, and tributaries near and within the site. The locations of the existing drainage ways within the proposed EMDF site were assumed equal to the top of the ground water ground water table during seasonal high conditions (i.e. the drainage ways would be a ground water discharge point). For the higher elevations of the proposed site, the seasonal high ground water elevations were predicted by assuming that the depth to ground water would be similar as seen in nearby wells at the same ground surface elevation and in the same geologic formation. Evaluation of the available data demonstrated that ground water could be very shallow within the EMDF footprint during certain times of the year, which lead to the conceptual design grades being set above the existing grades for a majority of the landfill footprint area.

Once the first iteration of the landfill conceptual design was finalized, the resulting proposed elevations for the key landfill layers were provided for comparison with model predicted ground water table elevations, to ensure the conceptual design did not infringe on the predicted ground water table. Phase I characterization has provided ground water elevations for the five well locations and a seasonal high water table was predicted based on this limited Phase I site characterization study data. The bottom (geobuffer and liner system) of the first iteration of the landfill design was then compared to these new ground water surfaces. This comparison showed areas where the more recently predicted ground water levels intruded into the geobuffer layer of the first iteration of the landfill design. A second iteration of the landfill conceptual design was then created to raise the bottom of the landfill, ensuring that it was feasible to construct the landfill such that it could provide long-term protection against ground water intrusion in the geobuffer. Some additional fill material was required in the conceptual design to accomplish this.

#### *6.2.2.6.4 Data Gaps and Uncertainties*

As previously stated, the currently available well and boring data within the proposed EMDF footprint are limited to those contained in the Phase I Site Characterization Report. However, the areas immediately adjacent to the site have been well characterized. The conceptual design for the EMDF is based on ground water, geologic, and geotechnical data obtained immediately east and west of the EMDF site and in other locations in EBCV in similar geology. These data, along with the limited Phase I characterization data are deemed sufficient for formulating a conceptual level design for the EMDF and assessing the feasibility of constructing a CERCLA disposal facility at the EMDF site. If the On-site Disposal Alternative is selected for implementation, a formal Phase II site characterization effort would be conducted as an early action in

support of detailed design, building onto the information gained and lessons learned during Phase I. The process of collecting, analyzing, and applying site specific data will continue into the final design to ensure that ground water buffer requirements are met.

Future mercury-contaminated debris that is planned to be treated in, and disposed of, at the EMDF using the macroencapsulation method is not currently addressed by the conceptual design. Final design considerations will include an analysis of the stresses this treatment (e.g., construction of concrete forms to hold debris, and subsequent macroencapsulation activities) would place on the landfill floor, above the liner. Calculations will be performed to clarify any requirements in terms of landfill construction and operations that may be necessary to safely carryout in-cell macroencapsulation activities on the floor of the landfill.

#### 6.2.2.7 Process Modifications

Based on future engineering studies and additional data on subsurface conditions, waste types, and volumes, process modifications may be incorporated into the final design. Process modifications or techniques could be used to maximize effectiveness and efficiency of EMDF.

Process modifications that may be considered for EMDF include geochemical immobilization technologies designed to retard movement of contaminants, in-cell solid waste treatment to enhance waste stability/reduce leachability and reduce waste transportation costs, and a modified cap vegetation strategy to enhance cap stability and reduce long-term maintenance costs. The process modifications discussed in this section are not included in the base conceptual design. If these enhancements are deemed to be beneficial and feasible, they could be added to the landfill design or operational procedures, as appropriate, to enhance the implementability, performance, or cost effectiveness of the project.

##### *6.2.2.7.1 Geochemical Immobilization*

PreWAC are presented in this RI/FS based on conceptual facility design and assumed receptor exposure conditions (see Appendix H). For calculating the PreWAC, wastes are conservatively assumed to be disposed of throughout the waste layer without segregation. However, geochemical immobilization of soluble waste radiological constituents with long half lives or other hazardous contaminants and an innovative waste placement strategy could enhance the performance of the landfill by reducing or limiting long-term migration of contaminants.

Immobilization technologies could be used to reduce solubility of uranium or other constituents in waste. Uranium immobilization technologies include:

- Performing pretreatment of soluble uranium ($U^{6+}$) to immobilize it as an insoluble mineral.
- Using Apatite II™ and zero-valent iron as reactive barriers or geochemically reactive fill additives in the waste disposal layer.
- Placing pulverized concrete in the waste layer to maintain a higher pH and promote geochemical stability of uranium minerals.

In terms of hazardous constituents, an example would be mercury. Although not very mobile in most soil environments, mercury immobilization can be improved by adding sulfur or sulfur-containing compounds to fill soil when disposing of mercury-containing materials to promote formation of highly insoluble mercury sulfide or cinnabar. Wastes containing mercury below specific limits and not considered hazardous would be the target of this type of treatment. Toxicity characteristic wastes contaminated with mercury (D009 waste) must be treated by macroencapsulation prior to disposal (See Appendix C). Waste to be immobilized could be disposed in one area in the landfill to reduce the area needed for application of geochemical immobilization technologies. Sustainable immobilization requires compatibility with the regional biogeochemistry.

#### *6.2.2.7.2 On-site Waste Treatment*

For some waste streams, it may be advantageous to reduce leachability or meet WAC by implementing some type of stabilization at the EMDF site. Treatment of mercury-contaminated debris and soil wastes are special cases and not part of this discussion; see Appendix C for a discussion of proposed management for mercury-contaminated debris and soils. In the case of waste treated by grout stabilization, the additional weight of wastes grouted at the generation site greatly increases the costs for transporting the treated waste from the generator site to the disposal facility. Mobile processing equipment would be available at EMDF and located adjacent to the active disposal cell. Treatability studies and other quality assurance steps would be implemented to ensure effective waste treatment.

#### *6.2.2.7.3 Cap Vegetation*

As an alternative post-closure strategy, the long-term maintenance costs could be reduced and the long-term stability of the EMDF cover system could be enhanced by early establishment of a controlled forest cover. The uppermost layer of the EMDF landfill cover system will be vegetated to protect underlying layers, reduce erosion, enhance evapotranspiration, and reduce infiltration. The mix of vegetation must be appropriate to regional climate and cap soil conditions. Grasses are commonly selected for cover vegetation because they can be rapidly established and grow shallow but dense root systems that stabilize the cap's surface. However, long-term maintenance of a grass cover requires periodic mowing to prevent colonization by shrubs and trees. It is expected that mowing would cease following the active institution control period.

One of the performance requirements for the EMDF cap is that it survive intact for more than 1,000 years with little or no maintenance. Assuming that climate remains temperate and no building occurs on the landfill, it is inevitable that the cap will undergo natural reforestation. It would therefore seem prudent to design the cap with eventual reforestation in mind. Perhaps the best means to do this is to use the expected post-closure maintenance period for the controlled establishment of a forest, so that a healthy stand of climax trees species is present when maintenance ceases. A forest will accomplish the same hydrologic goals of reducing infiltration, promoting run-off, and preventing erosion as well or better than grasses, and has the added benefits of requiring little or no maintenance and better prevention of inadvertent intrusion by making the site less attractive for use/clearing if administrative control is lost.

Objections to the establishment of forests on landfill caps include root penetration and pitting caused by wind-throw ( i.e., the holes where the tree's roots have been pulled up). While the tap roots of some eastern forest trees, such as hackberry and certain hickories, can extend more than 3 m (10 ft) into the soil and could thus potentially disrupt cap layers, most common trees, such as oaks, poplar, walnut, most hickories, and cherry, root within the upper 1 m of the soil. These shallow root systems would be beneficial by creating a zone of increased permeability that fosters rapid run-off as storm-flow, yet would not impinge upon the synthetic and engineered cap layers. Further, the dense mat of interwoven roots form an effective barrier to erosion and mass wasting.

Wind-throw of a shallow-rooted forest would create a pit-and-mound micro-topography that influences soil formation and natural plant restoration in a manner that would be beneficial to cap stability. Pit-and-mound topography slows erosion by acting to trap sediments and regenerate soil profiles within the root plate area (Bormann, et al. 1995; Clinton and Baker, 2000; Ulanova 2000; Hancock, et al. 2011). Trapping of sediments and organic matter restores soil productivity and, by providing fertile seeding sites, increases plant diversity. If the cap forestation effort is managed to prevent the establishment of species with deep tap roots, forestation of the cap would appear to be at least as beneficial, and possibly more beneficial, than the typically accepted strategy of long-term protection via native grass/vegetation growth.

### 6.2.3 Waste Acceptance Criteria

The characteristics of future CERCLA waste are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002. Appendix H describes modeling and calculations performed to develop analytic PreWAC for the EMDF that meets applicable risk and dose criteria. Other WAC types (physical, safety basis-derived, and administrative) will be developed as part of the final WAC for an on-site facility, and will be included in a primary FFA document, the WAC Attainment Plan. A discussion of WAC development is included in Appendix H.

### 6.2.4 Construction Activities and Schedule

Figure 6-14 shows the conceptual sequence of design, construction, operations, and closure actions. In practice, alternative construction sequencing could be implemented by the construction and operations contractor(s).

The on-site disposal facility construction elements include those described in Section 6.2.2. Ground water monitoring wells and surface water weirs would be installed as part of the early actions to support remedial design. Site development activities would be performed as a separate early phase of construction prior to construction of the landfill. Site development activities would include constructing access roads to the landfill site; preparing additional parking, laydown, spoil, and staging areas; creating/expanding wetlands as required; extending utilities to the landfill site; if necessary, relocating the Y-12 229 Security Boundary and installing new guard stations; clearing and grubbing for site development activities; installing initial sediment and erosion controls for site development activities; upgrading/installing a new weigh scale; and setting up construction trailers.

Subsequent to site development, the disposal cells would be constructed in phases consistent with waste generation schedules. The conceptual schedule used to support the RI/FS cost estimate assumes that the landfill would be constructed and operated in three phases. Phase I would include site preparation for construction of Cells 1 and 2; construction of the NT-3 underdrain and part of the rough grading for Phase II; construction of support facilities; and construction of the first two disposal cells, including clean-fill dike, perimeter road and ditches, upgradient shallow French drain, geologic buffer layer, liner system, and leachate collection and detection systems and piping. Operational readiness and startup would be part of Phase I construction. Waste disposal would begin after Phase I construction is completed. Phase II would include additional site preparation and construction of Cells 3 and 4 which would be ready to accept waste after the Phase I cells have been filled. Phase III would include additional site preparation, construction of Cells 5 and 6.

A large volume of clay-rich soil from a borrow area would be used for construction of the geologic buffer, compacted clay liner, and compacted clay layers of the final cover system. Due to the conservative estimate of the seasonal high ground water table, the conceptual design indicates that a large volume of structural fill will also be required from a borrow area. This is necessary to raise the bottom of the waste to maintain the appropriate buffer between the waste and the ground water table. This structural fill would be used for construction of clean-fill dikes, roadways, and placement of daily cover. Where available, excess cut from the landfill construction that was deemed suitable for reuse could be stockpiled onsite and reused as structural fill. For estimating purposes it was assumed that all structural fill would be purchased from an offsite source. However, as part of the final design process, it would be appropriate to evaluate on-site borrow source areas.

After completion of the three phases of construction and disposal operations, the final cap would be installed. Support areas (e.g., the temporary and permanent spoils areas) would be restored. Demobilization would include removal and disposal or reuse of unneeded support facilities and equipment.

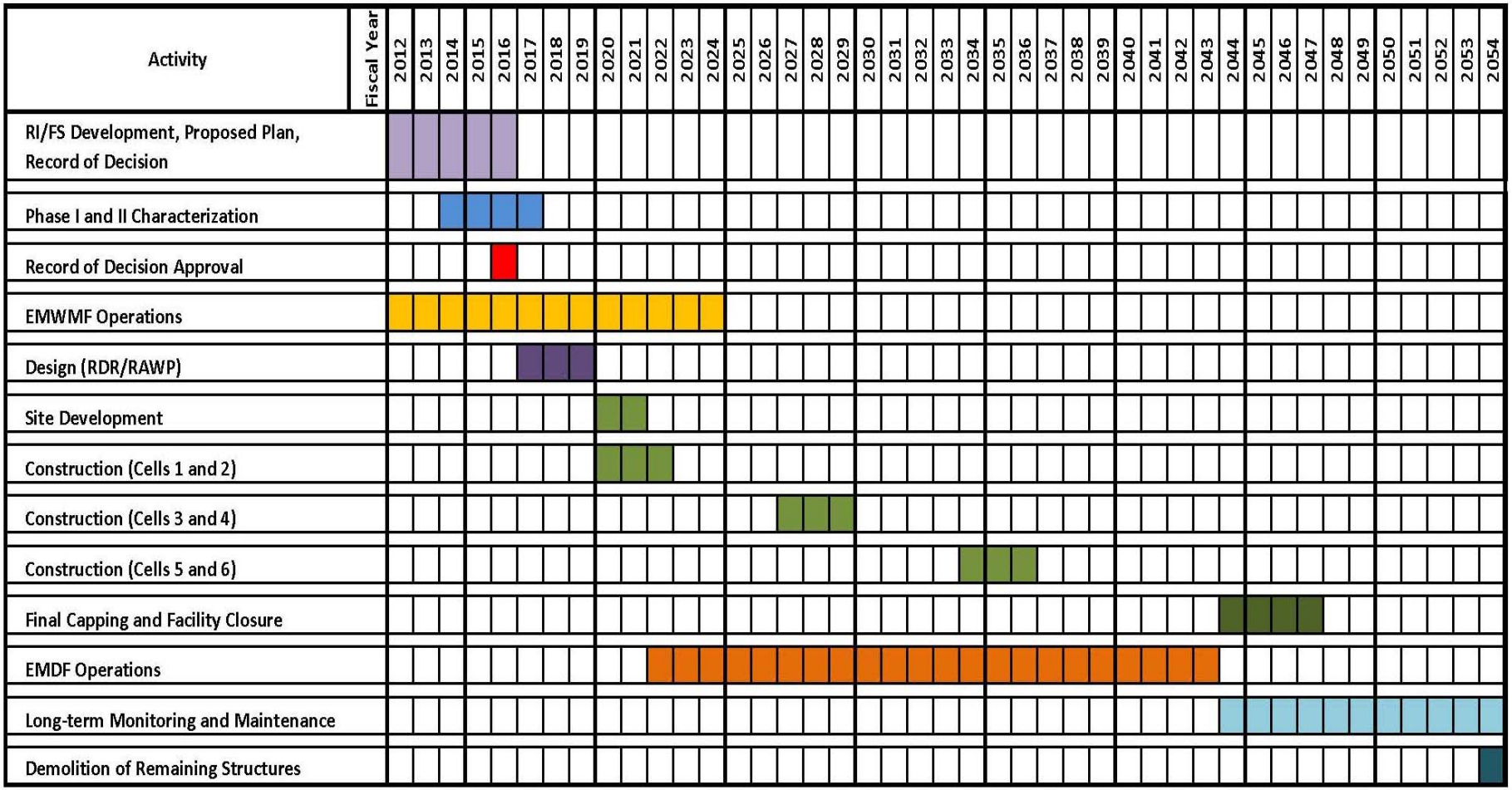



**Figure 6-14. On-site Disposal Alternative Schedule**

### 6.2.5 Operations

EMDF operational scope includes activities being conducted for the time period between 2022 to 2043 when waste placement is being performed, as well as closure and post-closure activities after 2043. In 2022, both EMWMF and EMDF will be operated with waste being placed in EMWMF Cell 6 and in EMDF Cells 1 and 2. In 2024, EMWMF will be filled to capacity and EMWMF final capping operations will begin. Wastewater will be generated from both sites and collected for storage and treatment as necessary. EMDF closure activities will involve construction of the final cap and post-closure will involve cap maintenance and continued leachate collection and management.

#### 6.2.5.1 Waste Placement

For the On-site Disposal Alternative, operations, including some personnel and equipment, would likely transition from the existing EMWMF operations to the new EMDF operations. Disposal operations would include waste receipt, inspection, WAC attainment, and recordkeeping; unloading waste into the disposal cell, placing the waste properly in the working area, compacting waste, and filling void spaces; maintaining work face; surveying incoming and outgoing trucks and containers and decontaminating as needed; dust control; management of wastewater; storm water management, etc.

EMDF facility maintenance would include providing daily cover over the emplaced waste, as required; maintaining roadways, buildings, equipment, utilities, and other facilities; and leachate management. Waste disposal operations would be similar to those at EMWMF. Additionally, macroencapsulation of mercury-contaminated debris is expected to be carried out at EMDF.

#### 6.2.5.2 In-cell Macroencapsulation

Mercury-contaminated debris that will result from the demolition of mercury-contaminated facilities at Y-12 is proposed to be completed at the on-site facility. This operation would require a significant effort including such activities as constructing macro forms on the cell floor, filling the macro form with debris, compacting the debris, periodically filling the voids within the macro form with flowable fill to meet macroencapsulation standards, various monitoring procedures and reporting (environmental and personnel), removal of precipitation contacting the waste for treatment, etc. Details regarding mercury-contaminated waste management at the on-site facility are presented in Appendix C.

#### 6.2.5.3 Wastewater Management

The IWM FFS (UCOR 2015) evaluates in detail the management of wastewater at both the EMWMF and the proposed EMDF. The IWM FFS recommends treatment of wastewater that fails to meet discharge criteria, and Managed Discharge for wastewater that meets discharge criteria (e.g., sampling and discharge). As mentioned previously, the on-site (EMWMF/EMDF) alternative was the selected treatment alternative for management of wastewater, therefore it is included in this RI/FS as part of the On-site Disposal Alternative. The lifecycle cost as presented in the IWM FFS is part of this RI/FS On-site Disposal Alternative lifecycle cost. Operation of an on-site system for treatment would be conducted as part of the landfill operations. Those costs are also included in this RI/FS On-site Disposal Alternative lifecycle cost.

For details regarding the proposed treatment system and its operation, refer to the IWM FFS. ARARs associated with the IWM FFS are presented in that document. It is intended that complete merging of conclusions reached in the IWM FFS and this RI/FS are addressed at the Proposed Plan stage. A single ROD will address the integrated alternative, and include ARARs from both the RI/FS and the IWM FFS. This is done to avoid “double review/double updating” of the water management approach and ARARs. Therefore, necessarily, the coverage of the wastewater management in this RI/FS document is kept to a minimum. Costs, however, are entirely captured within the On-site Disposal Alternative in this RI/FS.

### 6.2.6 Engineering Controls, Construction Practices, and Mitigation Measures

Appropriate engineering controls and construction practices would be implemented during construction, operation, closure, and post-closure care of the on-site disposal facility to minimize the potential for adverse effects. It is assumed the EMDF would be constructed and operated similarly to EMWMF.

Engineering controls, construction practices, and mitigation measures applicable to EMDF would include:

- Preparing and implementing worker health and safety plans.
- Implementing measures to protect air quality, such as wetting surfaces and using chemical dust suppressants and covers to control fugitive dust, and air quality monitoring to assess compliance with standards.
- Protecting aquatic and terrestrial habitat to the extent practical through appropriate planning and implementation of protective measures during construction, and restoring habitat, as needed, in consultation with appropriate state and federal agencies.
- Limiting the number of active working faces of exposed waste in the landfill to prevent contamination releases to air and reduce leachate generation.
- Use of appropriate construction practices in all excavation and construction areas to control surface water runoff and to minimize erosion and transport of sediment from exposed areas including:
  - Berms to direct the flow of surface water.
  - Silt fences to minimize the amount of sediment leaving the area.
  - Straw, mulch, riprap, membranes, or temporary vegetation mats in exposed areas.
  - Storm water detention basin(s) near the perimeter of the site (and at borrow areas, if needed) to protect surface water
  - Segregating runoff from contaminated areas and clean areas.
  - Clearing during autumn or winter to protect the nests of migratory birds during breeding season, to the extent practical.
- Surface water, and ground water monitoring before, during, and after facility construction and operation and implementing appropriate contingency plans if any adverse effects were detected.
- Using double-walled piping for containment of leachate during transfers.
- Using waste soil for void filling to minimize clean fill requirement and conserve landfill capacity.
- For on- or off-site disposal, transporting waste in closed or covered containers or vehicles and providing contingency plans to address potential spills.
- Decontaminating and inspecting haul vehicles, construction vehicles, and containers before they leave any contaminated area.
- Grading, re-vegetating, and restoring disturbed areas.
- Preparing and implementing long-term monitoring and maintenance plans and contingency plans.

A lesson learned from EMWMF personnel was in regards to the installation of the piezometers under the landfill to monitor ground water levels. Lack of redundancy in the piezometers has lead to confusion about how to interpret atypical water level readings. Personnel have questioned whether the readings are accurate or if equipment is faulty. It has been recommended that for the EMDF piezometers be installed in pairs and at varying depths in order to provide more control points and therefore better confidence in readings.

### 6.2.7 Management of Waste Exceeding WAC

Waste that exceeds the on-site disposal facility WAC would be shipped to an approved off-site facility for disposal. If no off-site facility is identified that can accept the waste, the "no path for disposal" waste would be placed in interim storage pending the availability of treatment or disposal capabilities. Actions and decisions to manage waste that do not meet the criteria for on-site disposal will be carried out, documented, and managed under project-specific activities, and thus are not part of this CERCLA remedy evaluation.

### 6.2.8 Closure

After completion of waste disposal, closure activities would include final capping (i.e., construction of the final cover system). A final cap design would be part of the overall cell design prior to Phase I construction and documented in the RDR and RAWP, and follow the ARARs for design given in Appendix G, Table G-4. Several years before closure, any necessary updating of the detailed final cap design would be initiated. Closure of the facility will include continued wastewater collection and treatment as required by ARARs (per the IWM FFS), cap construction per ARARs (Appendix G Table G-5), and monitoring (closure and post-closure) per ARARs (Appendix G Table G-7). Leachate collection, storage, and treatment systems would be decommissioned after rates of leachate generation diminish. Contact water basins and other temporary support facilities would be removed and disposed of appropriately or plugged and abandoned in place, salvaging equipment and facilities to the extent practicable. The site would be restored to maximize beneficial reuse of the property in accordance with the designated land use.

DOE intends to retain ownership of the EMDF site in perpetuity. In the unlikely event that DOE transfers the EMDF site out of federal control, DOE would comply with the requirements of CERCLA Section 120(h)(3), as applicable. This would include deed restrictions or covenants that would prohibit residential use of the property, construction of any facility that could damage the final cover system, or installation of ground water extraction wells for purposes other than monitoring and/or treatment. These deed restrictions would identify administrative controls necessary to protect the public and the integrity of EMDF and would be attached to the deed description and filed with the appropriate local government authority.

### 6.2.9 Post-Closure Care and Monitoring

Surveillance and maintenance (S&M) and performance monitoring would be performed during operation and after facility closure. The remedial design and subsequent documentation based on as-built conditions would include facility-specific S&M and monitoring plans including disposal facility performance goals, long-term S&M requirements, and performance monitoring requirements. The plans would identify required monitoring, features to be inspected, inspection frequency, and performance requirements. S&M and monitoring are assumed to be performed for a period of 100 years after facility closure. The on-site disposal costs cited in this document include costs for these post-closure activities, through the establishment of a perpetual care fee. This fee, incorporated into the On-site Alternative cost estimate, makes no assumptions regarding the entity performing the long-term care. Its purpose is only to capture the cost of the activities. Determinations regarding the entity performing the work are beyond the scope of this document, but would necessarily be determined and incorporated into the ROD. Post-closure surveillance, maintenance, and monitoring is required per ARARs given in Appendix G Table G-7 (monitoring) and Table G-8 (closure and post-closure requirements). Details regarding the cost estimate assumptions for post-closure care are given in Appendix I.

#### 6.2.9.1 Surveillance and Maintenance

Long-term S&M actions would be conducted to control erosion; repair cap settlement/subsidence, slope stability, repair run-on and run-off control systems, including the upgradient geomembrane-lined diversion ditch with shallow French drain, prevent rodent infestation, and prevent tree and other deep-rooted plant growth on the final cover and side slopes. Long-term S&M would also include maintenance of monitoring wells, fences, signs, access roads, survey benchmarks; and leachate collection, storage, and treatment systems. Collected leachate would be treated on a periodic basis and discharged to Bear Creek using appropriate discharge criteria. Leachate system facilities are assumed to be demolished after a ten-year period following the end of waste operations (see the schedule in Figure 6-14).

#### 6.2.9.2 Monitoring

Landfill performance monitoring could be accomplished by (1) monitoring leachate from the LCRS, (2) monitoring surface water in NT-2 and NT-3 at weirs on the upstream side of Haul Road, (3) monitoring seepage emanating from the facility underdrain, (4) ground water monitoring, (5) visual surveillance to detect erosion or indications of surface instability, and (6) periodic land surveys to monitor for settlement. Details about operational and post-closure monitoring would be specified in future post-ROD CERCLA documents that require regulator approval. Available methodologies and technologies, such as real-time down-hole sensors and well purging options for ground water monitoring, would be considered and incorporated as appropriate. Determinations of whether to use high-flow or low-flow methods for well purging and sampling would be made with due consideration given to the potential for inducing contaminant flow from surrounding contaminated areas. Monitoring would support annual Remediation Effectiveness Reports and Five-year Reviews required by the FFA.

Routine monitoring of the leachate detection and removal system would provide an initial warning of liner failure. Periodic monitoring of seepage emanating from the facility underdrain and surface water in NT-2 and NT-3 would serve as early indications of liner system failure. If a failure in the liner system occurred, some leachate would be captured in the underdrain system and discharge into surface water. Also, natural ground water flow paths are toward tributaries, so that contaminants reaching shallow ground water would enter the streams as base flow. Additional measures such as use of lysimeters within the final cover system should also be considered. Such devices could provide early warning that the final cover is not functioning as intended to limit infiltration. The relatively limited service life (as compared to the EMDF) and area of coverage for a typical lysimeter would need to be part of this consideration.

Ground water monitoring would take advantage of the bedrock joint systems believed to underlie NT-2 and NT-3. As discussed in Appendix E, these joints help to direct ground water flowing parallel to strike downgradient and across stratigraphic boundaries towards the Maynardville Limestone drainage system. Wells placed near the tributaries and screened in fractured rock could detect contaminants in the event of liner failure. Additionally, a well cluster placed at about the midpoint and on the downgradient side of the EMDF and screened in water-bearing fractures would act to monitor flow not captured by the tributaries and tributary joint system. One or two wells placed upgradient would provide background water data. Wells would be monitored for water level and indicator parameters, such as specific conductivity or radioactivity. This arrangement of three wells placed downgradient of the EMDF, when combined with one or two upgradient wells, and with indicator parameter monitoring, would meet the substantive RCRA monitoring requirements of 40 CFR 264.97 and 40 CFR 264.98.

Ground water and surface water monitoring results during facility operation and after facility closure would be statistically compared to baseline conditions established before disposal operations, to long-term trends, and to satisfy regulatory criteria. Decisions regarding the placement of monitoring wells would be made with consideration of contributions of contaminants from sources outside of the EMDF, such as the BY/BY, former Oil Landfarm, and S-3 Ponds. Use of low-flow well purging techniques for sampling could reduce the likelihood of inducing contaminant flow from neighboring areas. If baseline

monitoring identifies contaminants in the EMDF area, these data would be used to identify contributions of contaminants from sources outside of the EMDF during operational and post-closure care.

### 6.2.10 Lessons Learned Summary

Table 6-2 is a summary of lessons learned that were discussed in multiple previous sections.

**Table 6-2. Summary of EMWMF Lessons Learned**

| Topic | Lesson Learned Description | Reference Section |
|---|---|---|
| Action Leakage Rates (ALRs) | Use actual site and material specific data when calculating this value and not the general EPA equations and guidance. The initial EMWMF ALR was estimated far too low due to using generic input parameters for calculations. | 6.2.2.1 Remedial Design |
| Project Sequencing | Project sequencing must be improved to ensure maximum beneficial use of waste soil to replace clean fill during placement of debris and general landfill operations. | 6.2.2.1 Remedial Design |
| In-Cell Void Space Fill | Appropriate ratios of soil to debris must be used to estimate the soil needed for use as void space fill to ensure landfill stability. This should also recognize that even with mindful project sequencing soil-like waste will not always be available for use as the void filling material and certain quantities of clean soil fill will be required. | 6.2.2.1 Remedial Design |
| Site Characterization | Performing a thorough site investigation for not only the project footprint, but also for borrow areas can reduce unforeseen construction costs and delays. EMWMF had issues with over-estimating the suitable borrow from the borrow site, underestimating how much unsuitable soils would require hauling off site, and underestimating the seasonal high ground water levels at the site. | 6.2.2.2 Early Actions |
| Protective Soil Layer | The EMWMF design for the protective soil layer defines it as being a native soil with permeability lower than the granular leachate collection layer. This was specified in order to collect the in-cell runoff as clean before it mixed with the potentially contaminated leachate within the liner system. Actual operations of EMWMF have shown the difficulty of inhibiting the contact of the storm water with the waste, and, therefore, the contact water collected in the landfill cells has had to be managed as being potentially contaminated until it can be tested and deemed suitable for discharge. In some instances it has required shipment of contaminated contact water to the PWTC at ORNL for treatment prior to discharge. | 6.2.2.4.3 Liner System |
| Underdrains | Underdrains can be successfully utilized in managing existing ground water at sites, but should be appropriately designed in advance of landfill operations. The materials of the various components of the underdrain system and backfill should be carefully selected to ensure drain longevity. Underdrains can provide a back-up LDRS and should be part of the ground water monitoring plan for the facility. | 6.2.2.4.5 Facility Underdrain |
| Storm Water Management | The design basis for EMWMF used a 25-year, 24-hour storm event for sizing storm water management features. Final design for the EMDF should take into consideration the need to manage multiple back-to-back events and also consider that this is a more specialized construction project than what is typically being evaluated. | 6.2.2.5.3 Storm Water Management |
| Piezometers for ground water monitoring | Having too few piezometers under EMWMF has caused questions about the accuracy of the data collected. Installing piezometers under the landfill in pairs and at varying depths allows for more control points and better confidence in readings. | 6.2.6 Engineering Controls, Construction Practices, Mitigation Measures |

## 6.3 OFF-SITE DISPOSAL ALTERNATIVE

This alternative would provide for the transportation of future CERCLA candidate waste streams off-site to approved disposal facilities and placement of the wastes in those facilities. The waste generator would be responsible for separation of materials for potential recycle or that meet the criteria for local disposal at the ORR Landfill, treatment required to meet the off-site disposal facility's WAC, packaging of the waste at the point of origin, and local transportation. Wastes not meeting the WAC for any off-site facility would be placed in interim storage until treatment or disposal capacity becomes available.

DOE's policy is to treat, store, and dispose of LLW at the site where it is generated, if practical, or at another DOE facility if on-site capabilities are not practical and cost effective. For CERCLA actions that transfer wastes off-site, appropriate permits are required to be held by the receiving facility. In general, the following conditions must be met to use an off-site receiving facility in accordance with the "Off-site Rule" at 40 CFR 300.440 and CERCLA Section 121(d)(3):

- The proposed receiving facility must be operated in compliance with all applicable federal, state, and local regulations; there must be no relevant violations at or affecting the receiving facility.
- There must be no releases from the receiving unit and contamination from prior releases at the receiving facility must be addressed, as appropriate.
- For mixed LLW/RCRA materials, off-site treatment, storage, or disposal facilities must have an approved Nuclear Regulatory Commission (NRC) license and RCRA Part B permit.

These procedures require confirmation by the regional EPA office with jurisdiction over the chosen disposal facility, that indeed the facility is acceptable for the receipt of CERCLA wastes.

### 6.3.1 Candidate Waste Streams

Wastes requiring disposal include LLW and mixed waste with components of radiological and other regulated waste (LLW/RCRA, LLW/TSCA). Table 6-3 lists the candidate waste stream volumes by waste type, material type, and off-site disposal facility for the Off-site Disposal Alternative. As described in Chapter 2, these volumes are based on the as-generated waste volume estimate from FY 2022 through FY 2043 with a 25% uncertainty applied.

### 6.3.2 Description of Representative Disposal Facility Options

As shown in Table 6-3, non-classified LLW and LLW/TSCA waste and classified LLW waste would be shipped to NNSS in Nye County, Nevada or Energy*Solutions*, Clive, Utah. Soil that is LLW/RCRA (in the currently referenced WGF, this volume is attributed solely to mercury-contaminated soil/sediment from remediation projects at Y-12) is assumed to be treated by the applicable remediation project to meet LDRs, and would thus be considered LLW after treatment. LLW/RCRA (mixed) waste would be shipped for treatment and disposal at Energy*Solutions*, Clive, Utah, or WCS in Texas. The disposal facilities are described in the subsections that follow.

**Table 6-3. Candidate Waste Stream As-generated Volumes by Waste Type, Material Type, and Disposal Facility for Off-Site Disposal Alternative with 25% Uncertainty**

| Off-site Disposal Facility | Waste Type | Material Type | Volume ($yd^3$) |
|---|---|---|---|
| **NNSS (Non-Classified) and/or Energy*Solutions*** | LLW | Debris | 1,151,440 |
| | LLW and LLW/TSCA | Soil | 540,115 |
| | LLW/RCRA | Soil[a] | 67,353 |
| **NNSS (Non-Classified) SUBTOTAL** | | | **1,758,908** |
| **NNSS (Classified)** | LLW and LLW/TSCA | Debris | 40,233 |
| **NNSS (Classified) SUBTOTAL** | | | **40,233** |
| **Energy*Solutions* and/or WCS** | LLW/RCRA | Debris[b] | 149,418 |
| **Other SUBTOTAL** | | | **149,418** |
| **TOTAL** | | | **1,948,559** |

[a] This soil is assumed to be treated by the remediation project prior to transfer to off-site disposal such that it is no longer considered hazardous.
[b] This debris volume is expected to require treatment by the off-site facility prior to disposal.

#### 6.3.2.1 Energy*Solutions*, Clive Utah

Energy*Solutions* is located in Clive, Utah, approximately 75 miles west of Salt Lake City; the facility is licensed and permitted to receive the following waste types for disposal:

- Naturally occurring radioactive material/naturally accelerator-produced radioactive material
- Class A LLW per Nuclear Regulatory Commission (NRC) regulations in 10 CFR 61.55
- PCB radioactive waste
- Asbestos contaminated waste
- Mixed waste
- AEA Section 11e.(2) Byproduct material (i.e., uranium and thorium mill tailings)

Energy*Solutions* receives radioactive waste in all forms, including, but not limited to, soil, sludges, resins, large reactor components, dry active waste, and other radioactively contaminated debris.

The facility is located in a remote Utah desert within a 100 square mile hazardous waste zone established by the state of Utah. The nearest population center is approximately 40 miles away. In addition to LLW disposal, Energy*Solutions* offers a variety of mixed waste treatment processing and disposal options.

##### *6.3.2.1.1 EnergySolutions Waste Acceptance Criteria*

As described in the WAC for Energy*Solutions* (Energy*Solutions* 2011), the facility is authorized to receive radioactive waste in the form of liquids and solids. Solid radioactive waste must contain less than 1% free liquid by waste volume. Generators shipping solid waste must minimize free liquid to the maximum extent practicable.

Soil must be greater than 70% by weight compactable material less than ¾ in. particle size and 100% compactable material less than 4 in. particle size. The maximum dry density of soil must be greater than 70 pounds per $ft^3$ (dry weight basis). Soil may be mixed with debris composed of materials that are less than 10 in. in at least one dimension and no longer than 12 ft in any dimension. Debris may include contaminated concrete, wood, bricks, paper, piping, rocks, glass, metal, slag, PPE, and other materials.

Radioactive waste that contains greater than 1% free liquid by waste volume (e.g., sludge, wastewater, evaporator bottoms, etc.) is solidified at Energy*Solutions*' Treatment Facility prior to disposal. Energy*Solutions* is also authorized to receive gaseous waste in accordance with Utah Administrative Code R313-15-1008(2)(a)(viii). Gaseous waste must be packaged at an absolute pressure that does not exceed 1.5 atmospheres at a temperature of 20° C and the total activity of any container shall not exceed 100 Curies.

The following waste types are prohibited from disposal at Energy*Solutions*:

- Sealed sources (e.g., instrument calibration check sources, smoke detectors, nuclear density gauges, etc.).
- Radioactive waste which is classified per NRC 10 CFR 61.55 as Class B, Class C, or Greater Than Class C waste.
- Solid waste containing unauthorized free liquids.
- Waste material that is readily capable of detonation, of explosive decomposition, reactive at normal pressure and temperature, or reactive with water or air.
- Waste materials that contain or are capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste.
- Waste materials that are pyrophoric (pyrophoric materials contained in wastes must be treated, prepared, and packaged to be nonflammable).
- Waste materials containing untreated biological, pathogenic, or infectious material including contaminated laboratory research animals.

The following mixed wastes are not acceptable for treatment or disposal at Energy*Solutions*:

- Hazardous waste that is not also a radioactive waste.
- Wastes that react violently or form explosive reactions with air or water (without written approval by Energy*Solutions*).
- Pyrophoric wastes and materials (without written approval by Energy*Solutions*).
- U.S. Department of Transportation (DOT) Forbidden, Class 1.1, Class 1.2 and Class 1.3 explosives.
- Shock sensitive wastes and materials.
- Compressed gas cylinders, unless they meet the definition of empty containers.
- Utah waste codes F999 and P999.
- Aerosol cans that are not punctured or depressurized.

#### *6.3.2.1.2 Waste Treatment*

Waste shipped to Energy*Solutions* for treatment or liquid solidification prior to disposal is managed at Energy*Solutions*' Treatment Facility. The Treatment Facility is designed for radioactive waste that requires treatment for RCRA constituents and for liquid radioactive wastes requiring solidification prior to disposal. Energy*Solutions*' mixed waste treatment and solidification capabilities include:

- Chemical Stabilization – Including oxidation, reduction, neutralization and deactivation.
- Amalgamation – For the treatment of elemental mercury.
- Macroencapsulation – For the treatment of radioactive lead solids, RCRA metal-containing batteries, and characteristically hazardous radioactive debris.
- Microencapsulation – To reduce the leachability of hazardous constituents in mixed wastes that are generally dry, fine-grained materials such as ash, powders or salts.
- Liquid Solidification – For the solidification of radioactively contaminated liquids such as aqueous solutions, oils, antifreeze, etc., to facilitate land disposal. Mixed waste liquids can also be treated and solidified at the Treatment Facility.
- Vacuum Thermal Desorption of Organic Constituents – For the thermal segregation of organic constituents from wastes including wastes with PCBs. Waste containing PCB liquids is also acceptable for Vacuum Thermal Desorption treatment.
- Debris Spray Washing – To remove contaminants from applicable hazardous debris.

#### *6.3.2.1.3 EnergySolutions Waste Packaging*

Energy*Solutions* receives waste for disposal either in bulk or in non-bulk packages. The packaging used must be authorized for the specific material being shipped by the DOT Hazardous Materials Regulations. Each generator is responsible for ensuring that the packaging used meets the appropriate regulations.

Energy*Solutions* receives various bulk packages, including gondola railcars with either hard-top lids or super-load wrappers, intermodals and other cargo containers, roll-offs, etc. Bulk packages are unloaded at Energy*Solutions* and then decontaminated, surveyed, and returned. Non-bulk packages (disposal containers) include boxes, drums, super sacks, etc. The disposal container is generally disposed of with the waste contents and will not be returned to the generator.

#### *6.3.2.1.4 Transportation to EnergySolutions*

Energy*Solutions* is capable of receiving both truck and rail shipments. The existing rail spur at the ETTP truck-to-rail (transload) facility is available for use for rail shipments.

#### *6.3.2.1.5 EnergySolutions Documentation and Characterization Requirements*

A waste profile record is required for disposal of wastes at Energy*Solutions*. The profile record provides information related to the following areas:

- Generator and waste stream information – generator contact information, general overview of the type of waste, physical characteristics, transportation and packaging, identification of specific radionuclides, and the average and range of radionuclide concentrations.
- Chemical and hazardous waste characteristics – chemical properties of waste relative to RCRA regulations.
- Special Nuclear Material exemption – radiological information to evaluate waste containing Special Nuclear Materia.l
- PCB certification – information about the type of PCB waste included.

For waste streams requiring treatment or solidification, a pre-shipment sample is required for a treatability and/or solidification study.

#### 6.3.2.2 NNSS

The NNSS (formerly known as the Nevada Test Site), is located in Nye County, Nevada, approximately 65 miles northwest of Las Vegas, NV. The facility is licensed and permitted to receive the following waste types for disposal:

- LLW
- LLW containing PCBs
- Pyrophoric waste that has been treated, prepared and packaged to be nonflammable
- Radioactive sources
- LLW containing asbestos
- Radioactive animal carcasses (unless preserved with formaldehyde)
- Beryllium waste
- Classified waste

NNSS receives waste in solid form. Wastes containing liquids or fine particulates must be stabilized to minimize their presence to the maximum extent practicable.

##### *6.3.2.2.1 NNSS Waste Acceptance Criteria*

As described in the WAC for NNSS (DOE 2011b), the facility is authorized to receive LLW, mixed waste, or U.S. Department of Defense classified waste in solid form. Solid radioactive waste must contain less than 1% free liquid by waste volume. Generators shipping solid waste must minimize free liquid to the maximum extent practicable. Liquid waste and waste containing free liquids should be processed to a solid form or packaged with sufficient sorbent material. Compressed gasses are not accepted for disposal at NNSS.

The following waste forms are prohibited from disposal at NNSS:

- Hazardous waste regulated under RCRA
- LLW containing pathogens, infectious wastes, or other etiologic agents
- LLW containing chelating or complexing agents greater than 1% (unless stabilized)
- Waste containing un-reacted explosives

##### *6.3.2.2.2 Waste Packaging*

NNSS receives waste for disposal either in bulk or in non-bulk packages. The packaging used must be authorized for the specific material being shipped by the DOT hazardous material regulations. Each generator is responsible for ensuring that the packaging used meets the appropriate regulations.

The preferred packaging at NNSS for containers to be disposed are those that are easiest to handle and stack, although alternative packaging will be accepted with prior approval. Bulk packages that are requested to be returned to the generator are also accepted, as are bulk items with no packaging (i.e., large equipment and machinery). Bulk items with no packaging are evaluated on a case-by-case basis.

NNSS has specific criteria for waste received in intermodals that are to be returned after emptying. Intermodals must use an inner liner with 18 mil thickness for debris and 12 mil thickness for soil. Intermodals may not weigh more than 44,000-lb gross weight and there must be an 18 in. clearance

between the top of the waste and the bottom of the header brace near the door end of the container (this limits the waste volume within the intermodal to about 18 $yd^3$). Only soil, gravel, concrete rubble, scrap metal, and building rubble are acceptable for packaging and delivery in this manner. Debris items must not have a dimension greater than 3 ft in any direction. Soil must not contain debris or large rocks. Additional container design requirements, radiation dose, and radiological inventory limits also apply.

#### *6.3.2.2.3 Transportation to NNSS*

NNSS is only capable of receiving truck shipments; however, a portion of the shipment can be made by rail to a transfer station in Kingman, Arizona, and then transferred to trucks for final delivery to NNSS. The existing rail spur at the ETTP is available for rail shipments.

#### *6.3.2.2.4 NNSS Documentation and Characterization Requirements*

All waste disposed of at NNSS must be evaluated to ensure compliance with DOE O 435.1, "Radioactive Waste Management." The generator is required to develop, implement, and maintain the following documents:

- Quality Assurance Program Plan
- NNSS WAC Implementation Crosswalk
- Waste Profiles (summarize waste form, characterization data)
- Certification Personnel – list identifying the site waste certification officials

NNSS may require that a split sample be collected from a waste stream based on the annual volume, the potential for finding hazardous components, or the scope/complexity of the sampling process for the waste stream. If required, samples are collected by the generator under the observation of NNSS personnel.

### 6.3.3 Waste Control Specialists, Texas

WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, Texas. WCS offers management of radioactive waste, hazardous waste, and mixed waste. Evaluation of the WCS disposal alternative, assuming that disposal fees are comparable to Energy*Solutions*, indicates that WCS would be the lower cost option due to lower rail and truck transport costs. This assumes that the federal disposal site at WCS is available and bulk transport of debris is allowed with non-containerized disposal. Non-containerized disposal of debris at WCS is currently not allowed and will require approval of a license amendment. For this reason, WCS is not considered a viable alternative for the majority of LLW to be generated as containerizing that debris would be cost prohibitive.

WCS capabilities include:

- Treatment
- Storage
- Repacking/consolidation
- Decontamination and free release of materials
- Disposal

WCS can accept mixed Class A, B, and C LLW and has a separate Federal Waste Disposal (FWD) facility with a current capacity of 964,000 $yd^3$. WCS is licensed and permitted to perform treatment of mixed waste and RCRA/TSCA materials, including the following treatment technologies:

- Chemical oxidation, reduction, neutralization, and deactivation
- Macro- and micro- encapsulation
- Stabilization and solidification
- Treatment of water-reactive materials

Within the FWD, waste may be delivered in containerized or bulk form. Only bulk soil and containerized waste (debris, other) is acceptable in the FWD at the present time. License amendments are in progress to gain approval for acceptance of non-containerized bulk debris. Containerized waste materials such as debris must fit into a concrete canister known as the Modular Concrete Canister (MCC). Cylindrical MCCs are 6 ft, 8 in. diameter with a height of 9 ft, 2 in. Typically 14, 55-gallon drums fit in a cylindrical MCC. Rectangular MCCs are 9 ft, 6 in. long × 7 ft, 8 in. wide × 9 ft, 2 in. tall. Typically four B-25 boxes fit in a rectangular MCC. There are other limitations on Federal waste at the present time, but license amendments are in progress to allow additional waste types and compositions. General requirements for containerized waste include the following:

- Class A, B, or C.
- Depleted Uranium (DU) - Containerized waste streams containing DU in concentrations <10,000 pCi/gram are authorized.
- License Amendment currently under review with the Texas Commission on Environmental Quality to allow acceptance of any depleted uranium, except for uranium hexafluoride.
- Free liquids - must pass Paint Filter Liquids Test, SW-846, Method 9095; no visible free liquids are allowed in bulk waste shipments; containerized waste packages must have <1% free liquids.
- Mixed LLW is acceptable.
  - F020, F021, F022, F023, F026 and F027 (Dioxins & Furans) prohibited.
  - LDR notification required.
- TSCA regulated waste at FWD.
  - Containerized LLW and mixed LLW containing asbestos.
  - Request for TSCA authorization to accept PCBs submitted to EPA.
- Non-containerized bulk waste (soil only).
  - Class A only.
  - Less than 100 mR per hour at 30 cm.
  - Contains isotopes with half-lives less than 35 years.
  - Transportation by highway only.
  - DU and TRU isotopes not allowed.
  - Soil must be <1% debris per container.
- Bulk Debris (Debris & Rubble) for In-Cell Constructed Enclosure (when license amendment is approved).
  - Class A only.
  - Meets RCRA definition of debris and also includes monoliths (concrete-like forms generated by stabilization of waste).
  - Dose rate of waste <100 mR per hour at 30 cm.
  - Each container >50% debris.
  - Average organic content <5% for the entire waste.

The facility is accessible by rail or highway and has on-site rail and truck off-loading capabilities. The distance from the Oak Ridge Office (ORO) to Andrews, Texas is approximately 1,177 miles compared to about 2,290 miles for Energy*Solutions* and about 2,616 miles to NNSS. Consequently, WCS transportation costs may be about half of those for Energy*Solutions* or NNSS. DOE recently entered into a contract with WCS. If disposal rates are comparable to Energy*Solutions*, WCS overall off-site disposal costs would be competitive with other off-site facilities. However, based on the limited FWD capacity, WCS does not currently provide sufficient capacity to make it a viable option in this analysis for the large volume of LLW considered, leaving it as a process modification for that waste stream. It is considered here as a viable option for treatment and disposal of mercury-contaminated mixed waste debris.

### 6.3.4 Size Reduction Processing

Transportation is the most important cost element for the Off-site Alternative; therefore, it is important that materials be shipped efficiently through maximizing the quantity of waste material per shipment. For waste materials that are low in bulk density due to high void fraction, the quantity for shipment in a transport container is limited by the size and not the weight of the material. Transportation costs could be reduced substantially by reducing void volume through size reduction (as demonstrated in Appendix B), therefore, it is assumed that size reduction capability would be provided for this alternative. A centralized size reduction facility (SRF) would be constructed and operated to size reduce selected materials to increase the mass of waste material per shipment.

### 6.3.5 Off-site Disposal Alternative Description

Figures 6-15 and 6-16, respectively, show the off-site disposal activities and responsible entities for waste shipments to Energy*Solutions* or WCS and NNSS. Non-classified waste LLW and LLW/TSCA waste would be shipped by rail followed by truck transport to NNSS using a transload facility in Kingman, Arizona (Option 1). All classified waste LLW shipments to NNSS would be by truck transport, and LLW/RCRA (mixed) waste would be shipped by rail for treatment and disposal at Energy*Solutions*, Clive, Utah or WCS in Andrews, Texas (Option 1 or 2). Non-classified waste LLW and LLW/TSCA waste could also be shipped to Energy*Solutions* for disposal (Option 2). Appendix I contains the cost estimate and additional assumptions for the Off-site Disposal Alternative Options 1 and 2.

The waste generator would be responsible for waste removal; waste characterization, preparation of waste profile and certification; waste segregation; treatment as necessary to meet disposal facility WAC; packaging with exceptions as noted in Sections 6.3.5.2 and 6.3.5.3; local waste transport; and interim storage, as required, for waste not meeting disposal facility WAC.

#### 6.3.5.1 Characterization and Treatment

The waste generator would review all existing waste characterization information to determine compliance with the characterization requirements and the WAC of the designated disposal facility. Wastes with inadequate characterization data would be sampled and analyzed as necessary. The WAC documents for each of the off-site disposal facilities provides detailed information related to the required analyses for waste streams.

#### 6.3.5.2 Packaging of LLW and Classified Waste

Packaging requirements for wastes originating at each generator site would be determined based on waste form (e.g., treated or untreated soil, debris, miscellaneous solids, personal protective equipment /trash, sediment/sludge), waste type (e.g., LLW, mixed waste), transportation mode, destination, and other considerations. Generators would be responsible for waste packaging to reach the ETTP transloading station.

Intermodals are easy to load, are consistent for the projected waste streams, and, when sealed, can be loaded onto trucks and transferred from trucks to railcars with ease. Intermodals are also commonly used at ORR and the disposal facilities are familiar with their use. The intermodal containers would be dedicated to one or more DOE generator sites and would be recycled throughout the waste disposal process, unless used for classified LLW waste disposal at NNSS. Classified waste shipped to NNSS is assumed to be disposed in non-returnable containers.

#### 6.3.5.3 Packaging of Mixed Waste

Two disposal facilities have been identified as possible off-site treatment and disposal options for the management of mercury-contaminated debris expected to result from the demolition of mercury-use facilities at Y-12. Those are Energy*Solutions* and WCS. Those facilities provided vendor quotes for management of this waste stream, which were then applied as part of this Off-site Disposal Alternative. Both facilities were assumed to receive the waste prior to treatment, in appropriate packaging, via rail. The volume to be treated and disposed, as defined in Chapter 2 and again in Table 6-3 of this chapter, is nearly 150,000 $yd^3$, which includes a 25% contingency. Packaging at the generator site, because it is specific to and dependent on the treatment applied in the on-site alternative or vendor and off-site alternative, is assumed to be part of the alternative cost for this waste stream, as opposed to the assumption for LLW, which is independent of the alternative selected and thus NOT included in these estimates. Labor associated with packaging of the mercury debris waste is not considered as part of the on-site or off-site alternative, but is considered a generator activity/cost.

#### 6.3.5.4 Local Transportation

Local transportation methods would be determined at the waste generator site-specific level. There is little difference in local transportation costs between the On- and Off-site Disposal Alternatives because the average distance from the generator sites to either the on-site disposal facility or the transload facility at ETTP would be similar. Local transportation is considered the responsibility of the generator, and costs are not evaluated in the detailed analysis.

All waste containers would be loaded onto a truck at the generator site. The waste containers would be manifested and placarded appropriately for on-site transportation before placement on the trucks. LLW/RCRA waste would be transported to the transload facility at ETTP for rail shipments to Energy*Solutions* or WCS. Non-classified LLW and LLW/TSCA waste would be transported to the transload facility at ETTP for rail shipment to Kingman, Arizona, and subsequent transfer to trucks for transport to NNSS or to Energy*Solutions* in Clive, Utah.

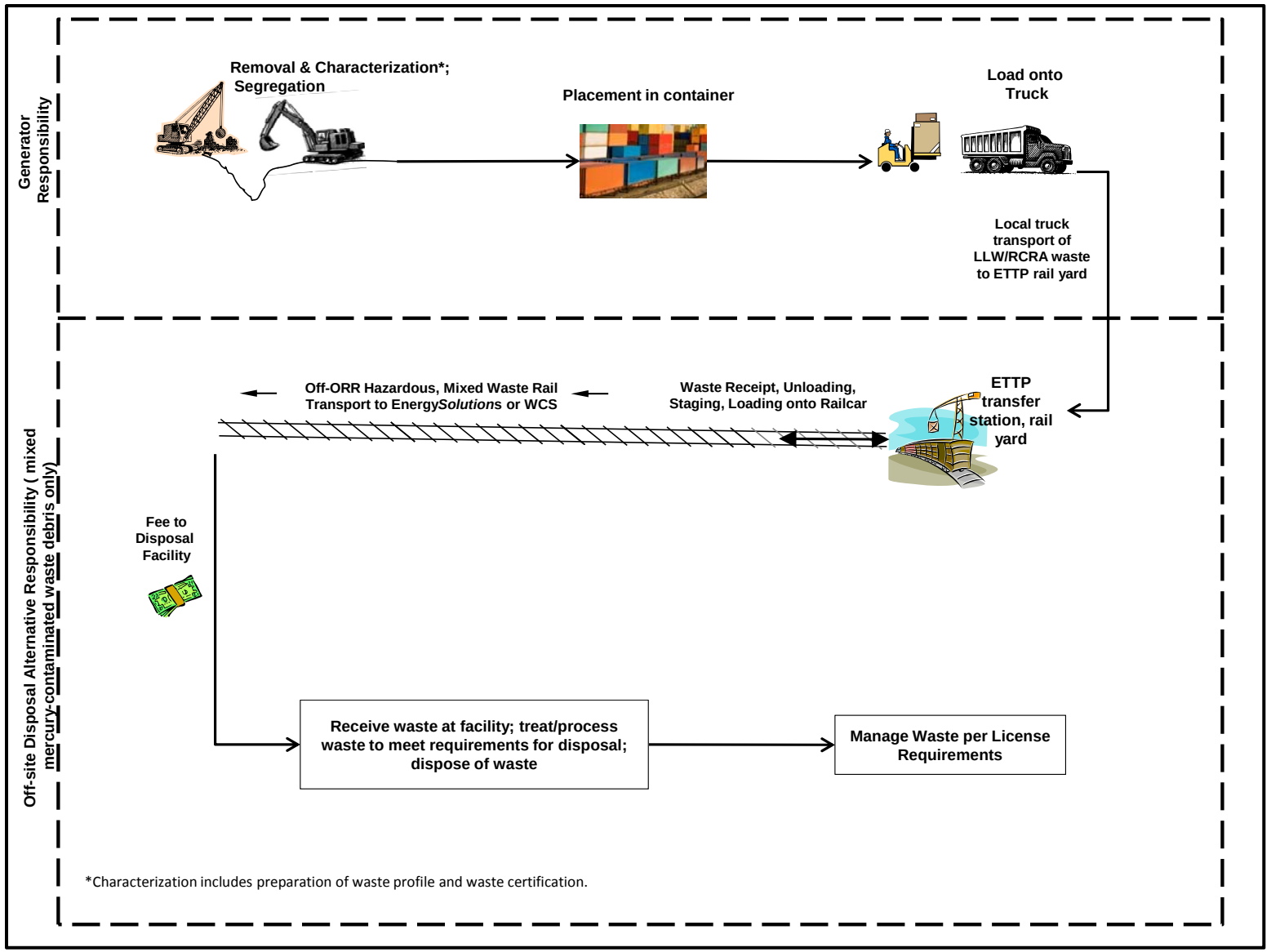



**Figure 6-15. Schematic of Responsibilities for Waste Shipments to Energy*Solutions* or WCS for Off-site Disposal Alternative**

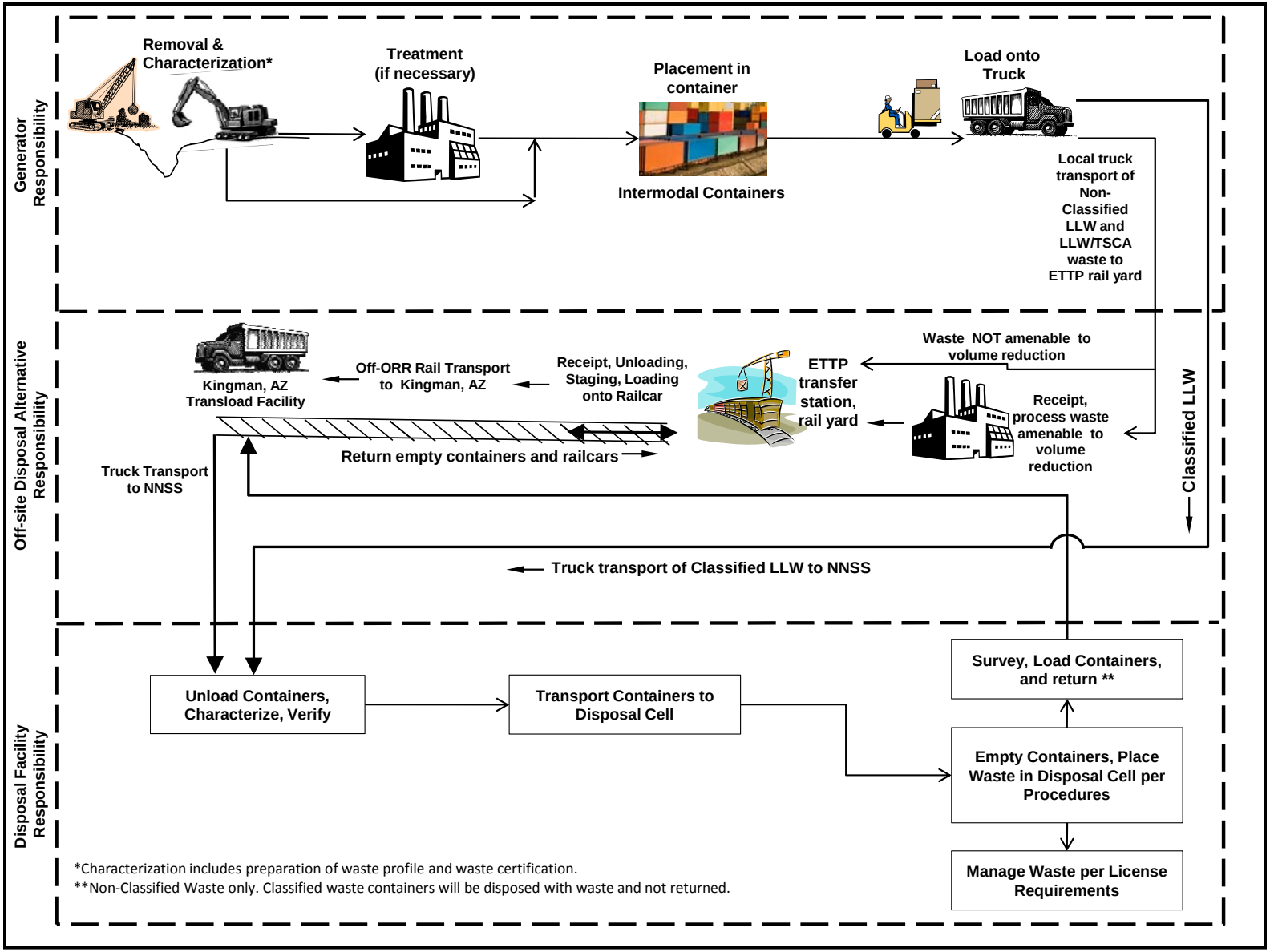



**Figure 6-16. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative**

#### 6.3.5.5 Transload Facility at ETTP

Rail transportation of waste is assumed for all non-classified waste being shipped for off-site disposal. The existing transload facility at ETTP would facilitate the transfer and staging of waste containers from trucks to railcars. Wastes delivered by truck from generator sites would be staged in intermodal containers at an existing docking area for rail shipment. Wastes that require size reduction would be processed prior to loading the intermodal containers and staged in similar fashion. The intermodals would be loaded onto articulated bulk container railcars using forklifts, access ramps, and overhead or mobile cranes. These railcars would be moved on this rail spur by a locomotive. When ready for shipment, one or more railcars would be transferred from the rail spur to the CSX system.

Some upgrades to the transloading facility, and maintenance for the term of the cleanup would be expected. Additionally, a contractor would have to operate the transloading facility. Activities would include exterior radiation scanning/control of incoming/outgoing containers; environment, safety, and health activities; waste manifesting; reporting; and management as well as actual transfer/loading of waste intermodal containers. The cost of transloading is assumed to be included in the transportation costs.

For Option 1, an estimated 116,216 intermodal containers would be transported from the individual remedial sites to the transload facility at ETTP. Each railcar would carry eight intermodal containers resulting in 1,037 railcar loads (mixed waste) to Energy*Solutions* in Clive, Utah, and 13,252 railcar loads to Kingman, Arizona, for truck transfer to NNSS. Classified waste is trucked in intermodals (1,898 shipments) to NNSS. Option 2 would include transport of the 116,215 intermodals in gondolas, by rail to Energy*Solutions* in Clive, Utah.

It is assumed that DOE would purchase dedicated returnable intermodal containers for transporting non-classified waste. Incoming intermodal containers could be staged directly on the cars until one or more cars could be transferred to the main line and shipped. This eliminates the need for construction of additional staging facilities or payment of demurrage fees for holding time at ORR or the disposal facilities.

#### 6.3.5.6 Size Reduction Facility at ETTP

The plan for the Off-site Alternative involves constructing and operating a SRF located in close proximity to the ETTP transload station. Waste targeted for size reduction would be transported by dump truck to ETTP and unloaded into the size reduction unit feed systems for processing. Space for staging waste materials would be available, but would be minimized through scheduling and coordination with SRF operators. Processed material would be loaded by conveyor or excavator into intermodals that would be staged for loading onto railcars.

The SRF would be an enclosed facility that would occupy about 6,400 $ft^2$, not including space for outdoor staging of waste materials. The facility would include industrial shearing and shredding machines designed for size reducing materials such as heavy gauge steel and structural beams, large and small diameter piping, sheet metal, siding, roofing materials, flooring, and other materials with high void fraction. Excavators and conveyors would be utilized for managing the feed and processed materials. The SRF enclosure would be equipped with the necessary ventilation controls and exhaust filters to provide for worker safety and contamination control. Materials that do not benefit from size reduction, and would not undergo processing, include concrete and masonry type materials that are limited by weight rather than volume for transportation. Appendix B includes details regarding size reduction equipment, facility requirements, operational characteristics, and estimated costs.

About 393,000 $yd^3$ as-generated debris volume could be processed for the baseline evaluation. This percentage includes only debris considered amenable to size reduction and does not include concrete or

other debris that does not benefit from processing. Based on cost estimate sensitivity analysis, the minimum quantity of debris processed that would result in a cost reduction that equals the cost of SRF implementation (break-even) would be about 30% of the forecasted debris quantity.

#### 6.3.5.7 Off-ORR Transportation

Non-classified LLW and LLW/TSCA waste being shipped to NNSS by rail would be unloaded from trains at a transload facility at Kingman, Arizona. The assumed rail route to Kingman, Arizona, (see Figures 6-17 and 6-18) involves three major railroads (CSX, Union Pacific, and BNSF) and is approximately 2,402 miles (3,866 km) long. The shipment would be originated by CSX railroad, the rail service provider at ETTP. From ETTP the route continues on the CSX main line west through Tennessee into Memphis. In Memphis, the cargo transfers to the Union Pacific line and continues west through Little Rock, Arkansas; Dallas, Texas; El Paso, Texas; and Phoenix, Arizona. In Phoenix the cargo transfers to the BNSF line and continues north through Flagstaff, Arizona before arriving in Kingman, Arizona. Based on 13,252 railcar loads to Kingman, Arizona, approximately 31.8 M railcar miles (40 M railcar km) would be traveled between Oak Ridge, Tennessee, and Kingman, Arizona.

At Kingman, Arizona, intermodals would be transferred from railcars to trucks for the trip to NNSS in Nye County, Nevada. The assumed truck route from Kingman, Arizona, to NNSS (see Figure 6-18) is approximately 214 miles (343 km) long. Based on 116,216 truckloads, approximately 24.9 M truck miles (35.6 M truck km) would be traveled between Kingman, Arizona, and NNSS. On the return trip, trucks would carry empty intermodals back to Kingman, Arizona, for transfer to railcars and the return trip to Oak Ridge, Tennessee. A 40-day round trip is assumed for rail transportation to Clive, Utah, or Kingman, Arizona.

For classified LLW waste, truck transportation is assumed for the trip from Oak Ridge, Tennessee to NNSS. There are various approved routes for shipments of classified waste. A representative route approximately 2,056 miles (3,309 km) long was used for purposes of the RI/FS analysis. Based on 1,898 truckloads, approximately 4 M truck miles (6.4 M truck km) would be traveled between Oak Ridge, Tennessee, and NNSS.

From Oak Ridge, Tennessee, the intermodals would be loaded onto trucks and the trucks routed to Nashville, Tennessee. From Nashville, the truck would proceed thru West Memphis, Arkansas, and Oklahoma City, Oklahoma. After passing thru Oklahoma City, the truck would pass through Vega, Texas; Kingman, Arizona, and then arrive at Amargosa Valley, Nevada.

All LLW/RCRA (mixed) waste would be transported by rail and disposed at the Energy*Solutions* facility in Clive, Utah, and/or WCS in Andrews, Texas. The assumed rail route to Energy*Solutions* (see Figures 6-17 and 6-18) involves three major railroads (CSX, Indiana Harbor Belt [IHB] Railroad, and Burlington Northern Santa Fe [BNSF] Railway) and is approximately 2,290 miles (3,686 km) long. This route was analyzed in the transportation risk, since it is the bounding case. The shipment would be originated by CSX railroad, the rail service provider at ETTP. From ETTP, the route continues on the CSX main line north into Corbin, Kentucky, through southern Ohio, north through Indiana, and into Illinois near Chicago. Here the cargo transfers to the IHB rail line for 16 miles and then transfers to the BNSF line at La Grange, Illinois. The route continues west through Illinois and crosses into Iowa at Burlington. The route continues through Lincoln, Nebraska; Denver, Colorado; and Grand Junction, Colarado, before arriving in Clive, Utah.

Similar to the rail route taken to get to NNSS, the rail route to Andrews would be originated by CSX railroad, the rail service provider at ETTP. From ETTP, the route continues on the CSX main line west through Tennessee into Memphis. In Memphis, the cargo transfers to the Union Pacific line and continues west through Little Rock, Arkansas; Dallas, Texas; and to Andrews where WCS is located.

#### 6.3.5.8 Disposal

Energy*Solutions*, WCS, and NNSS facilities are familiar with and equipped for the unloading of intermodal waste containers. The intermodal containers would be transferred to the facility's dedicated trucks/equipment, taken into the appropriate disposal cell, and emptied per approved procedures. The waste would be placed in the facility according to approved procedures. Empty containers for LLW and LLW/TSCA waste shipped to the disposal facilities would be surveyed at the disposal facility for release and return to ORR. It is assumed for purposes of this RI/FS that no decontamination of the containers would be required prior to their return. LLW/RCRA waste shipped to Energy*Solutions* and/or WCS for treatment/disposal is based on reuse and limited decontamination of containers as provided in quotes by the vendors. Classified LLW shipped to NNSS for disposal is assumed to be packaged in purchased (non-returnable) intermodal containers.

Table 6-3 provides the estimated volumes that would be disposed at Energy*Solutions* and/or WCS and NNSS. There is currently no disposal fee charged to DOE sites for waste disposal at NNSS; however, DOE costs for NNSS disposal are accounted for through applying a rate of $14.51 per $ft^3$ for estimating purposes (NNSA 2008). Fees at Energy*Solutions* and WCS for mixed (mercury) debris were provided in budgetary quotes obtained from the vendors. Mixed LLW/RCRA waste is assumed to undergo treatment to meet LDRs at the Energy*Solutions* and/or WCS sites prior to disposal. Mixed waste treatment by macroencapsulaton is assumed for purposes of the RI/FS. Fees at Energy*Solutions* for disposal of LLW and LLW/TSCA waste are per the current Indefinite Delivery/Indefinite Quantity contract (Energy*Solutions* 2012).

#### 6.3.5.9 Management of Waste Exceeding Off-site Disposal WAC

All waste disposed of under the Off-site Disposal Alternative would be required to satisfy the appropriate facility WAC. For wastes not meeting the designated facility's WAC or regulatory requirements regarding transportation or land disposal, the generator would be responsible for appropriate treatment in order to render the waste acceptable at an off-site disposal facility.

If an off-site facility is not identified that can accept a certain waste stream even with treatment, that waste stream would require interim storage until treatment or disposal capacity is identified and/or becomes available.

As discussed in Section 2.1.3, the expected volumes of waste exceeding WAC or shipped off-site for other project-specific factors are small and are comparable for both the On- and Off-site Disposal Alternatives. Those volumes are not considered as part of this RI/FS analysis.

#### 6.3.5.10 Process Modifications

Process modifications could be used to maximize effectiveness and efficiency of off-site disposal. Process modifications that may be considered include disposal at a WCS facility in Texas, transportation by gondola, and transportation by truck. If deemed beneficial and feasible, these process modifications could be incorporated into the Off-site Disposal Alternative.

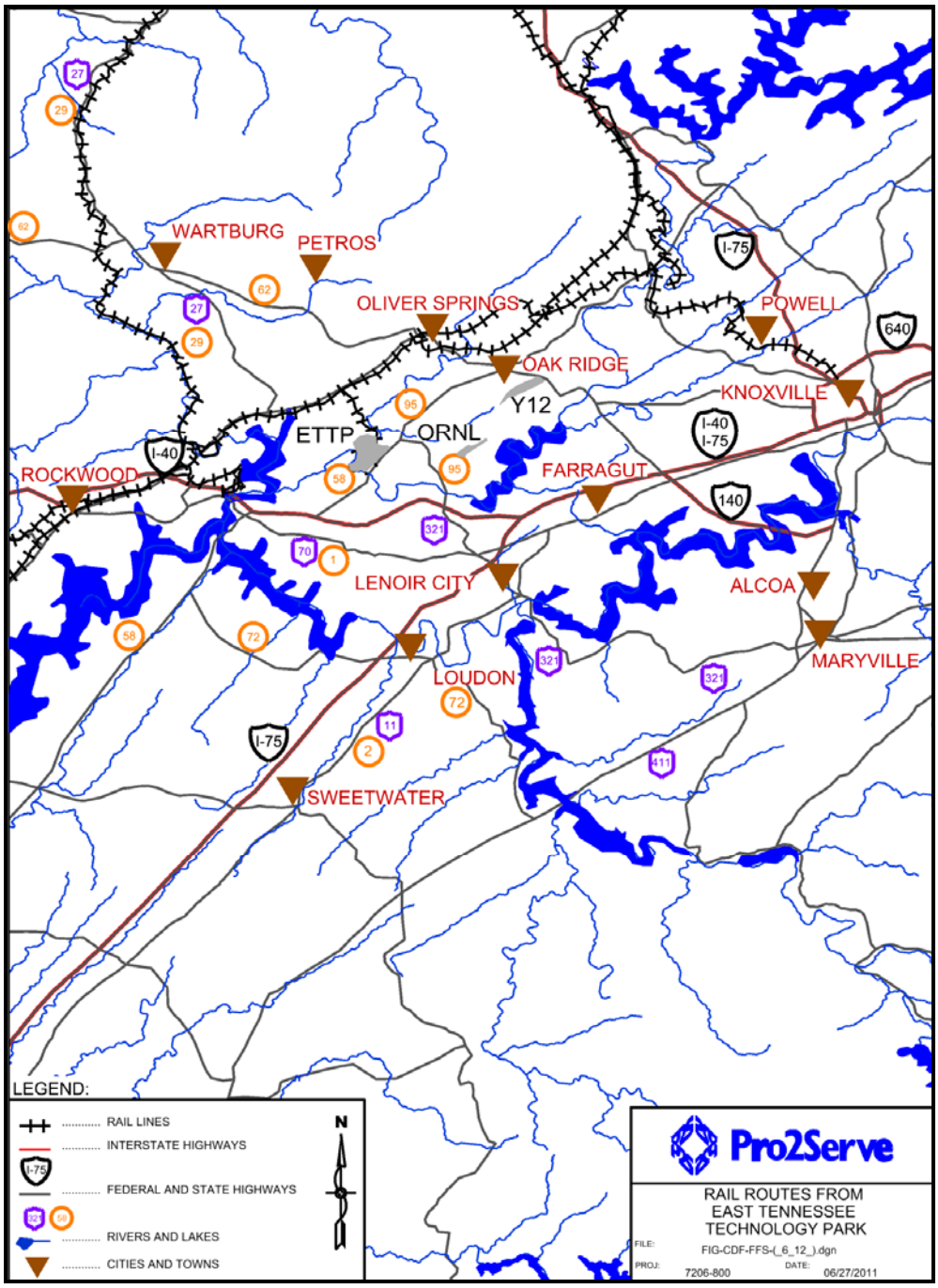



**Figure 6-17. Rail Routes from ETTP**

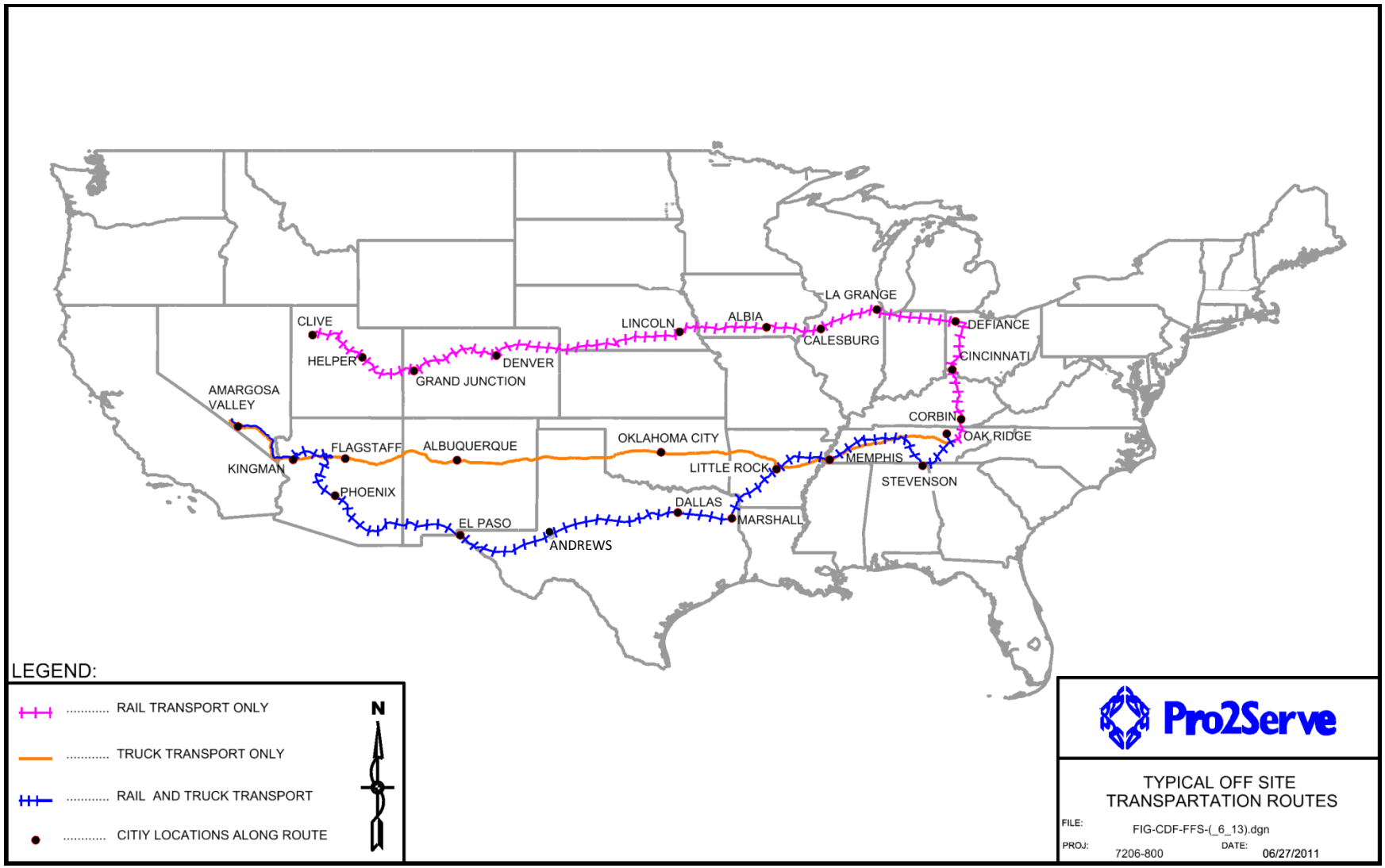



**Figure 6-18. Typical Off-site Transportation Routes**

#### *6.3.5.10.1 Disposal at WCS*

As discussed earlier, WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, Texas. WCS offers management of radioactive waste, hazardous waste, and mixed waste. As noted previously, WCS is not considered a viable alternative for the large volumes of debris expected to be generated in the future CERCLA cleanup on the ORR due to limitations in place concerning the receipt of debris waste (must be containerized). Additionally, the size of the facility (964,000 $yd^3$) precludes it from receiving the large volumes of waste predicted in future cleanup activities. The facility is kept as a process modification, for future consideration if the facility is expanded and/or debris may be received in bulk form. It is considered a viable option and included in the analysis for off-site treatment and disposal of the mercury-contaminated debris that will be generated when Y-12 mercury-use facilities are demolished.

#### *6.3.5.10.2 Transportation by Gondola*

Standard gondolas have a volume capacity of about 100 $yd^3$ and supergondolas have a volume capacity of about 230 $yd^3$. Only Energy*Solutions* at present has the capability to receive and unload gondolas for placement of the waste. The volume of waste per gondola may be limited by the bulk density of the waste material as the weight capacity is about 100 tons.

#### *6.3.5.10.3 Transportation by Truck*

Preliminary cost analysis indicates that cost savings by using rail shipment versus truck shipment would be approximately 11%. However, truck transportation to NNSS and/or Energy*Solutions* may be more favorable than rail in some cases (e.g., small projects where there is not enough material to justify rail shipments). Off-site waste shipment by truck provides a more direct mode of transport and more flexibility than rail and can be more economical depending on the project.

# 7. DETAILED ANALYSIS OF ALTERNATIVES

This chapter provides detailed analysis of the No Action Alternative and the On- and Off-site Disposal Alternatives described in Chapter 6. Relevant information is presented and assessed to provide the basis for identifying the preferred alternative in the proposed plan and the selected remedy in the ROD.

The detailed analysis consists of individual and comparative analyses. Building on the technology screening, alternative development, and detailed alternative descriptions, the individual analysis provides an in-depth evaluation of each alternative against the CERCLA threshold and primary balancing criteria identified in the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300.430). Following the individual analysis, the comparative analysis highlights the key advantages, disadvantages, and tradeoffs among the alternatives. NEPA values are incorporated into both the individual and comparative phases of the alternative analysis.

The CERCLA modifying criteria (state agency and community acceptance) are not addressed in the detailed analysis because these criteria rely on stakeholder participation and feedback to the proposed plan. The proposed plan, which documents the evaluation of remedial alternatives and presents the preferred alternative, will be issued for public review and comment subsequent to regulatory agency concurrence. Public comments on the proposed plan and any other components of the Administrative Record will be addressed in the ROD.

## 7.1 EVALUATION CRITERIA

CERCLA defines an approach that must be used to evaluate and compare the alternatives. This approach uses nine evaluation criteria to facilitate comparison of the relative performance of the alternatives and provides a way to identify their advantages and disadvantages. The nine criteria are divided into three categories – threshold criteria, balancing criteria, and modifying criteria.

**Threshold Criteria:** The two Threshold Criteria are minimum requirements that each alternative must meet in order to be eligible for selection in the ROD.

- Overall protection of human health and the environment
- Compliance with ARARs

**Primary Balancing Criteria:** The five Primary Balancing Criteria represent the primary technical, cost, institutional, and risk factors that form the basis of the evaluation and verify that the alternative is realistic.

- Long-term effectiveness and permanence
- Short-term effectiveness
- Reduction of contaminant toxicity, mobility, and volume through treatment
- Implementability
- Cost

The ability of alternatives to meet these criteria is evaluated in sufficient detail to enable decision makers to understand the significant aspects of each alternative and any uncertainties associated with the evaluation. Each of the three alternatives are assigned a numeric rating for each of the seven threshold and primary balancing criteria evaluated to enable rapid ranking of each. Numeric ratings are quasi-qualitative in that, while based on objective factors and data, they incorporate some degree of subjectivity as to the relative impact of the factors and data.

The ratings are:

0. Not applicable
1. Worst/Least
2. Worse/Less
3. Average/Neutral
4. Better/More
5. Best/Most

As discussed below, modifying criteria await state and public review of the proposed remedy.

**Modifying Criteria:** The viability of the preferred alternative is evaluated on the basis of two modifying criteria:

- State acceptance
- Community acceptance

Alternatives are not evaluated against the modifying criteria in this RI/FS. Modifying criteria will be addressed in the ROD based on stakeholder participation and feedback on the preferred alternative identified in the proposed plan.

In addition to these evaluation criteria prescribed under CERCLA, DOE policy directs that the substantive elements of analysis required under NEPA should be incorporated, to the extent practicable, into CERCLA decision documents (DOE 1994 and DOE 2010b). Elements common to both CERCLA and NEPA include protectiveness, long-term effectiveness and permanence, short-term effectiveness, and cost. Additional NEPA values are addressed for each alternative as described in Section 7.1.10.

### 7.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion assesses each alternative's ability to achieve and maintain adequate protection of human health and the environment in accordance with RAOs. All alternatives except the No Action Alternative must satisfy this criterion.

The scope of this criterion is broad and reflects other evaluation criteria, especially long-term effectiveness and permanence and short-term effectiveness. This criterion addresses how site risks associated with each pathway would be eliminated, reduced, or mitigated through treatment, engineering controls, or institutional controls. It also evaluates impacts to the site resulting from implementation of the remedial action.

### 7.1.2 Compliance with ARARs and To Be Considered Guidance

Appendix G presents a listing of ARARs and to be considered (TBC) guidance for the actions that would be taken to implement the On-site and Off-site Disposal Alternatives. This criterion addresses compliance with federal and state environmental requirements and facility siting requirements that are either legally applicable or relevant and appropriate. In certain cases, regulatory standards may not exist that address the proposed action or the contaminants of potential concern. In such cases, non-promulgated advisories, criteria, or guidance developed by the EPA, other federal agencies, or states can be designated as potential requirements TBC. Other requirements that do not fall within EPA-established criteria for ARARs include DOE orders that pertain only to DOE facilities. Further discussion of the status of DOE orders as ARARs is given in Appendix G.

### 7.1.3 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence criterion considers the degree to which the alternative provides sufficient engineering, operational, and institutional controls; the reliability of these controls to maintain exposures to human and environmental receptors within protective levels; and the uncertainties associated with the alternative over the long-term. Long-term environmental impacts evaluated include transportation impacts, air quality, wetland and aquatic resources, surface water resources, and groundwater resources.

### 7.1.4 Short-term Effectiveness

Short-term effectiveness provides a means of evaluating the effects on human health and the environment at the site posed by the construction and implementation of the alternative. Potential impacts are examined, as well as appropriate mitigation measures for maintaining protectiveness for the community, workers, environmental receptors, and potentially sensitive resources. Short-term environmental impacts evaluated include transportation impacts, air quality, wetland and aquatic resources, surface water resources, groundwater resources, threatened and endangered species, historical and cultural resources, noise, visual impacts, and duration of the alternative.

### 7.1.5 Reduction of Toxicity, Mobility, or Volume by Treatment

This criterion considers the extent to which alternatives can effectively and permanently fix, transform, or reduce the volume of waste materials and contaminated media. The evaluation also considers the amount of material treated; the magnitude, significance, and irreversibility of the given reduction; and the nature and quantity of treatment residuals.

### 7.1.6 Implementability

Implementability refers to the technical and administrative feasibility of implementing the alternative. Administrative feasibility addresses the need for coordination with other offices and agencies, including the ability to obtain permits and regulatory agency approvals. Technical feasibility considers difficulties and uncertainties associated with construction and operation of a given technology; the reliability of the technology; the ease of undertaking additional future remedial actions; the ability to monitor effectiveness of remedial action; and the potential risk of exposure from an undetected release. Evaluation of the availability of services and materials includes consideration of the availability of necessary facilities, equipment, technologies, and specialists, and the effect of reasonable deviations on implementability.

### 7.1.7 Costs

Cost estimates developed to support the detailed analysis are based on feasibility-level scoping and are intended to aid in comparisons between alternatives. EPA guidance states that these estimates should have an accuracy of +50% to -30% (EPA 2000). The cost estimates for this RI/FS are based on the conceptual design and assumptions provided in the detailed alternative descriptions in Chapter 6 and Appendix I. No direct costs are associated with the No Action Alternative. The cumulative disposal costs from cleanup of individual sites under the No Action Alternative cannot be accurately estimated because they depend on independent actions at individual sites. Therefore, these costs are addressed qualitatively. For the On-and Off-site Disposal Alternatives, the following costs are addressed:

- Capital costs (direct and indirect)
- Operations costs, including long-term monitoring and maintenance costs
- Contingency (applied per EPA Guidance [EPA, 2000], see Appendix I) at 22% for the On-site Disposal Alternative total cost and 27% for the Off-site Disposal Alternative total cost

Capital costs are those expenditures required to initiate and perform a remedial action, mainly design and construction costs. Capital costs consist of direct and indirect costs. Direct costs include design and construction (e.g., material, labor, and equipment), service equipment, buildings, and utilities. Indirect costs are mark-ups for fixed-price construction to cover expenses incurred by the subcontractor as described in Appendix I.

Operations costs include (1) long-distance transportation costs and fees paid to off-site disposal facilities; (2) waste handling and placement, facility maintenance, and monitoring during on-site disposal operations; and (3) costs for long-term monitoring and maintenance activities that would occur after closure of the on-site disposal facility. S&M costs for off-site disposal are assumed to be included in the disposal fees paid to the off-site facilities.

Present worth costs for the alternatives were calculated based on EPA guidance (EPA 2000) using a real discount rate of 2.0% according to the Office of Management and Budget (OMB) Circular No. A-94 (OMB 2012). The present worth costs are based on discounting costs given in 2012 dollars that have been escalated over the period of activity as determined by the project schedule. Present worth costs are reported in FY 2015 dollars.

### 7.1.8 State Acceptance

State acceptance of alternatives will be evaluated in the proposed plan issued for public comment. Feedback received on the preferred alternative identified in the proposed plan will be documented in the ROD. Therefore, this criterion is not considered in this RI/FS.

### 7.1.9 Community Acceptance

Community acceptance of alternatives will be evaluated in the proposed plan issued for public comment. Feedback received on the preferred alternative identified in the proposed plan will be documented in the ROD. Therefore, this criterion is not considered in this RI/FS.

### 7.1.10 NEPA Considerations

DOE policy (DOE 1994 and DOE 2010c) directs that CERCLA documents will incorporate NEPA values, such as analysis of cumulative, ecological, and socioeconomic impacts, to the extent practicable. The NEPA process informs decision makers on a wider range of environmental and socioeconomic concerns than those specifically addressed under CERCLA. While this RI/FS incorporates NEPA values throughout, the evaluation of alternatives presented here highlights, as appropriate, values that are not specifically included in the CERCLA criteria: socioeconomic impacts, land use, environmental justice, irreversible/irretrievable commitment of resources, and cumulative impacts.

## 7.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES

### 7.2.1 No Action Alternative Analysis

Evaluation of the No Action Alternative is required under CERCLA and NEPA to provide a basis for comparison with action alternatives. The No Action Alternative for this RI/FS assumes that no comprehensive strategy to address the disposal of waste resulting from any future CERCLA remedial actions at ORR would be identified or implemented. Under the No Action Alternative each CERCLA remedial action would be required to individually address the disposition of waste generated. Uncertainty about these future actions prevents specific identification of the impacts of no action. Efficiencies of consolidation and economies of scale would not be realized under the No Action Alternative.

#### 7.2.1.1 Overall Protection of Human Health and the Environment (No Action)

Overall protection of human health and the environment would depend on the actions ultimately taken at individual sites. Risk reduction would have to be addressed by CERCLA decisions at the individual sites without the benefit of a comprehensive disposal strategy. The effectiveness of these controls at multiple sites would depend on local site conditions, the effectiveness of engineered controls enhancing local conditions, continued maintenance and monitoring, and security measures. Land use restrictions would be required at any sites where waste would be left in place, whether the waste was treated, contained, or disposed of in situ. The failure of these measures would increase human and ecological risks.

#### 7.2.1.2 Compliance with ARARs (No Action)

Compliance with ARARs applies only to actions taken under CERCLA authority. No ARARs apply to the No Action Alternative which assumes no comprehensive disposal strategy for future waste generated by CERCLA actions. ARARs for remedial actions at individual sites that will generate future waste would be specified by separate CERCLA documents.

Under the No Action Alternative, there could be a future increase in the amount of stored waste because of a lack of readily available disposal capacity. Extended or indefinite waste storage could result in DOE being out of compliance with regulatory requirements and agreements.

#### 7.2.1.3 Long-term Effectiveness and Permanence (No Action)

There would be no direct long-term adverse environmental effects under the No Action Alternative because no construction or operations activities would take place to implement a comprehensive waste disposal strategy. Long-term effectiveness and permanence would be determined in CERCLA actions at individual sites. While individual actions at ORR could result in independent disposal capabilities that adequately prevent releases or exposure, the extent to which RAOs could be met would vary among sites. This alternative may not support timely cleanup or release of portions of ORR for beneficial use.

#### 7.2.1.4 Short-term Effectiveness (No Action)

Similar to long-term effectiveness, there would be no direct short-term adverse environmental effects under the No Action Alternative because no activities to implement ORR-wide waste disposal would take place. Short-term effectiveness would be determined in CERCLA actions at individual sites.

#### 7.2.1.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (No Action)

Reductions of toxicity, mobility, or volume would be determined in CERCLA actions at individual sites. If the lack of a coordinated disposal program under the No Action Alternative were to cause more waste to be managed in place, limitations on treatment activities could result in a lower overall degree of reduction in toxicity, mobility, and volume of contaminated media.

#### 7.2.1.6 Implementability (No Action)

No implementation would be required for this alternative. Activities associated with a comprehensive strategy for either on-site or off-site disposal of waste across projects would not be implemented.

#### 7.2.1.7 Cost (No Action)

There would be no cost directly associated with implementing the No Action Alternative; however, analysis and implementation of disposal options on a site-by-site basis could result in high cumulative cost over time because of the lack of economies of scale and the need to procure disposal services on a project basis. Conversely, if the lack of a comprehensive disposal program resulted in most of the waste

being managed in place, remediation costs at the individual sites and overall disposal costs could be lower.

#### 7.2.1.8 NEPA Considerations (No Action)

There would be no direct NEPA considerations under the No Action Alternative because no construction or operations activities would take place to implement a comprehensive waste disposal strategy. NEPA considerations would be determined in CERCLA actions at individual sites without the benefit of a coordinated disposal capacity. This could indirectly result in more wastes being managed in place, limited reuse of some land, and greater residual risk.

### 7.2.2 On-site Disposal Alternative Analysis

The On-site Disposal Alternative proposes consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, partially below-grade, engineered waste disposal facility (i.e., landfill) on the ORR, referred to herein as the EMDF. Wastes not meeting the EMDF WAC would be transported to off-site disposal facilities or placed in interim storage until treatment or disposal capacity becomes available. Section 6.2 gives a detailed description of this alternative. The On-site Disposal Alternative evaluates a proposed EMDF site in EBCV adjacent to the existing EMWMF.

#### 7.2.2.1 Overall Protection of Human Health and the Environment (On-site)

The On-site Disposal Alternative would meet risk-based RAOs and protect human health and the environment by consolidating most future generated CERCLA waste exceeding the capacity of the existing EMWMF from the cleanup of ORR and associated sites into an engineered waste disposal facility, isolating the wastes from the environment. Additional protection would be provided indirectly by treatment of waste to meet the EMDF WAC. Placement of wastes into the EMDF would result in an overall net reduction of risks associated with environmental contamination at the ORR and associated sites.

A new on-site waste disposal facility would be designed to control releases to groundwater, soils, surface water, and air, and to prevent inadvertent intrusion into the waste. The facility would be designed such that components would be operational and effective throughout operations and the post-closure periods, and containment would remain effective for 1,000 years to the extent practicable. Protection following closure also would be maintained by active institutional and engineering controls (including physical restrictions, groundwater use restrictions, monitoring, and maintenance) and permanent restrictions on land use (e.g., ROD restrictions on land use and deed restrictions in the unlikely event of land transfer).

Monitoring of potential migration pathways would allow evaluation of the effectiveness of waste containment and would provide advance warning of any releases so that appropriate mitigative measures could be taken. If the presence of on-site disposal capacity encouraged removal of waste from individual CERCLA sites, environmental benefits could result at those sites depending on eventual land use. Environmental impacts at the EMDF site would result from clearing, grading, construction, and operations conducted within the area designated as an Oak Ridge Environmental Research Park (ORERP). The ORERP encompasses 20,000 acres, the majority of the ORR (see Section 1.2.1 of Appendix E). Approximately half of the proposed EMDF site is located within the ORERP. Flora and fauna would be impacted by the permanent commitment of land to the disposal facility.

Certain waste streams may not meet the WAC for either the On-site EMDF or existing off-site disposal facilities. This waste, expected to be a relatively small volume, would be stored at compliant facilities with sufficient engineering controls and oversight to minimize the potential for exposure or release.

Human-health and environmental risks from transport of waste, disposal activities, and storage would be maintained as low as reasonably achievable (ALARA) through compliance with ARARs, DOE orders, and health and safety plans. Risk would be minimized through selection of appropriate transport routes, compliance with DOT requirements, and adherence to project-specific transportation safety, spill prevention, and cleanup plans. These activities would minimize the likelihood of an accident as well as the severity of a release should an accident occur, maintaining exposures ALARA. See Section 7.2.2.4 for a discussion of transportation risk for the On-site Disposal Alternative.

### 7.2.2.2 Compliance with ARARs (On-site)

The On-site Disposal Alternative would comply with chemical-, location-, and action-specific ARARs and pertinent TBC guidance, with the exception of one hydrologic condition ARAR for which a waiver would be requested (see Section7.2.2.2.3 below and Chapter 4 in Appendix G). Waste treatment by macroencapsulation is included as part of this alternative, and would require a waiver on the basis of implementing an interim action prior to the final action being completed. In general, waste generators at remediation sites would be responsible for treating wastes, if required, to ensure that wastes meet on-site EMDF WAC. Both waivers are discussed in detail in Appendix G.

#### *7.2.2.2.1 Chemical-specific ARARs*

Chemical-specific ARARs provide health- or risk-based concentration or discharge limitations in various environmental media (i.e., ground water, soil, and air) for specific hazardous substances, pollutants, or contaminants. Because no specific sites or media would be remediated under this action, no chemical-specific ARARs for contaminant cleanup levels would apply. Chemical-specific ARARs that address radiation protection would apply to this alternative. Radiation protection standards that limit exposure of the public and limit the release of radionuclides into the air are presented in Appendix G. Further radiation protection standards are addressed by DOE orders. The EMDF would meet these standards through control measures detailed in Section 6.2.

#### *7.2.2.2.2 Location-specific ARARs*

Location-specific ARARs and TBC guidance establish restrictions on permissible concentrations of hazardous substances or operational requirements to minimize damage to special or sensitive locations (e.g., wetlands, floodplains, critical habitats, historic districts, streams). TDEC substantive requirements for Aquatic Resource Alteration Permits would be triggered by construction of a road crossing a streambed, wetlands or stream alteration, or dredging. Construction of the EMDF would require modification of NT-3 (i.e., construction over a portion of NT-3 using an underdrain system and rerouting a portion of the stream), site improvements, and potential construction of new bridges or culverts that would impact existing wetlands. Actual design considerations would determine the potential impact to the aquatic environment. In addition, 10 CFR 1022 requires that detrimental effects to wetlands or a floodplain be evaluated and avoided wherever possible. If the On-site Disposal Alternative is chosen as the preferred alternative for CERCLA waste disposal, wetlands and stream assessments would be completed as necessary and results would be incorporated into planning and implementation, including mitigation of adverse impacts. There are currently no identified federal- or state-listed threatened and endangered species in the proposed EMDF site area. Should any of these species be identified in the area, consideration of the requirements of endangered, threatened, or rare species ARARs would be triggered before initiation of the action.

#### *7.2.2.2.3 Action-specific ARARs*

Action-specific ARARs for on-site disposal address construction, operation, closure, and post-closure care of the EMDF. The On-site Disposal Alternative, as described in this RI/FS, invokes CERCLA provisions for exemption from permitting requirements, although DOE could choose to permit the

facility. The variety of wastes disposed of on-site under this alternative would trigger requirements for RCRA-hazardous waste, radiological waste, and TSCA waste. No set of regulations is specifically tailored to the combination of waste forms, types, and constituents anticipated in these wastes. Action-specific ARARs include siting criteria and design components for a disposal facility appropriate to the EMDF, are based on the overriding priority to dispose of wastes in a manner protective of human health and the environment over both the long- and short-term. These ARARs include substantive requirements drawn from RCRA, TSCA, and TDEC regulations.

Waters contacting waste and collected during operation of the landfill and during the post-closure dewatering period will be collected and sampled. Alternatives for managing landfill wastewater are considered in the IWM FFS, and on-site treatment was identified as the preferred alternative. The IWM FFS provides details regarding the proposed treatment system and its operation. ARARs associated with leachate treatment are presented in the IWM FFS. It is intended that the conclusions reached in the IWM FFS and this RI/FS will be merged in the Proposed Plan. A single ROD will address the integrated alternative, and include ARARs from both the RI/FS and the IWM FFS. This is done to avoid "double review/double updating" of the water management approach and ARARs. Therefore, necessarily, the coverage of the wastewater management in this RI/FS document is kept to a minimum. Costs for leachate treatment, however, are entirely captured within the On-site Disposal Alternative in this RI/FS to fairly evaluate the full alternative in comparison to the other alternatives.

Facility design would also incorporate TSCA requirements for a chemical landfill to accommodate wastes containing PCBs at concentrations ≥ 50 ppm. Most TSCA requirements parallel those of RCRA. However, TSCA has a hydrogeologic requirement that the bottom of the landfill liner system be located 50 ft above the historical high water table (40 CFR 761.75[B][3]) for which a waiver would be requested. Implementation of more stringent RCRA requirements would meet or exceed the protectiveness of the TSCA requirement.

In-cell macroencapsulation of mercury-contaminated debris is included in the on-site alternative as a process option to enhance the safety and cost efficiency of treating this class of wastes. An interim waiver from the LDR prohibition on placement of untreated wastes would be requested in order to perform the treatment within the landfill. Once macroencapsulated, the waste would meet all applicable ARARs. Appendix C addresses in-cell macroencapsulation in detail.

A waiver from the TSCA 50 ft buffer requirement would be requested on the basis of demonstrated equivalent or superior protectiveness of the design or process. A waiver to the LDR placement prohibition would be requested on the basis that it serves as only an interim remedy prior to implementation of the final action (macroencapsulation) which would then meet all ARARs. The EPA Region IV administrator and other representatives of the FFA parties would be consulted with respect to these requests.

Other action-specific ARARs address management of stormwater runoff, fugitive dust emissions, leachate management, waste management, facility closure, and post-closure maintenance, and monitoring. These requirements would all be met. The IWM FFS contains water treatment ARARs. Appendix G contains a more detailed discussion of ARARs for this alternative.

#### 7.2.2.3 Long-term Effectiveness and Permanence (On-site)

For the On-site Disposal Alternative, the long-term period is considered to begin when all candidate waste has been disposed of or stored and the EMDF has been closed. Final capping and closure activities for this alternative are projected to be complete in FY 2047. Under this alternative, access to the EMDF would continue to be restricted. This evaluation does not address CERCLA remedial activities, waste or residuals that would be left in place at remediation sites, non-candidate waste streams, or any treatment residuals from on-ORR processing of waste to meet WAC.

Under this alternative, most future CERCLA waste, treated as appropriate, would be placed in an on-site engineered waste disposal facility designed to isolate waste from the environment and significantly reduce the possibility of intrusion or the migration of contaminants away from the facility, representing an overall collective decrease in residual risk. By design, meeting the facility WAC would ensure that the total ELCR from the EMDF would be less than $1\times10^{-5}$ and the total non-carcinogenic risk HI value would be less than one to a hypothetical future resident receptor living adjacent to the facility (see Appendix H) for a 1,000 year compliance period. Waste not meeting the EMDF WAC would be either shipped to off-site disposal facilities or stored by the generator pending availability of treatment or disposal options. The On-site Disposal Alternative uses proven technologies to protect human health and the environment and meet risk-based RAOs. Reliance on proven technologies reduces uncertainty associated with this alternative. The on-site disposal facility and support facilities under this alternative incorporate three types of controls to ensure protectiveness: engineered controls, S&M, and institutional controls.

Engineered controls would be built into the EMDF and support facilities to prevent exposure to contaminants and to prevent, detect, and mitigate contaminant releases. Workers and the public will be protected from direct exposure by a landfill final cover system that would prevent airborne releases of, and direct contact with or exposure to, the waste, as well as provide shielding for radiation. The geomembrane liners of the landfill liner system would control releases of leachate to groundwater for their design life, which is at least 200 years. The leachate collection and removal system above the primary liner and the leak detection and removal system below the primary liner would be effective for the period of active institutional controls. The period of active institutional controls is not known, but is assumed for design purposes to extend for at least 100 years. Subsequently, the final cover system, secondary liner, and geologic buffer would provide long-term control of leachate release since these engineered features would last for their design life of 1,000 years and probably for several thousand years. The final cover system would be designed to have a lower long-term vertical percolation rate than the basal liner system and geologic buffer. This would prevent leachate from mounding on top of the basal liner system after the period when the leachate removal system is no longer active and would control the long-term release of leachate by limiting the rate of infiltration into the waste and down through the basal liner system and geologic buffer.

Although it is extremely unlikely that DOE or a successor agency would lose complete control, scenarios in which a temporary loss of control allows some form of uncontrolled access and use of the site have been considered. Inadvertent intrusion occurs when a person without knowledge of the site comes into contact with the waste. One example might be construction of a house with basement on the landfill cap. Deliberate intrusion into the waste, as for example, to recover metals, is intentional intrusion and is not considered.

Inadvertent intrusion will be prevented by the design thickness and multiple layers of the final cover system (approximately 11 ft), including a 2 ft thick biointrusion layer. These structures are expected to warn people of, and discourage them from, inadvertent penetration of the landfill and exposures to waste. Excavation of basements for houses should not fully penetrate the cap, since basements in this area do not typically extend more than 10 ft deep. Excavating through the landfill cap would require heavy equipment or many laborers. Penetration of the cap by other means, such as drilling for a water well, would require heavy equipment and would produce artificial materials in the cuttings, which should signal the driller to stop work. In the event that the well does penetrate the waste, approximately 41 $ft^3$ of cuttings from the EMDF waste body (assumes 75 ft of waste penetrated by a 10 in. diameter borehole) would be brought to the surface. Given the estimated volume of clean soil that would be needed for void fill, only about 46% of the cuttings, or 19 $ft^3$, would be contaminated. This percentage would be further reduced by the amount of clean soils penetrated in the cap and liner and beneath the liner to the completion depth. The small volume of contaminated waste and short time of worker exposure would minimize the acute exposure risk. Risk due to chronic exposure, which would depend on how the cuttings are disposed after well completion, are also expected to be minimal. A more detailed and quantitative assessment of inadvertent

intrusion scenarios and risks will be performed per DOE requirements to be completed prior to landfill construction.

The thick cap and biointrusion layer are also intended to prevent or minimize damage from burrowing animals and tree roots for hundreds of years or longer. The landfill, including the liner system, leachate collection/detection and removal systems, clean-fill dikes, waste, and final cover system would be designed to remain stable under a range of environmental conditions. Design calculations evaluate the potential for erosion, mass wasting, and earthquake accelerations, for the foreseeable future. Survival of an engineered landfill structure for thousands of years is not unreasonable since, for example, many British earthen hill forts more than 2,000 years old are remain essentially intact. Native American mounds in the Ohio and Tennessee River valleys, many of which are more than 1,000 years old, have also survived with little erosion, as have similar structures built by pre-Columbian civilizations in the much wetter climates of Central and South America. Detailed design calculations will be conducted, in part, to assess the capability of the landfill design to protect from long-term geomorphic and seismic stresses. If final design efforts identify areas needing improvement, these would be incorporated into the final design.

Because sinkhole development presents challenges to long-term landfill integrity, site-selection criteria preclude construction of EMDF over a rock unit susceptible to extensive karst development and collapse. The rock units underlying the EMDF footprint are not karstic, and there are no observable karst surface features on the south flank of Pine Ridge, as further discussed in Appendix E of this RI/FS. Aside from intentional human disturbance or major global climate changes, no other credible scenarios for exposing human or ecological receptors to the waste have been identified.

Institutional controls would prevent access to EMDF and use of local ground water. Active institutional controls would continue for an indefinite period and land use restrictions would be made permanent through the property deed or ROD. Further, state and federal regulations (e.g. 40 CFR 264.116 and 40 CFR 62.151) require that local authorities be provided with a survey plat showing the locations and dimensions of the landfill cells. S&M of the facilities and monitoring to determine the effectiveness of the primary controls would continue for the period of active institutional controls.

Long-term environmental effects are those impacts that may occur following closure of EMDF. Cleared land over EMDF would represent a long-term loss of forest habitat. The spoils area would be planted with native vegetation after closure and, if not needed for other purposes, would be allowed to revert to forest. The support facility areas could be re-vegetated or allowed to revert to natural cover. Wildlife species displaced by the construction and operation activities would, to some degree, begin to reoccupy these areas again following closure. The species mix may be different than originally present. Birds and small mammals in the surrounding area may re-colonize and forage in the disturbed area as the vegetative cover develops. Large mammals would continue to be excluded from the area by the access control fence. Because active institutional controls would continue indefinitely, trees would be prevented from growing on the EMDF cap, but would probably be allowed to grow between the fence line and the EMDF, providing a small area of relatively isolated forest habitat. Should institutional controls lapse, the landfill area would eventually progress toward an upland forest and animals would reoccupy this small area. The biointrusion layer would discourage or prevent growth of deep-rooted trees and disturbance by burrowing animals. However, even if the cap is colonized by forest succession, the cap integrity is likely to be preserved, since most eastern upland forest species are relatively shallow-rooted. Wind throw could initiate erosion, though this too is unlikely.

Other long-term environmental effects for the On-site Disposal Alternative are addressed in the paragraphs that follow.

**Transportation Impacts:** The increased traffic from construction, operation, and closure of the EMDF would cease after closure. Long-term environmental effects associated with transportation required to maintain institutional controls and monitoring would be negligible.

**Air Quality Impacts:** Air emissions from construction, operation, and closure of the EMDF would cease upon completion of the final cap. No long-term impacts to air quality would be expected.

**Wetland and Aquatic Resource Impacts:** Impacts to aquatic resources in the vicinity of the disturbed area at the EMDF candidate site, primarily the upper reaches of the central and east branches of NT-3 and at least one draw that connects with NT-2, would be permanent and irreversible because the landfill would be constructed over them. Neither these streams nor the wetlands along them are known to harbor threatened or endangered species. Impacts to the lower reaches of NT-2 and NT-3 and Bear Creek from construction and operation of the landfill would significantly decrease following closure of EMDF, and long-term effects are not expected to be significant. Sediment detention basins would be removed and site restoration could include wetland or aquatic resource mitigation through restoration or replacement. Surface water would be routed around the waste cell and the impervious cap and vegetative cover would be maintained indefinitely, slightly increasing the volume of runoff water from the immediate area but preventing sediment loading of adjacent streams. Should institutional controls lapse, erosion of the landfill would likely be minimal because of the relatively gentle slopes (4:1 side slope and 5% top slope), the riprap erosion protection on the sides, and the vegetative cover on the top. Aquatic resources near the site could be impacted by future contaminant releases from EMDF to surface water, should such releases occur.

**Surface Water Resource Impacts:** The on-site EMDF would be designed, constructed, and maintained to prevent releases that could adversely affect surface water quality. The landfill is designed to resist erosion with minimal maintenance, and only extensive erosion would breach containment. The area is geomorphically stable, and extensive erosion so severe that it would breach the containment systems is unlikely. Contaminant releases to ground water from leachate migrating from the EMDF in the long-term could also eventually impact surface water quality (see Appendix H for modeling results).

**Ground Water Resource Impacts:** Design, construction, and maintenance of the EMDF would prevent or minimize contaminant releases to ground water. These control elements include a multilayer cap to minimize infiltration and biointrusion; a liner that includes synthetic and clay barriers, a geologic buffer; and institutional controls that would include monitoring and groundwater use restrictions. If releases were detected during the period of active institutional controls, mitigative measures would be implemented to protect human health and the environment. Results of modeling long-term impacts to ground water resulting from contaminants migrating from EMDF are provided in Appendix H. PreWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF site (see Appendix H).

#### 7.2.2.4 Short-term Effectiveness (On-site)

For the On-site Disposal Alternative, the short-term period is considered to include pre-construction investigations, construction, operation, and closure of EMDF. Operation of the on-site EMDF is expected to continue approximately 22 years through FY 2043 with closure activities completed in FY 2047 (waste generation and disposal is assumed to occur during those 22 years, beginning in FY 2022 ending in FY 2043). This evaluation does not address CERCLA remedial activities, waste or residuals that would be left in place at remediation sites, unacceptable waste streams, or any treatment residuals from on-ORR processing of waste to meet the EMDF WAC.

Potential risk to the public could result from transportation of hazardous and radioactive waste, operation of the on-site disposal facility, and wind-borne dispersion of contaminants. Risk to the public from waste handling and disposal activities at ORR would be low because of the robust and conservative protective

systems supporting all phases of operation. Public access would be restricted at on- and off-site disposal facilities and at all waste generation, packaging, and handling sites. Selection of appropriate transport routes, compliance with DOT packaging and other requirements, and adherence to project-specific transportation safety and spill prevention, control, and countermeasures (SPCC) plans would minimize the likelihood of an accident and the severity of a release should an accident occur.

All waste handling and packaging activities would occur within controlled areas at remediation sites at Y-12, ORNL, ETTP, or at the on-site EMDF. SPCC plans would be prepared and implemented to address any accidental releases. Higher-hazard wastes would be managed with additional institutional and physical safeguards. All packaging and handling activities would be conducted by trained personnel following approved health and safety plans in accordance with DOE, DOT, state, and Occupational Safety and Health Administration (OSHA) requirements. A dedicated haul road would be used for transport of waste to EMDF. Risks to the public from waste handling and packaging activities would be extremely low.

Transportation risks to individuals and the public in direct or indirect contact with the waste during travel were evaluated based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). Assessment of the risk was completed using the industry-recognized RADTRAN and RISKIND models. Additional risks, due to pre-operation (construction) activities and during operation (a catastrophic event) were analyzed for the On-site Disposal Alternative. A detailed discussion of the calculations and results is provided in Appendix F.

A single route transportation analysis was completed for the On-site Disposal Alternative. Individual receptors, MEIs, and collective populations were considered as receptors. Modeling of radiation exposure during routine and accident scenarios for MEIs resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from $5.31\times10^{-4}$ to $1.15\times10^{-2}$; a collective population risk (analyzed for a driver, off-link [persons along or near the route], and handlers) resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from $2.77\times10^{-8}$ to $1.37\times10^{-1}$. Even though it is assumed that the majority of on-site travel will occur on a dedicated haul road, there would be people working within the zone of consideration for the risk model and thus off-link risk was considered in the on-site analysis. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimated 0.83 total incidents of illness, trauma, or fatality. While these results appear to be high, they account for cumulative risk, for transporting and handling hundreds of thousands of shipments of waste. On a per-shipment basis, cancer risks due to exposure range in order of magnitude from $10^{-13}$ to $10^{-7}$ and vehicular risk from $10^{-9}$ to $10^{-6}$. The exact excess cancer risk value depends on the receptor being evaluated. Appendix F provides detailed analysis.

Pre-operational risks for an on-site facility result from fugitive dust emissions. EPA research has shown that particulate emissions from open sources such as unpaved roads, borrow areas, spoil areas, general grubbing, and landfill construction can contribute significantly to ambient air particulate matter (PM) concentrations and thus pose a risk to the local population. Regarding activities considered in the construction of an on-site disposal facility, the limit of interest is $PM_{10}$ (particles with a mean aerodynamic diameter greater than 2.5 μm and less than or equal to 10 μm). A limit of 150 $\mu g/m^3$ for the 24-hour averaged $PM_{10}$ has been established by EPA. Evaluations using an EPA model and applying control efficiencies to emission rates for some activities resulted in worst case $PM_{10}$ values of between 102 and 144 $\mu g/m^3$ for all activities. See Appendix F for detailed information regarding this evaluation.

The catastrophic event analyzed for on-site operation of a disposal facility was a tornado. In the east Tennessee area, the probability of a tornado strike is estimated at $4.26\times10^{-5}$ per year (FEMA 2009, NOAA 2011). Although a low probability is associated with this natural phenomenon, the consequences of such an event could be high. An estimate of the human health risk posed by a tornado striking the on-site disposal facility and releasing contamination was made using the RESRAD computer code

(ANL 2001). An aggregate risk factor of $3.71 \times 10^{-7}$ was determined, taking into account the facility operational lifecycle and the tornado probability. Appendix F provides detailed information for this assessment.

Risk related to seismic events will be evaluated in detail as part of the landfill design effort. However, the probability of occurrence of a damaging earthquake was qualitatively estimated for this RI/FS in Appendix F. The probabilistic seismic hazards for the Oak Ridge area are approximately Magnitude (M) 4.8 and radius (R) = 14.3 km for short-period spectral accelerations ($S_a$) (Peak Ground Acceleration and $S_a$ at time = 0.2 sec) and M7.7 and R = 448 km for long-period spectral accelerations ($S_a$ at time = 1.0 sec). These sources are consistent with the historical seismicity at ORR described previously.

The primary risks to workers for the On-site Disposal Alternative would result from construction and waste handling, transportation, and disposal activities. These activities would be conducted by trained personnel in accordance with ARARs, OSHA and DOT regulations, DOE requirements, approved health and safety plans, and ALARA principles. Risk from exposure during disposal activities would be generally limited because the waste would meet the EMDF WAC. Worker exposure would be further minimized by compliance with DOE waste packaging, transport, and handling requirements; the use of shielding and personal protective equipment; limits on driver work schedules; and other operational restrictions, such as spacing and distancing, to ensure that radiation doses to workers are kept ALARA. The overall risk to workers for this alternative is low.

It is assumed that waste would be disposed of in the same year it is generated. The potential for short-term environmental effects would be posed primarily by construction activities, spills during transportation and handling of wastes, operational releases, and closure activities. Short-term environmental impacts would be minimized by use of BMPs including engineered and administrative controls.

Land clearing, construction, and operations would cause the direct loss of small animals, and reduce the local habitat for larger mammals. Noise, fugitive dust, and forest clearing on and adjacent to the proposed EMDF would impact nearby habitats. Large mammals would be excluded from construction areas by access control fences. Small animals and birds feeding or living in the construction area would be driven out by construction activities. Other short-term environmental effects for the On-site Disposal Alternative are addressed in the following subsections.

**Transportation Impacts:** The short-term environmental risk from transportation would arise primarily from the potential for spills during waste shipment and impacts to air quality resulting from commuter, construction, and operations traffic. Adverse environmental effects in the event of a spill during waste transport would be minimal because:

- Wastes would not be in liquid form.
- Waste volumes per shipment would be small.
- Contaminant concentrations would be low for most waste streams.
- Waste would be properly packaged.
- The waste shipments would occur solely on non-public roads.
- SPCC plans would be quickly implemented if a spill occurred.

**Air Quality Impacts:** Potential short-term impacts to air quality would result from exhaust emissions and the generation of particulate matter during pre-construction investigations, construction, operation, and closure of the on-site disposal facility. Vehicular exhaust emissions would include volatile organic compounds from unburned hydrocarbons, carbon monoxide, sulfur dioxide, and nitrogen dioxide. A greater potential for short-term impacts to air quality would result from the increase in generation of fugitive dust by earth-moving activities and traffic on unpaved surfaces (see Appendix F).

**Wetland and Aquatic Resource Impacts**: A number of areas on the ORR have been identified as natural areas (NAs), aquatic natural areas (ANAs), RAs, aquatic RAs, special management zones, conservation easement areas, cooperative management areas, habitat areas (HAs), and potential HAs. As shown in Figure E-17 in Appendix E, the largest wetlands in or near the candidate site are on NT-3 and are included in RA-5 (Baranski 2009). RAs are defined as primarily terrestrial areas that contain special habitats or features and that also may serve as reference or control areas for research, monitoring, remediation, or characterization activities. RA-5, the Quillwort Temporary Pond, encompasses the largest wetlands on NT-3 and two of its draws/ravines north of the Haul Road (Baranski 2009). The Quillwort Temporary Pond is so named for the occurrence of a species of quillwort (*Isoetes caroliniana*). This species is not currently a federal- or state-listed sensitive species. Wetlands along draws/ravines that feed into NT-3, including much of RA-5, and a short draw/ravine west of NT-2 would be impacted by construction. A small emergent wetland occurs farther upstream on NT-3 from RA-5. Rosensteel and Trettin (1993) classified this wetland, but did not document the presence of any sensitive species.

Bear Creek is designated as ANA-2. The ANA designation is given to aquatic areas that contain listed species, in this case the Tennessee dace (*Phoxinus tennessensis)*, listed by the state as being in need of management. The eastern reaches of Bear Creek (ANA-2) were found by Southworth, et al. (1992) to be highly impacted by contaminants from the various waste management facilities in the area, and that aquatic species diversity and populations in the area were considerably reduced as compared to the lower reaches of Bear Creek.

Appropriate runoff and siltation controls would be implemented at the EMDF site to minimize impacts to wetlands or streams outside the construction area during construction and operation. A field wetlands delineation survey has been conducted along streams and other low-lying portions of the landfill site and adjacent areas, to determine the areal extent of wetlands. Wetland boundaries were mapped using civil land surveying techniques, the results of which are given in Appendix E.

Construction, operation, and closure of the on-site EMDF would be expected to have some short-term impacts on aquatic flora and fauna, potentially including the Tennessee dace, a Tennessee-listed in need of management species. Erosion and runoff controls included in the EMDF design would largely protect aquatic resources from increased turbidity and siltation. Sediment, dust, oil, diesel fuel, gasoline, antifreeze, and other chemicals from construction activities and equipment could potentially be released to the aquatic environment but would be minimized by mitigative controls such as spill controls and clean-up. Construction or expansion of bridges or culverts across tributaries would also disturb the aquatic environment. While fish, including Tennessee dace, would tend to avoid disturbed areas, disruption and reduction of the aquatic environment may stress or possibly temporarily reduce fish populations in nearby segments of Bear Creek and its affected tributaries.

**Surface Water Resource Impacts:** Potential short-term impacts to NT-3 and, to a lesser extent, NT-2 would be substantial, and would include channel modifications, re-direction of flows, increased scour, possible increases in storm flow, and increases in sediment load downstream from the construction area, as well as potential for spills to release contaminants (e.g., fuel spills). Impacts to Bear Creek would be confined to increased sedimentation because no construction is expected to be required on the stream. EMDF would be designed, constructed, and maintained to prevent releases that could adversely affect surface water quality. Land clearing and construction activities would expose varying areas depending on the site selected, the ultimate size of EMDF, phased construction implementation, and other detailed design considerations.

Surface water runoff from uncontaminated areas of the waste cell would be controlled by a run-on/run-off diversion and collection system that includes stormwater/sediment detention basins. These basins would prevent increased sediment discharge to the streams and control discharge during storms. A perimeter ditch and French drain system would be constructed around the landfill to prevent surface run-on and re-

direct water to the sediment basins before release to local streams. These basins would provide secondary containment for any fuel or oil spills that are not adequately contained at the spill site.

Potentially contaminated runoff from EMDF, water used for decontamination, water from the leachate detection/collection system, and other wastewater generated during the operational period would be collected, characterized, and either discharged directly or transported to the appropriate treatment facility, as required. All releases would meet ARARs that are currently summarized in the IWM FFS. The potential for impact to surface water resources from the migration of contaminants from EMDF in ground water would be exceedingly low because of engineered and active controls, as discussed previously in Section 7.2.2.3. Little or no overall short-term impacts to surface water resources would be expected from implementation of this alternative, with the exception of direct impacts to any water courses or wetlands displaced or eliminated by construction.

**Ground Water Resource Impacts:** Ground water resources could potentially be degraded in the short-term by contaminant releases from the surface or EMDF. Potential contaminant sources include construction materials (e.g., concrete and asphalt), spills of oil and diesel fuel, releases from transportation or waste handling accidents, and accidental releases of leachate from EMDF. Compliance with an approved erosion and sedimentation control plan and an SPCC plan would mitigate potential impacts from surface spills. Clean-up actions taken to mitigate spills or remove contaminated soils would reduce the source of contamination during the construction phase. Engineered controls and active controls, including the leachate collection system, would drastically reduce the potential for impact to groundwater resources that could result from contaminant migration from EMDF.

Localized, small-scale reduction in average water table elevation may occur as a result of decreased infiltration caused by more rapid run-off, which could in turn lead to an increase in the number and duration of zero-flow periods in nearby streams. This impact may be mitigated by groundwater inflow from surrounding areas, as well as the release of waters collected in retention basins. Implementation of this alternative would result in few or no overall short-term impacts to groundwater resources.

**Threatened and Endangered Species Impacts:** Tennessee Wildlife Resources Commission Proclamation 94-16 prohibits destruction of the habitat of a state-listed species. There are currently no identified federal- or state-listed species in the proposed EMDF construction area. A field survey of the EMDF construction site was performed prior the destructive wind storm to identify threatened and endangered species within areas of potential site disturbance before construction begins, and none were identified. Existing habitats in the area were found to be either not suitable or marginally suitable for status species. The wind damage further reduced habitat suitability. If status species are found at a later date, plans to mitigate adverse impacts would be developed and implemented in compliance with endangered, threatened, or rare species ARARs listed in Table G-2 of Appendix G.

Construction of EMDF would impact wetlands on a draw/ravine to the west of NT-2 and along the main channel and a western draw/ravine of NT-3. These wetlands are not currently known to harbor any federal- or state-listed threatened and endangered species, or sensitive species listed as in need of management by the state. The Tennessee dace is a species of fish that has been listed as in need of management by the state that may be found in the lower reaches of NT-2 and NT-3 during the wet season. Impacts to the Tennessee dace from stream alterations would likely be small because the fish could migrate to unaffected areas in Bear Creek.

**Historical and Cultural Resource Impacts:** There are no known significant historical or archaeological resources within, or in the vicinity of, the conceptual design footprint of EMDF or its support facilities. Two home sites once occupied areas adjacent to the junction of NT-3 with Bear Creek, well away from the proposed EMDF site. Little or nothing remains of these home sites except for scattered bricks and dimension stone and no relocation or salvage is anticipated to be needed. Surveys conducted in the EMDF

impact area did not find anything of archaeological or historical significance. No impacts to cultural resources would be expected from construction and operation of the proposed EMDF, and additional surveys or mitigative actions are not expected to be necessary.

**Noise Impacts:** There would be a short-term increase in noise levels during construction from sources such as earth-moving equipment, material handling equipment, waste transport vehicles, commuter traffic, and general human activity. However, noise levels during operation and closure of EMDF would not differ from those currently existing due to the operations of EMWMF. Trucks used to transport wastes to EMDF from ORR would use a dedicated haul road and avoid publicly accessible routes. The increase in noise at EMDF may disturb wildlife in the immediate area and cause animals to avoid the area, especially during periods of high noise levels. While it is assumed for purposes of this RI/FS that construction and operation activities would be conducted only eight hours per day during the daytime, actual construction activities could follow a different pattern. The impact of increased noise levels from facility construction and operation would be local, with little or no impact expected at the ORR boundary.

**Visual Impacts:** Construction and operation activities at the proposed EMDF would be visible from Bear Creek Road, western parts of the Y-12 Plant, Chestnut Ridge, and Pine Ridge. Because Bear Creek Road is not a public thoroughfare and Chestnut Ridge and Pine Ridge are restricted within the ORR boundary and accessible only by dirt road or by foot, there should be no short-term visual impacts to the public.

**Duration of the On-site Disposal Alternative:** As shown in Figure 6-14 in Chapter 6, the total duration of the alternative (over which short-term effectiveness is evaluated) is approximately 30 years, consisting of early actions and design beginning in FY 2014 and FY 2017, respectively, followed by facility construction. Waste disposal operations are estimated to begin in FY 2022 for approximately 22 years until FY 2043 when facility closure activities would begin. Waste generation is assumed to occur during the 22 years of operation. Facility closure activities would end in FY 2047. The post-closure period after FY 2047 is addressed in the long-term effectiveness evaluation in Section 7.2.2.3.

#### 7.2.2.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (On-site)

Except for treatment as necessary to meet the EMDF WAC, the On-site Disposal Alternative does not establish waste treatment requirements with the exception of mercury debris treatment by macroencapsulation. No reduction in toxicity or volume would be realized; however, mobility would be decreased. Waste generators would be required to treat wastes as needed to meet the EMDF WAC before on-site disposal which could reduce the toxicity, mobility, or volume of waste depending on the waste characteristics and treatment applied; however, these waste generator actions are excluded from the scope of the On-site Disposal Alternative. For portions of waste disposed of off-site, treatment would similarly be applied as needed before shipment or at the receiving facilities. The On-site Disposal Alternative would reduce the mobility of contaminants through isolation of waste in the EMDF.

#### 7.2.2.6 Implementability (On-site)

Implementation of the On-site Disposal Alternative would involve meeting administrative and technical requirements for waste handling, packaging, and transport and construction, operation, closure, and post-closure monitoring of an on-site EMDF. For the volume of waste not meeting the EMDF WAC, handling, transport; and off-site transportation and disposal or interim storage would be required. All of the proposed actions would be performed using standard construction equipment and techniques. Similar construction and operation has been successful at the EMWMF. Construction and operation of the on-site EMDF, including other support facilities, would involve no unusual or unprecedented conditions or technologies.

DOE O 435.1 (formerly DOE O 5820.2A) places requirements on DOE facilities concerning disposal of LLW. For CERCLA sites, it is DOE policy to use the CERCLA process to demonstrate attainment of the

human health and environmental protection performance objectives. DOE's Low-Level Waste Disposal Facility Federal Review Group (LFRG) is an independent group chartered (DOE 2011e) to ensure that DOE radioactive waste disposal facilities are protective of the public and environment. The LFRG assists EM senior managers in the review of operational envelope documentation that supports the approval of DOE O 435.1 requirements or appropriate CERCLA documents as described in Section II of the LFRG Charter. These LFRG reviews support the issuance of Disposal Authorization Statements for LLW disposal facilities and activities. The LFRG's review process supports DOE implementation of its regulatory responsibility under the Atomic Energy Act of 1954 as amended and DOE O 435.1, *Radioactive Waste Management*, and to maintain DOE's commitment to the Integrated Safety Management System process.

Construction of a disposal facility at the EMDF site may require moving the 229 Security Boundary for Y-12. The proposed location of EMDF is just inside the 229 Security Boundary at the west end of the plant. In order to revise this boundary, DOE would publish a notice of revision in the Federal Register. The required steps to move the security boundary have been accomplished in the past and are implementable for the new disposal facility.

The southern part of the proposed EMDF footprint would potentially impact three planned wetland expansion areas identified in the ARAP issued in support of the UPF construction project. If the On-site Disposal Alternative is selected, coordination of EMDF activities with planned UPF project activities, including a modification to the ARAP, would be required and are implementable.

All construction related activities would be conducted on-site and would not require permits to be issued by state or local governments; however, any substantive provisions of any permits (e.g., ARAP) that would otherwise be required would be considered ARARs. EMDF would be designed to meet all substantive requirements for a RCRA hazardous waste landfill and a TSCA chemical waste landfill (except for the 50 ft buffer requirement for which a waiver would be requested as described in Appendix G). NRC licensing would not be required because DOE is exempt from NRC requirements. The small volume of waste not meeting the on-site disposal facility WAC would be shipped off-site to approved facilities or stored on-site at compliant facilities pending identification of treatment and disposal options. The administrative feasibility of off-site disposal, including the issue of state equity, is discussed in greater detail in Section 7.2.3.6.

The technology currently available for disposal, treatment, transportation, storage, and supporting activities is proven and reliable for most waste projected to be generated at ORR and associated CERCLA sites, resulting in a low degree of uncertainty for the implementation of this alternative. This alternative could reasonably be implemented without schedule delays resulting from technical complications.

Hazardous waste landfill technology is the key component of the On-site Disposal Alternative. Many similar landfills, including EMWMF, have been constructed and are operating today, demonstrating their viability. Construction and operation of EMDF would involve no unusual or unprecedented conditions or technologies.

Future remedial actions at EMDF should not be required because of waste treatment by generators necessary to meet the disposal facility WAC, the protectiveness provided by implementation of the disposal facility WAC (see Appendix H), and the high level of isolation provided by the engineered landfill. Only limited additional actions would be possible once the landfill is capped because of the relative permanence and massive nature of the disposal facility. Additional actions would be warranted only if major deviations from the expected performance of the landfill features occurred. For example, remedial actions would be triggered by releases of contaminants to ground water or erosion of the cap and exposure of the waste to the environment.

All release pathways at EMDF would be monitored through leachate collection, leachate detection monitoring, surface water and ground water monitoring, air monitoring, and physical inspection of external EMDF conditions. The conceptual site model (Appendix E) and ground water modeling results (Appendix H) indicate that ground water and surface water under and near the site can be adequately characterized, modeled, analyzed, and monitored. Should releases to groundwater go undetected, ground water in the immediate vicinity of EMDF could be contaminated and minor releases to Bear Creek could occur. The actual risk of exposure from such a release would be low.

Services and materials required for EMDF construction, off-site disposal, treatment, storage, and supporting operations would be available for implementation of this alternative. EMDF would be designed and constructed to accommodate the projected waste volume. Construction would involve the use of standard equipment, trades, and materials. Many companies have successfully constructed disposal facilities and multiple bidders could be expected for procurements necessary to develop EMDF. Treatment services such as solidification and stabilization are available at both ORR and off-site disposal facilities. Permitted off-site disposal facilities are available with sufficient capacity to treat and dispose of the waste volume that exceeds on-site disposal facility WAC. Implementability of off-site disposal is further addressed in Section 7.2.3.6. Interim compliant storage for waste not meeting the WAC for the EMDF or off-site facilities can be reliably achieved.

This alternative is implementable. The administrative structures required for implementation are largely in place; the required technology is proven, and services and materials required to implement the action, including an adequate body of vendors, are available.

#### 7.2.2.7 Cost (On-site)

Estimated total project cost for the On-site Disposal Alternative at the proposed EMDF site in EBCV is given in Table 7-1.[15] The cost estimate is based on a conceptual design that yields an approximate landfill waste disposal capacity (i.e., air space volume) of 2.5 M $yd^3$, but does not include the cost for construction of the sixth cell as the current waste generation forecast (with a 25% volume contingency) would only fill five cells. Cost contingency (22% for construction, 5% for operations) has been assumed, and is included in this estimate in Table 7-1.

In terms of Present Worth, the estimated total project cost of the On-site Disposal Alternative correlates to:

- An estimated cost of $396 per unit volume of waste disposal capacity for the EMDF in Present Worth 2015 dollars.
- An estimated cost of $447 per unit volume of as-generated waste for the EMDF in 2015 dollars. This on-site cost may be directly compared to the cost per unit volume for off-site disposal (see Section 7.2.3.7).

These costs include a "Perpetual Care Trust Fund" intended to cover S&M and ground water monitoring needs for the 100-year period of active controls after closure of the landfill. It assumed that these post-closure activities will be funded in a similar fashion as was implemented for EMWMF, through a perpetual care fee. The cost was derived by estimating the needed annual S&M budget after closure of the landfill, assuming an annual compound interest rate, and using the operational life of the landfill to back calculate the needed annual deposit (Perpetual Care Fee) that would be required to meet the annual S&M budget. There are no assumptions regarding which entity will actually perform the post-closure care; the

[15] This cost is based on the construction of five cells, which is the capacity (2.2 M $yd^3$) currently forecasted to be required for the volume of waste projected to be generated in this RI/FS. The conceptual design provides for six cells (2.5 M $yd^3$) to be constructed. Cost details are provided in Appendix I.

purpose of this Perpetual Care Fee in this document is to incorporate the expected cost in the estimate. The cost estimates were prepared using the methodology described in Section 7.1.7 and the technical scope and assumptions for the proposed EMDF site are described in Chapter 6. Appendix I provides further description of the project costs and assumptions for the candidate site, including those for long-term S&M.

**Table 7-1. Summary of the On-site Disposal Alternative Costs**

| Cost Element | Year(s) Implemented | Cost (FY 2012 Dollars) | Total Cost (FY 2012 Dollars) |
|---|---|---|---|
| **CAPITAL COSTS** | | | |
| **Phase I Cells 1 and 2:** | | | |
| Engineering | FY 2019 - 2022 | $22,598,979 | $125.2M |
| Site Development | | $11,495,076 | |
| Support Facilities | | $9,553,055 | |
| Construction of Cells 1 and 2 | | $81,578,821 | |
| **Phase II Cells 3 and 4:** | | | |
| Engineering | FY 2027 - 2029 | $2,102,443 | $44.3M |
| Construction of Cells 3 and 4 | | $42,225,701 | |
| **Phase III Cells 5 and 6:** | | | |
| Engineering | FY 2034 - 2036 | $2,102,443 | $31.0M |
| Construction of Cell 5 | | $28,848,064 | |
| **Final cap:** | | | |
| Engineering | FY 2044 - 2047 | $2,046,565 | $65.4M |
| Quality Assurance | | $6,173,495 | |
| Construction of Final Cap | | $57,178,863 | |
| **Total Capital Cost (FY 2012 dollars)** | | | **$265.9M** |
| **OPERATIONS COSTS** | | | |
| Base Operations | FY 2022 - 2043 | $266,399,602 | $365.5M |
| In-cell Macroencapsulation Operations | | $77,613,391 | |
| Leachate System Operations | | $17,825,000 | |
| Security Operations | | $3,657,045 | |
| **OTHER COSTS** | | | |
| Pre-Construction Costs (e.g., Characterization) | FY 2012 - 2017 | $11,294,257 | $48.0M |
| Perpetual Care Fee & Post-closure Care [a] | FY 2022 - 2054 | $28,999,475 | |
| Support Structure Demolition/Removal | FY 2054 | $7,718,800 | |
| **Subtotal (Capital, Operations, Other)** | **FY 2012- 2054**<br>**43 Years Total** | **$ 679.4M** | |
| **Contingency (22% Capital, 5% Operations)** | | **$ 97.7M** | |
| **Total (FY 2012 dollars) Life Cycle Cost** | | **$ 777.1M** | |
| **Average Annual Cost (FY 2012 dollars)** | | **$18.1M** | |
| **Average Annual Present Worth Cost (FY 2015 dollars)** | | **$20.3M** | |

[a] The Perpetual Care Fee funds the 100 year post-closure care of the facility. It is paid out during the operating life of the facility, invested, and provides enough income to fund the S&M of the facility for the 100-year period assuming a 3% return.

#### 7.2.2.8 NEPA Considerations (On-site)

**Socioeconomic Impacts:** The short-term socioeconomic impact associated with the workforce required for construction, operation, and closure of EMDF would be small. The workforce would vary with project phases and would likely be drawn from the local labor market, resulting in minimal influx of workers to the area. If local waste disposal capacity provided by EMDF encourages more cleanup of individual sites, additional workers could be needed to support implementation of remedial actions at individual sites. The numbers of additional workers needed for remediation would be variable and most likely drawn from the local labor force.

There would be no long-term socioeconomic impacts associated with the On-site Disposal Alternative since the small workforce required to construct, operate, and close EMDF would no longer be required after closure activities cease. The post-closure care activities to be implemented would require a minimal workforce.

**Land Use Impacts:** The candidate site lies partially within the ORERP, which includes industrial areas, NAs, ANAs, RAs, field research areas, and other areas designated for their unique natural attributes. Construction and operation of the EMDF would require clearing land within the ORERP that could result in short-term effects on ANA-2 and adjacent activities such as research, and would impact most of RA-5 which is situated on NT-3. Use of ORERP land for a disposal facility would represent a trade-off between the current use of the land for forest and use of the land for waste disposal. To minimize impacts during construction, roads and utility corridors would be located in existing rights-of-way wherever possible. Areas not immediately required for construction of EMDF would be seeded to minimize erosion. Potential impacts to ORERP environmental resources would be minimized by the buffer provided by the restricted area around the facility and by use of BMPs, including sediment and storm water controls during landfill operation.

The proposed EMDF site is adjacent to a brownfield area where the existing EMWMF and former waste disposal sites are located. Any future development in that area would be influenced by the presence of EMDF and other disposal facilities. In addition to its co-location with a brownfield area, other advantages for the proposed EMDF site include the lack of public access and visibility and the presence of existing infrastructure. The proposed EMDF site is co-located with other pre-existing waste disposal facilities in an area that is already subject to monitoring and oversight.

BCV was divided into three zones in the BCV Phase I ROD (DOE 2000) for the purposes of establishing and evaluating performance standards in terms of resulting land and resource uses and residential risks following remediation (see Figure E-1 in Appendix E). The EBCV site is located in Zone 3, with an agreed upon future land use goal of "DOE-controlled industrial use" stated in the BCV Phase I ROD. Construction of a disposal facility at the EBCV site should not require a change to the BCV Phase I ROD to revise designated future land use for areas impacted by EMDF construction. The proposed EMDF site would remain under DOE control within DOE ORR boundaries for the foreseeable future.

The approximate areas impacted by EMDF at the proposed site and corresponding conceptual design capacity are summarized in Table 7-2. The area impacted during construction, operations, and final closure is the approximate area which may be cleared or otherwise impacted by construction and operations (e.g., landfill, perimeter roads, parking areas, temporary construction staging areas, sediment detention basins, spoils areas, etc.). Institutional controls would restrict access to impacted areas during construction, operations, and closure. Phased construction, reuse of construction spoil, implementation of BMPs, and other detailed design considerations would likely reduce the total area impacted.

**Table 7-2. EMDF Impacted Areas and Disposal Capacity at the EBCV Site**

| Description | EBCV |
|---|---|
| Approximate total area impacted during construction, operations, and final closure | 92 acres |
| Approximate area permanently committed after closure | 60 to 70 acres |
| Approximate landfill disposal capacity | 2.5 M $yd^3$ |

After the landfill is closed, the area requiring permanent commitment would be reduced to an area slightly greater than that of the landfill footprint with allowance for monitoring and maintenance and security. The landfill footprint corresponds to the area of the landfill, including perimeter ditches and clean-fill dikes. The landfill footprint would be permanently maintained, representing long-term impact on the direct use of that land.

**Environmental Justice Impacts:** No environmental justice impacts have been identified for this alternative. The Scarboro community is the only formally identified environmental justice community near the ORR, and is not anticipated to be impacted by construction, operation, or closure of the On-site Disposal Alternative. Details are given in Appendix E, Section 1.2.2.

**Irreversible/Irretrievable Commitment of Resources Impacts:** Flora and fauna requiring forest habitat would be impacted by the permanent commitment of land to the EMDF (see Table 7-2). Additionally, one draw/ravine of NT-2 and the upper reaches of NT-3, including springs, seeps, and wetlands associated with each, would be permanently impacted. Transportation, construction, operation, closure, and long-term institutional controls for EMDF would require an irreversible and irretrievable commitment of fuel and other nonrenewable energy resources; geologic resources such as gravel, rock, and borrow soil; and manufactured landfill components (e. g., synthetic liner material). There are no known economic geologic materials in or near the candidate site that would be irreversibly affected.

**Cumulative Impacts:** Construction of EMDF would not result in any significant cumulative impacts to the surrounding environment if BMPs, including engineering and administrative controls, are used. Incremental impacts to air quality, traffic, and noise levels from construction and operation of the on-site disposal facility and from transportation of waste would not significantly alter existing or future conditions, although impacts would be noticeable to site workers. Ground water would not be used for construction or operation of EMDF. Only minor quantities of potable water would be used for dust control and other purposes and would not impact on- or off-site users.

Cumulative effects on ecological resources in the short-term depend largely on actual impacts to the area associated with the site. Construction of the EMDF would disturb forested areas in EBCV and result in a net loss of forested area. The EMWMF as well as old waste disposal facilities are located in EBCV, adjacent to the proposed EMDF site. Environmental impacts from the old waste disposal areas that were not constructed and operated by today's environmental standards are already present, as shown by the decreased health of the upper portions of Bear Creek. Construction of the EMDF in EBCV could contribute to the cumulative degradation of Bear Creek.

The evaluation of cumulative impacts for the On-site Disposal Alternative assumes that future activities at ORNL and Y-12 facilities continue at current levels throughout the construction, operation, and closure period of the EMDF. Existing non-DOE industrial facilities located adjacent to ORR are assumed to continue operations at their current levels.

The primary long-term cumulative impacts on ORR for this alternative would result from the commitment of land within the permanent institutional control boundary, and the potential benefit that local waste disposal capacity may impart to the overall cleanup of ORR and resulting land use. The loss of potential wildlife habitat or future land use at the EMDF may be at least partially offset by the cleanup and release of individual CERCLA sites elsewhere on the ORR. Removal of contamination and waste from these sites should result in positive long-term environmental effects by reducing the potential for exposure to and migration of contaminants, although some short-term impacts would be expected. The potential for contaminant releases from waste isolated in the EMDF would be less than the cumulative potential for releases from uncontained waste sources at multiple CERCLA sites. As a result of cleanup, habitat quality and biodiversity are expected to improve over time at these sites.

While cost, risk, and impacts are estimated in this RI/FS, the perpetual controls required for hosting an additional LLW-mixed waste disposal facility on the ORR must be considered in the evaluation of cumulative impacts. The presence of a new disposal facility requires resources for monitoring and maintenance over the long-term. However, the co-location of the EMDF with the EMWMF and former waste management sites (i.e., Bear Creek Burial Grounds, BY/BY, Oil Landfarm, etc.) in one area aggregates the post-closure care and monitoring efforts.

### 7.2.3 Off-site Disposal Alternative Analysis

The Off-site Disposal Alternative involves transporting wastes generated at ORR to licensed or permitted off-site disposal facilities, and disposal of the waste in those facilities. Waste that does not meet the off-site disposal facility WAC would be placed in compliant storage pending the availability of treatment or disposal options. A detailed description of the Off-site Disposal Alternative is provided in Section 6.3.

#### 7.2.3.1 Overall Protection of Human Health and the Environment (Off-site)

The Off-site Disposal Alternative would protect human health and the environment by removing wastes generated at ORR CERCLA sites, transporting them off-site, and isolating them from the environment by disposal in engineered facilities. Implementation of this alternative would prevent access to contaminated media and reduce the overall potential for releases from multiple sites on the ORR. Remediation of ORR and associated sites could result in human health or environmental benefits, depending on the eventual land use of these sites.

Human health and the environment would be protected in the vicinity of the receiving facilities by disposing of contaminated material appropriately. Operation of these facilities is not likely to result in exposure to waste or releases to the environment because the facilities are designed, licensed, monitored, and maintained to ensure reliable waste containment. The addition of CERCLA waste from ORR to these facilities would result in a negligible increase in risk above that resulting from disposal of other wastes at the facilities. The Energy*Solutions,* WCS*,* and NNSS facilities are located in isolated arid environments with few nearby human receptors.

Certain waste streams may not meet the WAC for existing off-site disposal facilities. This waste, projected to be a small volume, would be stored at ORR facilities with sufficient engineering controls and oversight to minimize the potential for exposure or release.

Worker risks from exposure during handling and preparation for transportation would be maintained to ALARA levels and comply with DOE orders through implementation of engineering controls and health and safety plans. The increased risk to transportation workers and the community from moving the waste within ORR and off-site would be minimized by compliance with DOT requirements; however, those risks in transporting the waste over thousands of miles, multiplied by thousands of shipments, become measurable. The considerable transportation distances required for off-site disposal result in an increased potential for accidents that result in higher risk of injuries, fatalities, or contaminant releases.

Transportation risks from both vehicular accidents and exposure to contaminants are detailed in Section 7.2.3.4.

### 7.2.3.2 Compliance with ARARs (Off-site)

The actions included in the scope of the Off-site Disposal Alternative would comply with all ARARs and TBC guidance (identified in Appendix G). There are relatively few ARARs for this alternative because there are no chemical- or location-specific ARARs after waste is removed from the ORR and associated sites. Chemical- and location-specific ARARs, as well as action-specific ARARs associated with removal and treatment of wastes would be developed as part of individual site-specific remedial evaluations.

ARARs for this alternative are limited to requirements associated with transportation of waste. These requirements include shipping, packaging, labeling, record keeping, manifesting, and reporting requirements under DOT and RCRA regulations (49 CFR 171-174 and 177, 40 CFR 262 and 263) and Rules of the TDEC 0400-12-01-.03 and -.04. Because DOE O 435.1 specifies a preference for on-site disposal of LLW, shipment to a commercial disposal facility would require an exemption on a per project basis. Similar exemptions have been routinely approved since DOE began using commercial disposal capacity in 1992.

The off-site facilities considered for this alternative are appropriately licensed and qualified in accordance with 40 CFR 300.440; the waste would be required to meet the receiving facilities' WAC. Once wastes were transferred from ORR, both administrative and substantive regulatory provisions would need to be met. Accordingly, requirements for permitting, recordkeeping, assessments, and/or other non-substantive elements would be triggered. Administrative and substantive regulatory requirements would be met through the facility's license or permit requirements and not as ARARs for this alternative after the waste is accepted by the facility. The owner/operator of the receiving facility would be responsible for all of its financial, operating, and closure requirements, including long-term S&M.

### 7.2.3.3 Long-term Effectiveness and Permanence (Off-site)

For the Off-site Disposal Alternative, the long-term period is considered to begin when all candidate waste has been disposed of off-site or placed in appropriate storage facilities. This evaluation does not address remedial activities, CERCLA waste or residuals that would be left in place at CERCLA remediation sites, non-candidate waste streams, or any treatment residuals from waste processing required to meet the WAC.

No residual risk would remain at ORR from candidate waste streams after the waste has been disposed off-site. The waste would be placed in off-site engineered disposal facilities designed to isolate waste from the environment, significantly reducing the possibility of intrusion or the migration of contaminants away from the facility. For the portion of waste requiring treatment to meet facility WAC prior to disposal, the potential for contaminant mobility would be further reduced. The receiving facilities would be responsible for monitoring and maintenance to ensure the effectiveness of waste isolation. In the case of LLW/RCRA waste shipped to Energy*Solutions,* the facility has waste treatment capabilities and the WAC allows for receipt of untreated waste. It is assumed for the Off-site Disposal Alternative that the Energy*Solutions* facility would provide treatment of the waste prior to disposal to reduce the potential for contaminant mobility. Acceptable risk levels would be achieved by compliance with existing licenses or permits and regulatory requirements.

The Energy*Solutions* facility, WCS, and NNSS are located in arid environments with deep and/or saline ground water, and both are distant from population centers, fctors that minimize long-term risk to human health. The off-site facilities use conventional, durable designs and materials to effectively isolate the waste. The arid climate at the facilities contributes to the long-term reliability of engineered features by

minimizing infiltration. The engineered and natural features at these facilities are expected to provide adequate and reliable safeguards over the long term.

Under the Off-site Disposal Alternative, waste would be placed in licensed or permitted engineered disposal facilities that have been receiving wastes for a number of years and have operated in compliance with their permits and federal, state, and local regulations. Reliance on proven technologies minimizes uncertainty associated with this alternative.

For purposes of this evaluation, long-term environmental effects are those impacts that may be evident following receipt of the last shipment of waste off-site. Any potential environmental effects associated with transportation, including air emissions and accidental releases, would cease after this period. No long-term impacts to air quality, surface water, biota, wetlands, and aquatic or visual resources are anticipated at ORR or the vicinity from implementation of this alternative.

Potential long-term environmental effects at the off-site disposal facilities from the presence of ORR wastes are expected to be minimal; these wastes would represent a relatively small portion of the total waste inventory, and the receiving facilities are designed to minimize long-term environmental effects. No long-term impacts to air quality are expected at the receiving facilities from the inclusion of ORR waste because air emissions from vehicular use and construction activities for long-term monitoring and maintenance of the off-site facilities would not be increased.

#### 7.2.3.4 Short-term Effectiveness (Off-site)

Short-term effectiveness for the Off-site Disposal Alternative is evaluated for the period beginning with the generation of CERCLA waste at ORR remedial sites and ending with disposal of all candidate waste streams at the receiving facilities. This evaluation does not address removal activities, CERCLA waste or residuals that would be left in place at individual units being remediated, or the risk associated with these elements.

As discussed in Section 7.2.2.4, risk to the public from waste handling activities at ORR would be extremely low. Public access would be restricted at waste generation, packaging, and handling sites, and activities would be governed by appropriate regulations and conducted by trained personnel. Risks at the receiving facilities would be controlled by compliance with permit requirements; access restrictions during disposal operations would minimize any impact to the community. For the Off-site Disposal Alternative, potential risk to the public would result from shipment of hazardous and radioactive waste.

The primary risks to workers for the Off-site Disposal Alternative would result from waste handling, waste transportation, and disposal activities. These activities would be conducted by trained personnel in accordance with ARARs, OSHA, and DOT regulations, DOE requirements, approved health and safety plans, and ALARA principles. Radiation exposure would be minimized by compliance with DOT regulations and DOE requirements for waste packaging, as well as the use of shielding and limits on driver work schedules. Risk from disposal activities at the receiving facilities would be minimized by compliance with their permit requirements. The overall risk to workers for this alternative is low.

Transportation risks to individuals and the public in direct or indirect contact with the waste during transport of the waste for off-site disposal were evaluated based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). Assessment of the risk was completed using the industry-recognized RADTRAN and RISKIND models. A detailed discussion of the calculations and results is provided in Appendix F.

For the transportation risk analysis, several routes were evaluated: a route for classified waste that travels by truck to NNSS for disposal; a route for mixed (LLW/RCRA) waste that would be transported by truck from the generating site to the local ETTP rail system, then by rail from the ETTP rail yard to

Energy*Solutions* in Clive, Utah, for disposal; and a third route (for Option 1 only) that LLW and LLW/TSCA waste would travel from the generating site to the ETTP rail system, from the ETTP rail system to a transfer facility in Kingman, Arizona, where it would be transferred to truck for the final leg to NNSS for disposal. Alternatively, in Option 2 the third route is a repeat of the route for Energy*Solutions* in Clive, Utah. Henceforth, in this risk discussion, Option 1 is considered as the bounding off-site case.

Individual receptors (MEIs) and collective populations were considered as receptors. Modeling of radiation exposure for routine and accident scenarios (all shipments), for MEIs, resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from $7.75\times10^{-4}$ to $6.48\times10^{-2}$; a collective population risk (analyzed for workers, on-link [persons sharing the road], and off-link [persons along the route]) resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from $1.61\times10^{-4}$ to $2.15\times10^{-1}$. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 23.8 total incidents of illness, trauma, or death for the Off-site Disposal Alternative (majority of waste going to NNSS for disposal). If the majority of waste were transported to Energy*Solutions* for disposal, an estimated 6.65 incidents of illness, trauma, or death result. These results account for cumulative risk for transport and handling hundreds of thousands of waste shipments. On a per-shipment basis, both the estimated excess cancer risks due to exposure and estimated vehicular risk range in order of magnitude from $10^{-9}$ to $10^{-5}$. The exact excess cancer risk value depends on the receptor being evaluated. Appendix F provides detailed analysis.

A comparative analysis was performed to assess risk of truck transport versus rail transport. The ORR to NNSS route was explored as an example. If all waste transported to NNSS via the ORR to Kingman, Arizona, to NNSS route were transported entirely by truck to NNSS, the overall (routine and accident) MEI and collective population risks due to radiation exposure would increase by a factor of about 10. Vehicle-related risk of fatalities (from emissions and accidents) increases approximately 5-fold going from rail to truck transport, and non-fatal accident risk increases by a factor of more than 10. Details of the analysis are provided in Appendix F.

**Duration of the Off-site Disposal Alternative:** For the Off-site Disposal Alternative, waste disposal operations are estimated to begin in FY 2022 and continue through FY 2043, a duration of approximately 22 years.

#### 7.2.3.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (Off-site)

Although the Off-site Disposal Alternative does not directly establish waste treatment requirements, wastes would be treated as needed to meet WAC before shipment and/or at the receiving facility. Waste treatment prior to shipment would remain the responsibility of the waste generator and would reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied. In the case of LLW/RCRA waste shipped to Energy*Solutions* or WCS, the facilities have waste treatment capabilities and their WAC allow for receipt of untreated waste. It is assumed for the Off-site Disposal Alternative that the Energy*Solutions* or WCS receiving facilities would provide treatment of the waste prior to disposal to reduce the potential for contaminant mobility. Transportation and disposal actions considered in this alternative would have no effect on toxicity or mobility through treatment.

#### 7.2.3.6 Implementability (Off-site)

This alternative is implementable. Off-site disposal would entail meeting administrative and technical requirements to coordinate the transportation and off-site disposal of waste and the continued availability of off-site disposal capacity. Implementation of this alternative would require compliance with state and federal regulations; compliance with licensing, permitting, and DOE administrative requirements.

Review of state and federal regulations (addressed in Section 7.2.3.2 and Appendix G) indicates that there are no provisions that would prohibit shipment of waste derived from ORR sites to the receiving facilities. These facilities are appropriately licensed or permitted and would be qualified prior to shipment per 40 CFR 300.440. Administrative and substantive regulatory requirements for handling and disposing of waste would be met through compliance with the facilities' permit requirements. Shipment of waste from ORR remedial sites would require an exemption from the DOE O 435.1 preference for on-site disposal. Similar exemptions have been routinely approved since DOE began using commercial disposal capacity in 1992. Shipment of waste from ORR would also have to take into consideration the prohibition of transporting radioactive waste through the Las Vegas Metropolitan Area, Callaghan-Tillman Bridge (Hoover Dam bypass), and North Las Vegas.

Agreements between and among states for the shipment and disposal of waste involve the issue of state equity, that is, the balance of benefits associated with activities that generate waste and the burden of resulting life-cycle waste management. The regulatory and administrative viability of off-site waste transportation and disposal is indicated by past and current operations. Previous ORR shipments to Energy*Solutions* and NNSS demonstrate that sustained waste shipment to these facilities is feasible. The states of Utah and Nevada have historically agreed to the transport and disposal of DOE wastes. Therefore, it is likely that these states would not object to continued operations. The administrative feasibility of this alternative could be challenged by future changes in the states' acceptance of waste transport and disposal. Additionally, those states that waste would be required to travel through to access the disposal facilities could challenge the pass-through of waste along public highways and roads.

Another consideration is the ability of off-site facilities to continue to receive waste in the event of an upset such as happened at WIPP in New Mexico. Operations and waste receiving has been halted at WIPP due to an accident occurrence. It is feasible that any disposal facility might undergo a similar incident resulting in the cessation of waste shipments for an undetermined length of time. It is currently projected that the WIPP shutdown could be as long as two to three years.

Wastes that exceed the off-site disposal facilities' WAC would require compliant storage pending the availability of treatment technologies or disposal options. For waste generated for which no treatment or disposal options could be identified, extended or indefinite waste storage could result in DOE being out of compliance with parameters for the treatment and storage of hazardous or radioactive materials established in Section 105 of the Federal Facility Compliance Act of 1992 and the ORR mixed waste Site Treatment Plan (EPA 1992, TDEC 2008).

The technical feasibility of the Off-site Disposal Alternative depends directly on the implementability of waste transportation, disposal, and supporting activities. Technical feasibility indirectly depends on the implementability of treatment, storage, and other waste generator activities. The implementability of the technologies currently available for these components are proven and reliable for most waste projected to be generated at ORR, resulting in a low degree of uncertainty for the implementation of this alternative. It is expected that this alternative could be implemented without schedule delays resulting from technical complications. A technical uncertainty relative to this alternative is the availability of treatment and disposal options for waste exceeding the off-site facilities' WAC. However, as discussed in Chapter 2, the volume of waste generated with no currently defined path for disposal is anticipated to be small.

Future remedial actions at the receiving facilities should not be required because of waste treatment and the high level of isolation provided by the engineered facilities. Only limited additional actions would be possible, but difficult to implement, because of the relative permanence and massive nature of the disposal facilities. Additional actions would be warranted only if major deviations from expected performance of the disposal facilities occurred. Site conditions are well known at the receiving facilities and potential migration pathways are monitored to detect any contaminant releases and evaluate the effectiveness of waste confinement.

Services and materials required for waste transportation, treatment, storage, and disposal for implementation of the Off-site Disposal Alternative, would be readily available. Rail and truck transportation have been used to ship ORR waste in the past. Waste management facilities and services are available at ORR, including the administrative infrastructure to support comprehensive waste handling and storage operations.

The Energy*Solutions*, WCS, and NNSS facilities are permitted to treat and dispose of most waste types, forms, and quantities expected to be generated by the remediation of ORR, and both facilities currently accept comparable waste. Waste disposal services would be required for approximately 22 years at both Energy*Solutions* and NNSS facilities; WCS does not currently have capacity to receive a large portion of the projected waste volume so it is considered only for receipt of mixed waste. Although considered minimal, some uncertainty exists about whether the services currently provided by Energy*Solutions* (a commercial, non-DOE facility), and, to a lesser extent, by NNSS would be available for the duration of this alternative. Disposal capability would be assessed throughout the implementation of the alternative to determine the viability of continued cost-effective, reliable, and safe off-site waste disposal.

#### 7.2.3.7 Cost (Off-site)

Estimated total project costs for the Off-site Disposal Alternative Options are given in Table 7-3. The cost estimates are based on the estimating methodology described in Section 7.1.7 and the technical scope and assumptions described in Chapter 6. A 27% contingency has been assumed, and is included in these estimates. Details are provided in Appendix I.

For Option 2, the lowest priced option, the estimated total project cost of $1,920.5M in 2015 dollars correlates to an estimated cost of $986 per unit volume of as-generated waste in 2012 dollars ($1,920.5M/1.95 M $yd^3$ as-generated waste[16] = $986 per $yd^3$ as-generated waste).

Fuel surcharges that may be incurred during transportation of the waste to off-site disposal facilities are not included in the estimate. Oversize shipments (e.g., as in the case of equipment) is not part of the estimate, although there will be disposal of oversized equipment, which will not only incur surcharges for disposal but also cost more to load and transport. Rail transportation, which is approximately 11% less expensive than truck transport, is assumed for all shipments (with the exception of classified waste shipments to NNSS).

Appendix I provides a detailed description of the total Off-site Disposal Alternative costs for Options 1 and 2, and assumptions.

#### 7.2.3.8 NEPA Considerations (Off-site)

**Socioeconomic impacts:** The short-term socioeconomic impacts associated with waste handling, transportation, and disposal activities for the Off-site Disposal Alternative would be minimal. This alternative would require minimal additional manpower resources at ORR. No new local facilities would be constructed. Because the receiving facilities are already operating, the manpower required to support the facilities' infrastructure is already in place. The incremental increase of waste from ORR could increase short-term manpower needs at these facilities.

Potential short and long-term socioeconomic benefits could be realized from the release or reuse of land resulting from the remediation of ORR and associated CERCLA sites. There would be no direct long-term socioeconomic impacts to ORR and the vicinity from activities associated with off-site transportation of waste under this alternative.

[16] The as-generated waste volume includes 25% uncertainty (see Chapter 2 and Appendix A).

**Table 7-3. Summary of Off-site Disposal Alternative (Options 1 and 2) Costs**

| Option 1 Cost Elements | Volume ($yd^3$) | Cost (FY2012 dollars) | |
|---|---|---|---|
| | | NNSS | Energy*Solutions* or WCS[1] |
| Classified Waste – Debris with 25% uncertainty | 35,612 | $58,902,061 | NA |
| Mercury-contaminated Debris for macroencapsulation | 149,418 | NA | $216,740,474 |
| LLW or LLW/TSCA – Debris | 1,151,440 | $783,614,291 | (see Option 2) |
| LLW or LLW/TSCA – Soil | 607,468 | $455,733,332 | |
| Project Management and Oversight | $37,874,754 | | |
| Subtotal (FY 2012 dollars) | $1,553,914,913 | | |
| Subtract the net cost avoided by implementing volume reduction for Option 1 only (see Appendix B) | – $ 80,501,000 | | |
| **Revised Subtotal (FY 2012 dollars)** | **$1,473,413,913** | | |
| Contingency (12% Scope, 15% Bid) 27% | $397,821,756 | | |
| **Total with Contingency (FY 2012 dollars)** | **$1,871,235,669** | | |
| **Escalated Cost with Contingency** | **$3,122,038,955** | | |
| **Present Worth with Contingency (FY 2015 dollars)** | **$2,119,688,651** | | |
| **Present Worth Average Annual Cost (22 year duration) (FY 2015 dollars)** | **$96.3M** | | |
| **Option 2 Cost Elements** | | | |
| Classified Waste – Debris with 25% uncertainty | 35,612 | $58,902,061 | NA |
| Mercury-contaminated Debris for macroencapsulation | 149,418 | NA | $216,740,474 |
| LLW or LLW/TSCA – Debris | 1,151,440 | (see Option 1) | $791,390,054 |
| LLW or LLW/TSCA – Soil | 607,468 | | $236,835,160 |
| Project Management and Oversight | $33,646,694 | | |
| **Subtotal (FY 2012 dollars)** | **$1,337,514,442** | | |
| Contingency (12% Scope, 15% Bid) 27% | $267,502,888 | | |
| **Total with Contingency (FY 2012 dollars)** | **$1,605,017,331** | | |
| **Escalated Cost with Contingency** | **$2,793,560,511** | | |
| **Present Worth with Contingency (FY 2015 dollars)** | **$1,920,534,551** | | |
| **Present Worth Average Annual Cost (22 year duration) (FY 2015 $)** | **$87.3M** | | |

[1] WCS destination only for mixed, mercury-contaminated debris.

**Land Use Impacts:** Disposal of ORR waste at the receiving facilities would have no short or long-term land use impacts in the vicinity of those facilities. These facilities are already operating and are committed for the long-term to waste disposal and supporting operations. The incremental increase of waste to these facilities from ORR would not affect the existing long-term land use commitment and would have little or no effect on the workforce required for operation and maintenance. No changes in local population or nearby industrial or commercial operations would be expected.

**Environmental Justice Impacts:** No environmental justice impacts have been identified for this alternative. The vicinity of the Energy*Solutions* Clive, Utah, landfill is essentially uninhabited desert (no population within 5 mi.) and is within a 100 square mile Hazardous Industrial Zone designated by the State of Utah. The NNSS disposal site is entirely contained within the DOE-controlled land, and there are no publically accessible areas within 15 miles.

**Irreversible/Irretrievable Commitment of Resources Impacts:** Implementation of the Off-site Disposal Alternative would require the irreversible and irretrievable commitment of land and geologic materials (e.g., gravel and borrow material) and non-renewable energy resources at any disposal site; however, land at the receiving facilities is already dedicated to waste disposal, and the addition of ORR waste would not alter that level of commitment. There would be no long-term commitment of land at ORR or the vicinity.

Waste packaging, handling, and transportation activities would require an irreversible and irretrievable commitment of fuel and other nonrenewable energy resources. Intermodal containers for classified waste shipment to NNSS and LLW/RCRA waste shipment to Energy*Solutions* or WCS would be irretrievably committed; other containers would be reused.

**Cumulative Impacts:** Implementing the Off-site Disposal Alternative would not result in any significant cumulative impacts to the environment. Incremental impacts to air quality, traffic, and noise levels from waste transportation would not noticeably alter existing or future conditions. Any potential environmental effects from these factors, as well as the potential for accidental releases, would cease after the shipment and off-site disposal of all waste.

No direct long-term impacts to air quality, surface water, biota, wetlands, aquatic, or visual resources are anticipated at ORR or the vicinity from the implementation of this alternative. Residual risk would be reduced or eliminated at ORR and associated sites that are remediated. Removal of contamination and waste from these sites and disposal at an off-site facility could result in positive long-term environmental effects by reducing the potential for exposure to and migration of contaminants. Habitat quality and biodiversity may improve over time at these sites, depending on future land use decisions.

The potential for long-term cumulative impacts at the off-site disposal facilities from the presence of ORR wastes is expected to be minimal. These wastes would represent a relatively small portion of the total waste inventory, and the receiving facilities are designed, licensed or permitted, monitored, and maintained to ensure reliable waste containment and minimize long-term environmental effects.

## 7.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

This comparative analysis evaluates the relative ability of the three alternatives to accommodate disposal of future generated CERCLA waste with respect to the evaluation criteria described in Section 7.1 and RAOs described in Chapter 4. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others and to identify the trade-offs to be made in selecting the preferred alternative.

Table 7-4 summarizes the differences among the alternatives. The No Action Alternative may not be supportive of timely remediation of ORR sites due to lack of a coordinated disposal strategy and could result in actions that are less protective and less costly than either of the action alternatives. The On-site Disposal Alternative would be less costly than the Off-site Disposal Alternative, but an additional land area would have to be permanently dedicated to waste disposal, resulting in impacts on future land use and the environment. The Off-site Disposal Alternative could isolate the wastes more effectively long term than the On-site Disposal Alternative due to the arid climate, but long-distance waste transportation in the short-term could result in more accidents, resulting in injuries or fatalities. Figure 7-1 illustrates the significant difference in vehicular risk for the alternatives.

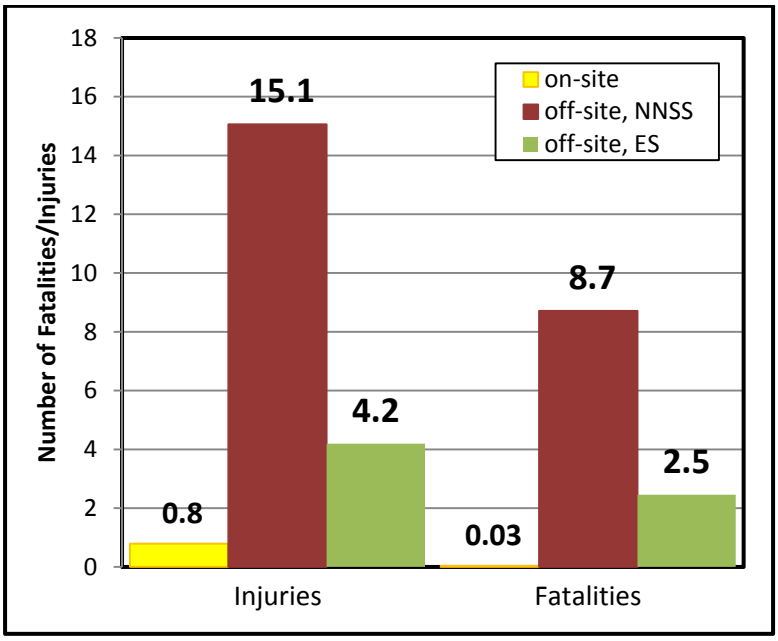



**Figure 7-1. Comparison of Transportation Risk for On-site and Off-site Disposal Alternatives**

**Table 7-4. Comparative Analysis Summary for Disposal of ORR CERCLA Waste**

| Evaluation Criterion | No Action Alternative | On-site Disposal Alternative | Off-site Disposal Alternative |
|---|---|---|---|
| Overall protection of human health and the environment | If more wastes were managed in place, protection would depend on long-term institutional controls at multiple sites. | Protective because of waste being disposed in a landfill designed for long-term containment in site-specific conditions. More protective in the short term because of decreased transportation risks but slightly less protective in long-term because wastes remain on the ORR. | Protective because waste would be disposed in a landfill designed for site-specific conditions. More protective than the On-site Disposal Alternative in preventing releases on the ORR because waste is permanently removed. Less protective in the short term because of increased transportation risks. |
| *Rating* | *1* | *4* | *5* |
| Compliance with ARARs | No action; therefore, no ARARs apply. ARARs for remedial actions at individual sites are specified in separate CERCLA documents. The potential exists for increased interim waste storage at individual waste sites. | Would comply with all chemical-specific, all but one action-specific ARAR, and all but one location-specific ARAR. A CERCLA Section 121(d)(4) waiver would be requested for the 50 ft TSCA buffer requirement on the basis of equivalent protectiveness provided by landfill design and one action-specific ARAR based on the waiver allowing an interim measure that will attain the ARAR upon completion of the remedy (macroencapsulation). | Would comply with all ARARs. Receiving facility compliance with licenses and permits would be determined prior to transport. |
| *Rating* | *0* | *4* | *5* |
| Long-term effectiveness and permanence | May not meet the RAO to facilitate timely cleanup of ORR and associated facilities. | Provides effective long-term protectiveness because of landfill design and use of risk-based WAC. Potential non-acute residual hazards may be greater than for off-site disposal because of higher regional population, wetter climatic conditions, and shallower depth to ground water. Operational and post-closure controls are expected to be equivalent at On- and Off-site facilities. Environmental impacts and permanent loss of forest habitat and wetland would result from siting the EMDF at EBCV. These effects may be partially offset by the cleanup and release of individual ORR remediation sites by ultimately returning other ORR footprints to "greenfield" conditions and consolidating ORR "brownfield" areas. These affects could be further enhanced by implementation of mitigation measures. | Provides effective long-term protection for waste meeting the facility WAC. Land use at Energy*Solutions* and NNSS is already dedicated to waste disposal. ORR waste volume would represent a relatively small portion of the total permitted waste volume available at off-site facilities. The off-site facility locations in arid environments reduce the likelihood of contaminant migration, and fewer receptors exist in the vicinity of Energy*Solutions* and NNSS than near the ORR. Operational and post-closure controls are expected to be equivalent at On- and Off-site facilities. Environmental impacts and permanent loss of desert habitat would result if landfill expansions are required to accommodate ORR CERCLA wastes. Once disposed at a commercial landfill, ORR CERCLA wastes will be outside of direct DOE control and oversight. |
| *Rating* | *1* | *4* | *5* |

**Table 7-4. Comparative Analysis Summary for Disposal of ORR CERCLA Waste (Continued)**

| Evaluation Criterion | No Action Alternative | On-site Disposal Alternative | Off-site Disposal Alternative |
|---|---|---|---|
| Short-term effectiveness | If more wastes were managed in place because no coordinated disposal option is available, less aggressive actions at remediation sites would cause no adverse short-term effects. May not meet the RAO to facilitate timely cleanup of ORR and associated facilities. | Risks to workers and the public at remediation sites and disposal facilities would be similar for both Disposal Alternatives. Some adverse environmental effects would result from construction and operation of the EMDF but would be controlled or mitigated per regulatory requirements and engineering practice. The On-site Alternative is more protective in the short term because of lower transportation risks. | Risks to workers and the public at remediation sites and disposal facilities would be lower than for the On-site Disposal Alternative because nearby areas have a lower population density. Transportation risks are significantly greater than for the On-site Disposal Alternative. Only minor, incremental environmental effects would occur at the existing off-site facilities. |
| *Rating* | *2* | *5* | *2* |
| Reduction of toxicity, mobility, or volume through treatment | Reductions of toxicity, mobility, or volume would be determined in individual CERCLA actions. If more wastes were managed in place because no coordinated disposal option is available, less reduction in toxicity or mobility may result. | Mobility of contaminants would be reduced through isolation of waste in the EMDF. Any ex situ treatment to meet the facility WAC would additionally reduce toxicity, mobility, or volume. | Mobility of contaminants would be reduced through isolation of waste. Any ex situ treatment to meet the disposal facility WAC would additionally reduce toxicity, mobility, or volume. Potential for waste transportation accident(s) increases risk of mobilizing contaminants in clean areas. |
| *Rating* | *1* | *5* | *4* |
| Implementability | No implementation required. | Technically feasible; landfills design will overcome site deficiencies. Properly designed and constructed landfills have been shown to be protective of the environment. Extensive new construction is required. Administrative requirements are considered achievable. Services and materials required for design, construction, and operation of the landfill are readily available, as are qualified personnel, specialists, and vendors. Construction would involve the use of standard construction equipment, trades, and materials; no new technology development is required. | Administrative and technical requirements are implementable. Properly designed and constructed landfills have been shown to be protective of the environment. Disposal of waste at commercial and DOE facilities relies on continued availability of off-site disposal capacity. Future changes in the states' acceptance of waste transport and disposal are not likely, but could challenge implementation of the alternative. Travel through multiple states could raise challenges. The On-site Disposal Alternative provides a much greater level of certainty than the Off-site Disposal Alternative that long-term disposal capacity would be available. |
| *Rating* | *0* | *5* | *3* |

**Table 7-4. Comparative Analysis Summary for Disposal of ORR CERCLA Waste (Continued)**

| Evaluation criterion | No Action Alternative | On-site Disposal Alternative | Off-site Disposal Alternative |
|---|---|---|---|
| Cost | No direct cost; however, efficiencies of consolidation and economies of scale would not be realized. | Average annual project cost is $35.3M (FY 2012 dollars) or $39.6M (Present Worth) based on a 22-year time period.<br>Cost per $yd^3$ of as-generated waste disposed is $447 (Present Worth 2015 dollars).<br>Risk:<br>• Material and/or labor cost increases (moderate cost, unlikely)<br>• Waste not meeting facility WAC and requiring off-site disposal (moderate cost, unlikely)<br>• Compliance issues/operational issues requiring corrective actions (low cost, unlikely)<br>• Increased long-term S&M costs (moderate cost, moderate)<br>• Post-closure, extreme maintenance issues (high cost, unlikely) | Option 2 is the lower estimate, average annual cost is $73.0M (FY 2012 dollars) or $87.3M (Present Worth) based on a 22-year time period.<br>Cost per $yd^3$ of as-generated waste disposed is $986 (Present Worth 2015 dollars).<br>Risk:<br>• Public road travel from demolition site to rail transloading station (high cost, very likely)<br>• Fuel surcharges (low to high cost, likely)<br>• Debris size surcharges (low to high cost, likely)<br>• Shutdown of off-site facilities due to violations (very high cost, unlikely)<br>• Unavailability of facilities due to state equity issues (very high cost, unlikely)<br>• Multi-state travel; equity issues (moderate to very high cost, moderate)<br>• Long-term DOE liability at an off-site location (moderate to very high cost, unlikely) |
| *Rating* | *0* | *5* | *1* |
| ***Summed ratings*** | **5** | **32** | **25** |

Rating key:

0. Not applicable
1. Worst/Least
2. Worse/Less
3. Average/Neutral
4. Better/More
5. Best/Most

### 7.3.1 Overall Protection of Human Health and the Environment

The No Action Alternative could be least protective if the lack of a coordinated disposal program resulted in an increased reliance on management of waste in place at CERCLA remediation sites, or if the pace of clean-up were slowed.

Selection of either the On- or Off-site Disposal Alternative could encourage more waste removal at remediation sites. If the presence of on-site disposal capacity encouraged removal of waste from individual CERCLA sites, environmental benefits could result at those sites depending on eventual land use. The Off-site Disposal Alternative would be more effective in preventing potential future releases on the ORR because most of the CERCLA waste would be disposed of in off-site permitted facilities.

Both the On-site and Off-site Disposal Alternatives would be protective of human health and the environment. The On-site Disposal Alternative would be protective primarily through design and construction to required specifications and compliance with the WAC established for a new on-site CERCLA waste disposal facility. The Off-site Disposal Alternative would be protective through compliance with the WAC for each of the off-site existing permitted facilities.

Waste removal would require local and long-distance transport of waste, treatment of some waste streams, and waste handling and placement at the disposal facilities. These intensive actions would increase the probability of normal industrial or transportation accidents. Because of the greater volumes of waste shipped over long distances, transportation risks are significantly higher for the Off-site Disposal Alternative.

### 7.3.2 Compliance with ARARs

No ARARs or TBC guidance are directly associated with the No Action Alternative; however, lack of a coordinated disposal program may make it more difficult for CERCLA actions at individual remediation sites to comply with some regulatory requirements. The potential for increased interim waste storage exists under the No Action Alternative. ARARs would be developed for each site-specific CERCLA action. On- and Off-site Disposal Alternatives would support individual CERCLA actions and meet most of the ARARs, with the exceptions noted below.

Certain waste streams may not meet the WAC for either the on-site EMDF or existing off-site disposal facilities. This waste, expected to be a relatively small volume, would be stored at compliant facilities with sufficient engineering controls and oversight to minimize the potential for exposure or release.

The On-site Disposal Alternative would be designed to meet all ARARs and TBC guidance with the exception of the TSCA hydrologic requirement that specifies a buffer of at least 50 ft above the historical high water table and LDR placement requirements (temporarily would not be met) prior to macroencapsulation of mercury-contaminated debris. These waivers would be requested on the basis of "Equivalent protectiveness" and "Interim Measure", respectively, per 40 CFR 300.430(f)(1)(ii)(C), and would be requested as described in Appendix G.

The Off-site Disposal Alternative would comply with all ARARs and TBC guidance, which are limited to requirements associated with transportation of waste. Compliance of the disposal facilities with their licenses and permits would be determined prior to transport in accordance with the CERCLA Off-site Rule.

### 7.3.3 Long-term Effectiveness and Permanence

Both the on-site and off-site disposal would be effective and permanent in the long-term. The Off-site Disposal Alternative offers the greatest level of long-term protectiveness because the climate and hydrogeology offer the highest potential for permanence of containment. The No Action Alternative

would likely be less protective if more wastes were managed in place at individual CERCLA sites rather than being consolidated in an engineered landfill. The No Action Alternative and the lack of a coordinated disposal capacity may not optimally meet the RAO to facilitate timely cleanup of ORR and associated sites.

Preventing exposure to the contaminants placed in EMDF over the long term depends on success of the facility's waste containment features, characteristics of waste placed in EMDF, and institutional controls. The multilayer cover system would be designed to decrease migration of liquids, minimize erosion, accommodate settling and subsidence, and prevent burrowing animals and plant root systems from penetrating the cover system and reduce the likelihood of inadvertent intrusion by humans by increasing the difficulty of digging or drilling into the landfill. With proper design and installation of the landfill systems (underdrain, liner, and final cover) there is no reasonable expectation of failure of these components. Institutional controls would restrict access to the site and prohibit actions that could penetrate the cover and expose the waste. Barring extraordinary efforts to penetrate the cover, it should remain effective for hundreds to thousands of years. While the cover remains in place, migration of contaminants into groundwater and surface water is the only credible pathway for exposure. PWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF site (see Appendix H).

The Off-site Disposal Alternative also relies on engineering and institutional controls at the off-site disposal facilities to prevent inadvertent intrusion, including engineered barriers to intrusion and waste migration. Off-site disposal of waste at Energy*Solutions*, WCS, and NNSS in the long-term may be more reliable at preventing exposure than on-site disposal on the ORR. Energy*Solutions*, WCS, and NNSS are in arid environments that reduce the likelihood of contaminant migration or exposure via ground water or surface water pathways. Fewer receptors exist in the vicinity of Energy*Solutions*, WCS, and NNSS than on the ORR.

Long-term effects at the proposed EMDF site would consist of impacts to biota and habitat, primarily by the loss of forest cover and stream and wetland impacts.

### 7.3.4 Short-term Effectiveness

Short-term effectiveness includes protection of the community and workers during remedial action, short-term environmental effects, and the duration of remedial activities. For purposes of this RI/FS, the short-term period lasts through closure of the EMDF but does not include the subsequent period of institutional controls.

On-site disposal presents the greatest challenges to the Oak Ridge area during remediation. Construction and operation of EMDF would present more local risk and impact to human health and the environment than off-site disposal, which does not involve new construction. Off-site disposal would generate few local impacts other than possibly encouraging cleanup of individual sites, and only incremental and minor impacts at the receiving disposal facility. Off-site disposal would result in additional risk from long-distance transportation.

Under all the alternatives evaluated, risks to workers and the community from actions at the remediation sites and disposal facilities would be controlled to acceptable levels through compliance with regulatory requirements and health and safety plans. These risks would be similar and would be comparable to risk for industrial operations. The No Action Alternative would present no specific short-term risks or benefits to the community or workers other than those associated with individual actions at individual sites and off-site disposal. Less-intensive remedial actions may be implemented at some remediation sites under the No Action Alternative. If so, the replacement of excavation, treatment, transport, and disposal actions with in situ containment or treatment options would reduce the likelihood of adverse short-term effects on the community and workers. For sites undergoing removal, short-term effectiveness would be equivalent

under all alternatives. The level of activity and resulting probability of exposure to contamination or industrial accidents at waste generation sites, treatment facilities, and disposal facilities would be similar.

For the On-site and Off-site Disposal Alternatives, the most significant risks to the public would result from waste transportation. Potential risks result from exposure to gamma radiation during routine (accident free) transportation, from exposure to radionuclides during accidents, and from physical trauma or illness associated with vehicular accidents and emissions, regardless of the waste being carried. Table 7-5 contains a summary of the calculated risks for the On-site and Off-site Disposal Alternatives, for all shipments. As seen in the table, off-site transportation carries a much higher risk than on-site transportation, due to the public roads and railroads travelled and the long distances involved. On-site transport carries a considerably lower risk due to the short travel distances and the non-public routes that would be followed. Figure 7-1 illustrated this significant human health risk difference between the off-site and on-site alternatives. A breakdown of the risks for the individual routes travelled, accident versus routine travel, and fatal/non-fatal statistics is provided in Appendix F.

**Table 7-5. Comparison of Risk Factors for On-site and Off-site Disposal Alternatives, All Shipments**

| Receptor | On-site Disposal Alternative | | Off-site Disposal Alternative | |
|---|---|---|---|---|
| | Radiological Risk Range | Vehicle-related Risk (death/injury) | Radiological Risk Range | Vehicle-related Risk (Death/Injury) |
| Maximum Exposed Individuals | $4.97\times10^{-4}$ to $1.08\times10^{-2}$ | 0.83 | $7.75\times10^{-4}$ to $8.64\times10^{-2}$ | 23.8 (NNSS) |
| Collective Population | $3.46\times10^{-8}$ to $1.28\times10^{-1}$ | | $1.21\times10^{-4}$ to $2.16\times10^{-1}$ | 6.65 (ES) |

Short-term environmental effects would be least for the No Action Alternative, minimal for the Off-site Disposal Alternative, and greatest for the On-site Disposal Alternative. For the No Action Alternative, no specific environmental impacts other than those associated with individual actions would be expected. Environmental effects could result from a spill during transport and handling for the Off-site Disposal Alternative, but there is a low risk of a spill and only minor adverse effects are likely to result. Vehicles along the transportation corridor would cause an inconsequential increase in pollution and noise levels. The additional environmental effects at the receiving off-site disposal facilities would be negligible over and above those caused by current and continuing operation of the facilities.

Construction and operation of EMDF would cause local short-term environmental effects typically associated with a large construction project. Sensitive human receptors (e.g., residence, church, school) would not be impacted because of the proposed EMDF site distance from these receptors. Disturbance to terrestrial resources would be expected, with land use resulting in temporary losses of habitat; destruction of small, limited-range animals; and displacement of wildlife adjacent to the construction areas. The potentially sensitive forest at the EMDF site that would be impacted includes a portion of the NT-3 stream and wetlands.

Other potential short-term effects from EMDF construction and operation include the probable slight degradation of surface waters by increased sediment and runoff in NT-2 and NT-3 at the EBCV site. Aquatic resources, including the Tennessee dace, may be somewhat impacted in Bear Creek. Additional assessments of effects on protected and sensitive resources, if present, would be performed as necessary

and mitigative measures would be identified and implemented in consultation with the appropriate state or federal agencies.

Lack of a coordinated disposal capacity may hinder remediation. As a result, the No Action Alternative may not meet the RAO to support timely cleanup of ORR and associated sites.

The duration of remedial activities for the No Action Alternative would depend on CERCLA actions selected for the individual remediation sites. The duration of disposal activities for the On- and Off-site Disposal Alternatives would be similar based on generation schedules at the remediation sites described in Chapter 2 and Appendix A.

### 7.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Although the disposal alternatives evaluated do not directly establish waste treatment requirements, wastes would be treated as needed to meet WAC either before shipment or at the receiving facility (the Energy*Solutions* and WCS facilities have treatment capabilities). Waste treatment prior to shipment would remain the responsibility of the waste generator. For mercury-contaminated debris, treatment by either the On-site or Off-site Disposal Alternatives is assumed to be macroencapsulation. An increased risk is associated with transporting the untreated waste to the Off-site Disposal facility as compared with the waste remaining on-site and treated at the EMDF. Waste treatment by the generator or at the receiving facility could reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied. For the No Action Alternative, if more wastes are managed in place because of the lack of a coordinated disposal option, containment or in situ treatment technologies could be less effective in reducing toxicity or mobility than the ex situ treatment technologies that would be used for removal and disposal options.

### 7.3.6 Implementability

All three alternatives considered are implementable. All are administratively feasible, although not without substantial effort. Both on-and off-site disposal are technically feasible, although the on-site component presents greater technical challenges. Services and materials for either the On- or Off-site Disposal Alternative are readily available.

Development of an on-site EMDF would require cooperation with and support from federal and state regulatory agencies and must include public involvement. Administrative feasibility of disposal activities for the No Action Alternative would be considered under CERCLA decisions for individual sites. For the Off-site Disposal Alternative, existing agreements with state agencies for interstate shipment of waste, and with the states of Utah and Nevada for disposal of wastes are likely to continue. A DOE exemption from the requirement to dispose of LLW at the generation site or at another DOE site could be readily obtained.

For both the On- and Off-site Disposal Alternatives, wastes that do not meet the WAC for any disposal facility would be stored in compliant facilities that would meet the administrative requirements for storage.

Technical implementability of waste disposal for the No Action Alternative would be considered under CERCLA decisions for individual sites. The technical components of the On- and Off-site Disposal Alternatives would be straightforward to implement using existing and readily available technologies. Once the wastes are disposed of on- or off-site, the need for additional actions in the future would be extremely unlikely. The main difference between the On- and Off-site Disposal Alternatives is the requirement for construction of the EMDF versus the long-distance transport requirements for off-site disposal. Both are readily implementable, but construction of the EMDF is more complex.

Services and materials needed for construction and operation of the EMDF or for shipment and disposal of waste under the Off-site Disposal Alternative are readily available. Disposal capacity is available for

waste that would not meet on-site facility WAC under the On-site Disposal Alternative and would require off-site disposal, and storage capacity would be available for waste not meeting any facility's WAC. Disposal capacity is currently available at the representative off-site disposal facilities and is anticipated to continue to be available. The availability of services and materials does not apply to the No Action Alternative. Services and materials needed for waste disposal would be determined in CERCLA actions at individual sites without the benefit of a comprehensive strategy.

Because of state equity issues, it is possible that public concerns regarding shipments outside of Tennessee could affect the availability of off-site disposal facilities. Uncertainty about continued availability of the off-site disposal capacity at both representative facilities, NNSS (a DOE facility) and Energy*Solutions* (a non-DOE, commercial facility) presents a risk to the program, especially when the current shut-down situation of the WIPP disposal facility is considered. Given the 30 years of anticipated CERCLA waste generation, the On-site Disposal Alternative provides a much greater level of certainty than the Off-site Disposal Alternative that long-term disposal capacity would be available at the time wastes are generated.

### 7.3.7 Cost

Specific disposal costs cannot be estimated for the No Action Alternative. Disposal costs would depend on the individual actions taken at the CERCLA remediation sites. If lack of a coordinated disposal program under the No Action Alternative encourages management of wastes in place at individual CERCLA sites, rather than removal and disposal, disposal costs would be avoided. If on- or off-site disposal is selected, the removal, ex situ treatment, and local transport portion of alternatives requiring disposal may be more costly than in situ remedial actions at a remediation site. For those CERCLA sites that select removal and disposal without the benefit of a coordinated ORR-wide disposal program, transport costs and disposal fees could be higher due to procuring disposal services on a project basis and lack of economies of scale.

The projected cost for the Off-site Disposal Alternative is approximately two times that of the On-site Disposal Alternative. These estimated total project costs correlate to an estimated \$447 per $yd^3$ as-generated waste (Present Worth 2015 dollars) for the On-site Disposal Alternative and an estimated \$986 per $yd^3$ as-generated waste (Present Worth) for the Off-site Disposal Alternative, Option 2 (lowest priced option) with the same assumed uncertainty of 25% in waste volumes for each alternative, and appropriate cost contingency applied to both estimates (details are given in Appendix I).

Rail transportation, which is approximately 11% less expensive than truck transport, is assumed for the majority of shipments. Risk figures identified in Table 7-5 associated with the off-site alternative far exceed risks identified for the on-site alternative. Risk, if realized, translates to increased costs.

### 7.3.8 NEPA Considerations

Land use within the permanent institutional control boundary of all alternatives would be restricted. Other areas used during construction and operations of on-site facilities could be released for other uses after facility closure.

If the On- or Off-site Disposal Alternatives encourage more thorough remediation of CERCLA environmental restoration sites than under the No Action Alternative, reduction or elimination of restrictions at those sites could have a positive effect on socioeconomics and land use. The effects of implementing the No Action Alternative would depend on decisions at individual sites, but could result in less release and less beneficial reuse of the individual sites if more waste is managed in place because of the lack of coordinated disposal capacity. Multiple sites could be more difficult to manage and less reliable than institutional and engineered controls at disposal facilities where large volumes of wastes are consolidated.

Implementation of the Off-site Disposal Alternative would have only a minor socioeconomic impact. The Off-site Disposal Alternative could encourage remediation at generator sites, but socioeconomic impacts associated with waste handling, packaging, and transport would be minimal. Only a slight incremental increase in the workforce at the off-site disposal facilities would be needed to accommodate ORR-generated wastes.

On-site disposal would likely have the greatest effect on socioeconomics and land use. The construction and disposal actions for the On-site Disposal Alternative would increase the number of jobs locally, but the maximum increase would not be significant relative to the total current workforce. Loss of land use at the disposal site could be partially offset by reductions in restrictions at the remediation sites, but it is possible that the same improvements in land use opportunities at generator sites could occur under the No Action and Off-site Disposal Alternatives without the commitment of additional land on ORR. The proposed site location adjacent to existing waste disposal sites minimizes the potential impact of the presence of a new facility on future use of the area. To some extent, differences in cost between on- and off-site disposal could impact decisions and remediation progress at individual sites.

The primary adverse environmental effect of the On-site Disposal Alternative at the EMDF site would result from the permanent commitment of the EMDF area for waste management, replacement of woodland habitat with grass and shrub habitat, and loss of sensitive stream and wetland habitat. The commitment of land area may be offset in part by cleanup and release of some of the ORR remediation sites. Any cumulative impact in the forested areas near the proposed EMDF site or on future land use is anticipated to be minimal.

The immediate area surrounding the EBCV site is currently unpopulated. The nearest residential area is approximately 0.84 mile north of the EBCV site.

Cumulative effects of the Off-site Disposal Alternative would be caused by increased traffic along the transportation corridor. The short-and long-term effects at the disposal facilities would be minor as described for the On-site Disposal Alternative. If the cleanup and release of remediation sites is encouraged by this action, environmental benefits at ORR could result.

Cleanup actions at remediation sites could be similar for all alternatives. Off-site disposal would provide a greater cumulative benefit because the On-site Disposal Alternative would permanently alter the proposed EMDF location. The cost differential between the On-site and Off-site Disposal Alternatives is substantially in favor of on-site disposal and could encourage greater cleanup of individual ORR remedial sites.

### 7.3.9 Summary of Differentiating Criteria

The No Action Alternative may not support the RAO of facilitating the timely cleanup or release of portions of ORR and associated facilities for beneficial use. The success of the No Action Alternative in meeting the other RAOs would depend on the individual decisions made for each CERCLA remediation site. Overall remediation and disposal costs and local socioeconomic benefits could be lower if less aggressive remedial actions result from the lack of a coordinated disposal program. By virtue of compliance with the CERCLA process, cleanup actions would be protective, but if increased management of waste in place and long-term restrictions on land use resulted from no action, long-term effectiveness could be reduced. The need to coordinate and implement disposal services on a project-by-project basis could increase the time and cost required to complete remedial actions at individual sites.

For most of the CERCLA and NEPA evaluation criteria, the differences between on-and off-site disposal are minor. These two alternatives are differentiated by five key criteria, (1) long-term effectiveness, (2) short-term transportation risk, (3) availability of services and materials, (4) land use, and (5) cost.

**Long-term Effectiveness:** Both the On-site and Off-site Disposal Alternatives would be considered protective long term of human health and the environment by disposal of waste in a landfill designed for site-specific conditions. Off-site disposal at Energy*Solutions* and NNSS may be more effective long term in preventing exposure to or migration of contamination because of the climatic and geologic conditions. Fewer receptors exist in the vicinity of Energy*Solutions* and NNSS than near the ORR. The Off-site Disposal Alternative would be more effective in preventing future releases on the ORR because CERCLA waste would be disposed in off-site facilities.

**Short-term Transportation Risk:** Risk associated with local transport of waste to either the on-site disposal facility or the truck-to-rail transfer facility at ETTP for subsequent off-site shipment would be the same for both alternatives. For the Off-site Disposal Alternative, there would be additional significant radiological risk and vehicle-related risk due to transportation of the waste to off-site locations. Waste may be transported off-site by rail, truck, or a combination. Comparative analysis of risk incurred by these scenarios demonstrates that rail transport results in a significantly lower health risk overall to MEIs and collective populations than does truck transportation of the waste, both from radiation exposure risk and vehicular accident risk. An analysis of transportation risk associated with using the NNSS facility or the EnergySolutions facility shows a factor of 3 decrease in risk for the Energy*Solutions* destination, mainly because all waste could travel right to the facility by rail (no truck transfer is needed as in the case of NNSS). However, it is still measurably higher than the On-site Disposal Alternative risk.

**Availability of Services and Materials:** Currently services and materials needed for pre-construction investigations, construction and operation of the On-site Disposal Alternative and transportation and disposal capacity for the Off-site Disposal Alternative are available. No impediments to continued operation for the On-site Disposal Alternative are likely to arise. State equity issues and reliance on off-site facilities introduce an element of uncertainty into the continuing viability of off-site disposal during the anticipated operational period. Because CERCLA waste generation on the ORR is likely to continue for 30 years, on-site disposal would provide much greater certainty that sufficient disposal capacity is actually available at the time the wastes are generated.

**Land Use:** Construction of the EMDF would result in significant environmental impacts, mainly arising from rerouting a portion of a tributary and permanent loss of wetlands and forested habitat. The proposed EMDF site, while undeveloped, is adjacent to a brownfield area where the existing EMWMF and former waste disposal sites are located. Land use at the on-site EMDF would be restricted in perpetuity. Land at off-site facilities is already committed to waste disposal.

**Cost:** The estimated project cost for Option 2 of the Off-site Disposal Alternative is approximately twice the estimated project cost of the On-site Disposal Alternative. Additionally, risks identified with the Off-site Disposal Alternative have the capacity to greatly increase the cost associated with this alternative, compared with risks associated with the On-site Disposal Alternative.

# 8. REFERENCES


ANL 2001. *User's Manual for RESRAD Version 6*, ANL/EAD-4, Argonne National Laboratory, July 2001, Argonne, IL.

B&W (Babcock & Wilcox Technical Services, Y-12, LLC) 2010. *Application for the Department of Army Permit for the Y-12 National Security Complex Uranium Processing Facility Project Site Preparation*, March 24, 2010.

B&W 2011. *Calendar Year 2010 Groundwater Monitoring Report, U.S. Department of Energy Y-12 National Security Complex, Oak Ridge, Tennessee*. Y/SUB/11-073231/1, December 2011, Oak Ridge, TN.

B&W 2012. *The Y-12 Groundwater Protection Program Location Information Database*. v1.7.8, current as of 04/10/2012, Oak Ridge, TN.

Baranski 2009. *Natural Areas Analysis and Evaluation: Oak Ridge Reservation.* ORNL/TM-2009/201. November 2009, Oak Ridge National Laboratory, Oak Ridge, TN.

Benson, C.H., Albright W. H., Ray, D. P., & Smegal, J. 2008. *Review of the Environmental Management Waste Management Facility (EMWMF) at Oak Ridge.* Independent Technical Review Report: Oak Ridge Reservation, February 2008, Oak Ridge, TN.

Benson 2014. *Performance of Engineered Barriers: Lessons Learned, Performance and Risk Assessment Community of Practice*, Webinar, February 20, 2014.

BJC 2002. *Record of Decision for Phase I Interim Source Control Actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee*, DOE/OR/01-1951&D3, Bechtel Jacobs Company LLC, May 2002, Oak Ridge, TN.

BJC 2006. *Record of Decision for Phase II Interim Remedial Actions for Contaminated Soils and Scrapyard in Upper East Fork Poplar Creek, Oak Ridge, Tennessee*, DOE/OR/01-2229&D3, Bechtel Jacobs Company LLC, March 2006, Oak Ridge, TN.

BJC 2008. Safety Analysis Document Environmental Management Waste Management Facility, SAD-YT-EMWMF-0029, Rev. 1, Bechtel Jacobs Company LLC, November 2008, Oak Ridge, TN.

Bormann, B.T., Spaltenstein, H., McClellan, M.H., Ugolini, F.C., Cromack, K., and Nay, S.M. 1995. "Rapid soil development after windthrow disturbance in pristine forests", *in Journal of Ecology*, vol. 83. pp. 747-757.

Clinton, B.D. and Baker, C.R. 2000. "Catastrophic Windthrow in the southern Applachians: characteristics of pits and mounds and initial vegetation responses", in *Forest Ecology and Management*, vol. 126, pp. 51-60.

DOE 1992. Federal Facility Agreement for the Oak Ridge Reservation. DOE/OR-1014. January 1992, U.S. EPA Region IV, Atlanta, GA; U.S. DOE, Oak Ridge, TN; and TDEC, Nashville, TN.

DOE 1994. *Memorandum for Secretarial Officers and Head of Field Elements: National Environmental Act Policy Statement.* DOE Headquarters, June 1994, Washington, DC.

DOE 1996. *Identification and Screening of Candidate Sites for the Environmental Management Waste Management Facility, Oak Ridge, Tennessee*, DOE/OR/02-1508&D1. Oak Ridge, TN.

DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

DOE 1999. *Record of Decision for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, Tennessee*. DOE/OR/01-1791&D3, Jacobs EM Team, November 1999, Oak Ridge, TN.

DOE 2000. *Record of Decision for the Phase I Activities in Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1750&D4, U.S. Department of Energy, Office of Environmental Management, May 2000, Oak Ridge, TN.

DOE 2001a. *Remedial Design Report for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, Tennessee*, DOE/OR/01-1873&D2, Oak Ridge, TN.

DOE 2001b. *Attainment Plan for Risk/Toxicity-Based Waste Acceptance Criteria at the Oak Ridge Reservation*, DOE/OR/01-1909&D3. Oak Ridge, TN.

DOE 2002. *A Resource Handbook on DOE Transportation Risk Assessment*, DOE/EM/NTP/HB-1, DOE Transportation Risk Assessment Working Group Technical Subcommittee, July 2002, Albuquerque, NM.

DOE 2005. Letter from DOE Oak Ridge Operations to TDEC, "Listed/Non-listed Determination Evaluation for Mercury-contaminated Media and Debris at the Y-12 National Security Complex", DOE-05-0600, June 20, 2005.

DOE 2008a. Environmental Management Waste Management Facility 2008 Capacity Assurance Remedial Action Report. DOE/OR/01-2377&D2, Bechtel Jacobs Company LLC, September 2008, Oak Ridge, TN.

DOE 2008b. Oak Ridge Reservation Planning: Integrating Multiple Land Use Needs, DOE/ORO/01-2264, U.S. Department of Energy, Oak Ridge Office, May 2008, Oak Ridge, TN.

DOE 2008c, Proposed Plan for the Bear Creek Burial Grounds at the Y-12 National Security Complex, Oak Ridge, Tennessee, DOE/OR/01-2383&D1, September 2008, Oak Ridge, TN.

DOE 2009a. Environmental Management Waste Management Facility 2009 Capacity Assurance Remedial Action Report. DOE/OR/01-2403&D1, March 2009, Oak Ridge, TN.

DOE 2009b. *Modification Record to Federal Facility Agreement for the Oak Ridge Reservation, Major Modification to Appendix J,* FFA Change Control Number FFA-PM/09-010, U.S. EPA Region IV, Atlanta, GA; U.S. DOE, Oak Ridge, TN; and TDEC, Nashville, TN, July 2009.

DOE 2010a. *Environmental Management Waste Management Facility 2010 Capacity Assurance Remedial Action Report.* DOE/OR/01-2463&D1, March 2010, Oak Ridge, TN.

DOE 2010b. *Explanation of Significant Differences for the Record of Decision for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, Tennessee*, DOE/OR/01-2426&D2, May 2011.

DOE 2010c. *National Environmental Policy Act Compliance Program*. DOE O 451.1B Chg3. U.S. Department of Energy, January 19, 2012, Washington D.C.

DOE 2011a. *Environmental Management Waste Management Facility 2011 Capacity Assurance Remedial Action Report*. DOE/OR/01-2514&D1., March 2011, Oak Ridge, TN.

DOE 2011b. Nevada National Security Site Waste Acceptance Criteria, DOE/NV-325-Rev. 8-01, January 2011.

DOE 2011c. *U. S. Department of Energy Strategic Plan May 2011.* DOE/CF-0067, U.S. DOE, May 2011, Washington DC.

DOE 2011d. *Derived Concentration Technical Standard*, DOE-STD-1196-2011, April 2011, Washington, D.C.

DOE, 2011e. *Charter, Office of Environmental Management, Low-Level Waste Disposal Facility Federal Review Group*. Available at http://energy.gov/sites/prod/files/em/LFRGCharter-2011.pdf.

DOE 2012a. *Environmental Management Waste Management Facility 2012 Capacity Assurance Remedial Action Report.* DOE/OR/01-2567&D1, March 2012, Oak Ridge, TN.

DOE 2012b. *Characterization Report for Alpha 5 Building 9201-5 at the Y-12 National Security Complex, Oak Ridge, Tennessee Volume I*, DOE/OR/01-2540&D2, March 2012, Oak Ridge, TN.

DOE 2013. *Fiscal Year 2013 Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Facility*, DOE/OR/01-2603&D0, February 2013, Oak Ridge, TN.

DOE 2014. *Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Facility*, DOE/OR/01-2643&D2, October 2014, Oak Ridge, TN.

DuVall, G.D., 1998. *An Archaeological Survey of Approximately 125 Acres for the Environmental Management Waste Management Facility (EMWMF) Disposal Area, Oak Ridge Reservation, Anderson County, Tennessee*. BJC/OR-97.

DuVall, G.D. and Souza, P.A. 1996. *An Evaluation of the Previously Recorded and Inventoried Sites on the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-4964.

Energy*Solutions* 2011. *EnergySolutions Clive, Utah Waste Disposal and Treatment Facilities Waste Acceptance Criteria Revision 8*, January 2011.

Energy*Solutions* 2012. IDIQ contract no. DE-EM0002406.

EPA 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*, EPA/540/G-89/004. Office of Solid Waste and Emergency Response, October 1988. Washington, D.C.

EPA 1989. *Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, Office of Emergency and Remedial Response, December 1989, Washington, D.C.

EPA 1991a. *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part C)*, Publication 9285.7-01C, October 1991, Washington D.C.

EPA 1991b. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions,* OSWER DIRECTIVE 9355.0-30, Environmental Protection Agency, April 1991, Washington D.C.

EPA 1992. *Mixed Waste Inventory Reports and Plan*. Federal Facilities Restoration and Reuse Office (FFRRO), Sec. 105. http://www.epa.gov/fedfac/documents/ffc92.htm.

EPA 1993. *Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities*, EPA/600/R-93/182. Risk Reduction Engineering Laboratory Office of Research and Development, September 1993. Cincinnati, OH.

EPA 2000. A *Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA/540/R-00/002. Office of Solid Waste and Emergency Response, July 2000. Washington, DC.

FEMA 2009. *FEMA Benefit-Cost Analysis Reengineering (BCAR) Version 4.5*, BCAR Ver. 4.5, Federal Emergency Management Agency, May 2009, Washington D. C.

Fielder, G.F. Jr., Ahler, S.R., and Barrington, B., 1977. *Historic Sites Reconnaissance of the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-5811.

Hancock, G.R., Evans, K.G., McDonnell, J., and Hopp, L. 2011. "Ecohydrological controls on soil erosion and landscape evolution", in *Ecohydrology*, accessed at wileyonlinelibrary.com

Needham, A. D., Smith, J. W. N., and Gallagher, E. M. G. 2006. *The service life of polyethylene geomembrane barriers*. Engineering Geology, Vol. 85, pp. 82-90.

NNSA 2008. Memorandum from the National Nuclear Security Administration, *Request for Fiscal Year 2009 Preliminary Mixed and Low-Level Radioactive Waste Forecasts and Transmittal of the NNSA-Nevada Site Office Program Management Strategy for Disposal Operations*, July 15, 2008.

NOAA 2011. National Oceanic and Atmospheric Administration (NOAA) National Weather Service Weather Forecast Office Records, 1953 to June 2011, http://www.srh.noaa.gov/mrx/?n=mrx_tornado_db

OMB 2012. Memorandum for the Heads of Departments and Agencies from Jacob J. Lew, OMB Director, 2012 Discount Rates for OMB Circular No. A-94, January 3, 2012.

ORSSAB 2011. Oak Ridge Site Specific Advisory Board Recommendation 200: Recommendation on the Decision Process for Siting a Second CERCLA Waste Disposal Facility, June 2011.

ORSSAB 2014. Oak Ridge Site Specific Advisory Board Recommendation 223: Recommendations on Additional Waste Disposal Capacity on the Oak Ridge Reservation, May 2014.

Rodriguez et al. 1992. *Surface Debris Inventory at White Wing Scrap Yard, Oak Ridge Reservation, Oak Ridge, Tennessee.* ORNL/ER-135. U.S. Department of Energy, Office of Environmental Restoration and Waste Management, August 1992, Oak Ridge, TN.

Rosensteel, B. A., and C. C. Trettin. 1993. *Identification and Characterization of Wetlands in the Bear Creek Watershed.* Y/TS-1016.

Rowe, R.K., Rimal, S. and Sangam, H.P. 2009. *Ageing of HDPE geomembrane exposed to air, water and leachate at different temperatures.* Geotextiles and Geomembranes, Vol. 27, No. 2, pp. 137-151.

Southworth, G.R., Loar, J.M., Ryon, M.G., Smith, J.G., Stewart, A.J., and Burris, J.A. 1992. *Ecological Effects of Contaminants and Remedial Actions in Bear Creek*. ORNL/TM-11977.TDEC 2008. S*ite Treatment Plan for Mixed Wastes on the U.S. Department of Energy Oak Ridge Reservation*, TDEC-REV. 12.2, March 2008.

TDEC 2010. *Section 401 Water Quality Certification/ARAP ARAP application NRSI0.083 Y-12 access haul road, Oak Ridge, Anderson County*, June 10, 2010.

Ulanova, N.G. 2000. "The effects of windthrow on forests at different spatial scales: a review", in *Forest Ecology and Management*, vol. 135. pp. 155-167.

UCOR 2015. *Focused Feasibility Study for Water Management from the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee*, DOE/OR/01-2664&D0, February 2015.

This page intentionally left blank.

# APPENDIX A:
# WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION DATA

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... A-3
1. INTRODUCTION ..... A-4
1.1 "AS-GENERATED" WASTE VOLUME ESTIMATE ..... A-4
1.2 "AS-DISPOSED" WASTE VOLUME ESTIMATE ..... A-4
1.3 WASTE CHARACTERIZATION DATA ..... A-7
1.3.1 Radionuclide Characterization ..... A-7
1.3.1.1 Data Collection ..... A-8
1.3.1.2 Data Set Development Exceptions ..... A-8
1.3.1.3 Development of Data Set for Natural Phenomena and Transportation Risk Evaluation ..... A-9
2. REFERENCES ..... A-52

# FIGURES

Figure A-1. Base As-generated Waste Volume Estimate by Material Type (FY 2014 to FY 2043) ..... A-6
Figure A-2. Base As-generated Waste Volume Estimate by Waste Type (FY 2014 to FY 2043) ..... A-6
Figure A-3. Schematic of Calculations to Determine As-disposed Waste Volumes ..... A-7

# TABLES

Table A-1. Base As-generated Waste Volume Estimate (FY 2014 to FY 2043)[a] ..... A-10
Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043)[a] ..... A-11
Table A-3. As-generated Waste Volume Estimate (FY 2022 to FY 2043)[a] with Uncertainty ..... A-15
Table A-4. As-disposed Waste Volume Estimate ..... A-16
Table A-5. Radionuclide Concentration Data Set ..... A-17
Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) ..... A-32

# ACRONYMS

| | |
|---|---|
| AD | As-disposed (waste volume) |
| AG | As-generated (waste volume) |
| CARAR | Capacity Assurance Remedial Action Report |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| COPC | contaminant of potential concern |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| FY | Fiscal Year |
| LLW | low-level waste |
| M | Million |
| ORNL | Oak Ridge National Laboratory |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RI/FS | Remedial Investigation/Feasibility Study |
| TSCA | Toxic Substance Control Act of 1976 |
| WAC | waste acceptance criteria |
| WACFACS | Waste Acceptance Criteria Forecast Analysis Capability System |
| WGF | waste generation forecast |
| WL | waste lot |
| WTMS | Waste Transportation Management System |

# 1. INTRODUCTION

This Appendix presents further detail about the waste volume estimates, estimated waste generation schedules, and waste characterization data that are used as the basis for the Remedial Investigation/ Feasibility Study (RI/FS) alternative development and evaluation.

## 1.1 "AS-GENERATED" WASTE VOLUME ESTIMATE

As described in Chapter 2, the as-generated (AG) waste volume estimate from the waste generation forecast (WGF) was used to predict as-disposed (AD) waste volumes for the On-site Disposal Alternative and to provide the basis for waste shipment analysis in the Off-site Disposal Alternative.

Figure A-1 and Figure A-2 present the annual base as-generated waste volume estimates for Fiscal Year (FY) 2014 to FY 2043 by material type and by waste type, respectively. The base as-generated waste volume estimates do not include uncertainty.

Table A-1 shows the annual base as-generated waste volume estimate for FY 2014 to FY 2043 by material type, waste type, and year. Table A-2 provides the total base as-generated waste volume estimate for FY 2014 to FY 2043 by project, material type, and waste type, per the WGF, with subtotals for the following timeframes:

- FY 2014 to FY 2024: FY 2024 is the estimated year when the Environmental Management Waste Management Facility [EMWMF] reaches maximum capacity based on a 25% uncertainty allowance added to the as-disposed volume estimate as described below and in Section 2.2.2 of the RI/FS.
- FY 2022 to FY 2043: Estimated timeframe for operation of the new Environmental Management Disposal Facility [EMDF] under the On-site Disposal Alternative and for waste shipments under the Off-site Disposal Alternative.

Table A-3 provides the annual as-generated volume estimate (FY 2022 to FY 2043) with 25% uncertainty that is the basis for the Off-site Disposal Alternative waste shipments. The calculation, by year, is given by:

$$AG * 1.25 = AG25$$

Where AG is the as-generated waste volume in cubic yards ($yd^3$) for the year, and AG25 is the as-generated waste volume for the year including 25% uncertainty. Annual AG25 are summed for all years (FY 2014 to FY 2043) to obtain the total, 1.95 Million (M) total $yd^3$ of waste ($AG25_{total}$).

$$\sum AG25 = AG25_{total}$$

## 1.2 "AS-DISPOSED" WASTE VOLUME ESTIMATE

Prediction of as-disposed waste volumes for the RI/FS uses a methodology that starts with the as-generated waste volume estimates. Figure A-3 is a schematic showing the calculations used to obtain the final as-disposed volume from the as-generated waste volume estimates; these calculations are performed for each year and summed to obtain final totals. The following steps also outline the calculations that are used to obtain as-disposed volumes by year (as given in Figure A-3):

| | |
|---|---|
| 1. $AG = AG_{soil} + AG_{debris}$ | AG waste volume for the year is the sum of soil and debris AG waste volumes. |
| 2. $AG_{soil} / 1.2984 = AD_{soil}$ | The factor 1.2984 is the density ratio of as-disposed to as-generated soil (1.61/1.24) used to calculate the AD soil volume. $AD_{soil}$ is defined in Appendix A of the 2004 CARAR[1] and revised per the 2009 CARAR, Section 3.1. |
| 3. $AG_{debris} / 2.01235 = AD_{debris}$ | The factor 2.01235 is the density ratio of as-disposed to as-generated debris (1.63/0.81) used to calculate the AD debris volume. $AD_{debris}$ is defined in the 2004 CARAR, Appendix A for general construction debris. |
| 4. $AD_{debris} * 2.26 =$ Total Fill Required | The factor 2.26 provides the Total Fill volume required when disposing of debris, and is based on operational experience as described in the 2012 CARAR, Section 3.2. |
| 5. Total Fill Required $- AD_{soil} =$ Clean Fill | Clean fill is additional material that is required over and above the available waste soil ($AD_{soil}$). It is possible for $AD_{soil}$ to exceed the Total Fill Required, in which case there will be excess volume of waste soil fill, and no Clean Fill required that year. |
| 6. $AD = AD_{debris} + AD_{soil} +$ Clean Fill | AD waste volume total for the year is the sum of $AD_{debris}$, $AD_{soil}$, and Clean Fill. |
| 7. $AD * 0.25 = U25$ | AD is multiplied by 0.25 to determine the 25% uncertainty allowance, U25. |
| 8. $AD + U25 = AD25$ | The uncertainty allowance is added to AD to obtain the AD plus uncertainty (AD25) for the year. |
| 9. $\sum AD25 = AD25_{total}$ | $AD25_{total}$ is the sum of AD25 for all years. |

Table A-4 shows the as-disposed waste volume estimate per year through FY 2043 and delineates the volume estimate by debris ($AD_{debris}$), waste used as fill ($AD_{soil}$), clean fill, excess soil waste, and the 25% uncertainty allowance added for the total AD25 yearly as-disposed waste volume with uncertainty. Based on the as-disposed waste volume estimate, the On-site Disposal Alternative assumes maximum capacity of EMWMF (2.18 M $yd^3$) is reached in FY 2024 and a new Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste disposal facility becomes operational in FY 2022, allowing overlap of approximately two years for operational flexibility. Table A-4 also shows the estimated dates when new disposal facility cells begin operation and reach capacity (capacity is 2.5 M $yd^3$), when CERCLA waste disposal is complete and disposal facility closure begins.

[1] CARAR is the Capacity Assurance Remedial Action Report.

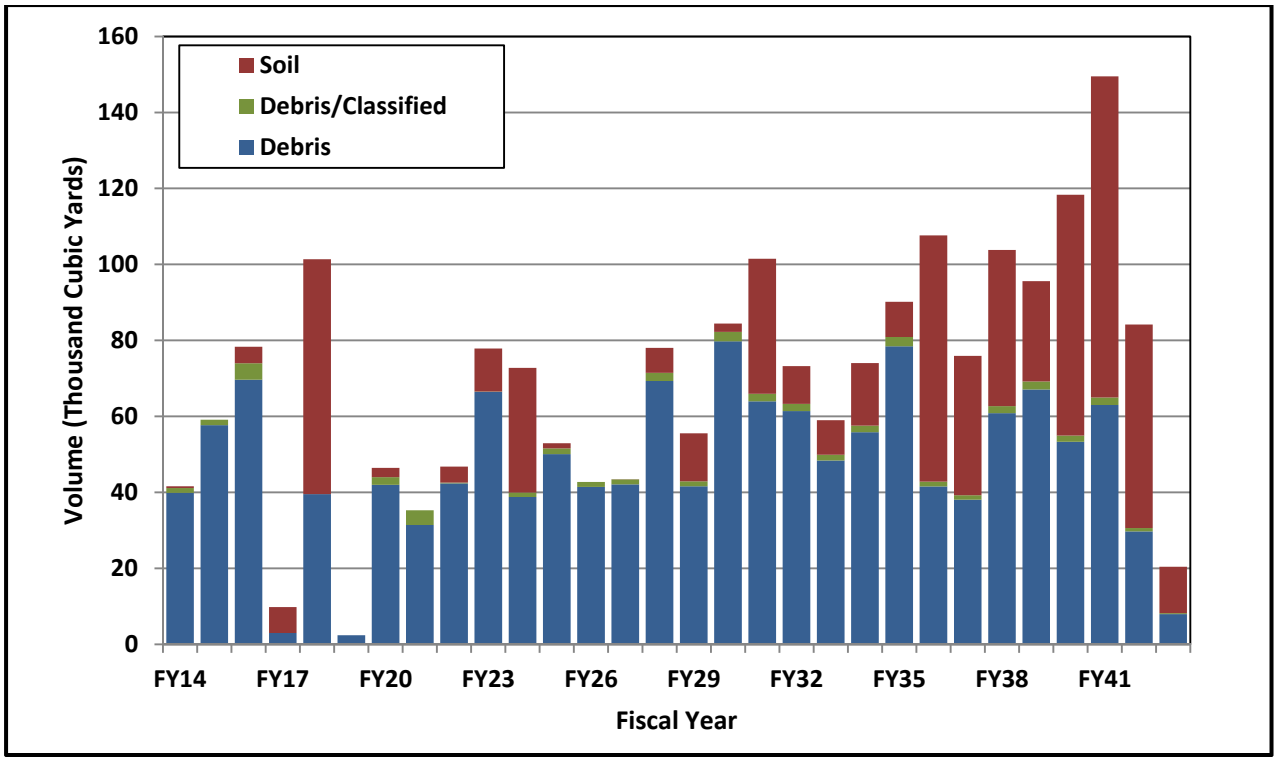



**Figure A-1. Base As-generated Waste Volume Estimate by Material Type (FY 2014 to FY 2043)**

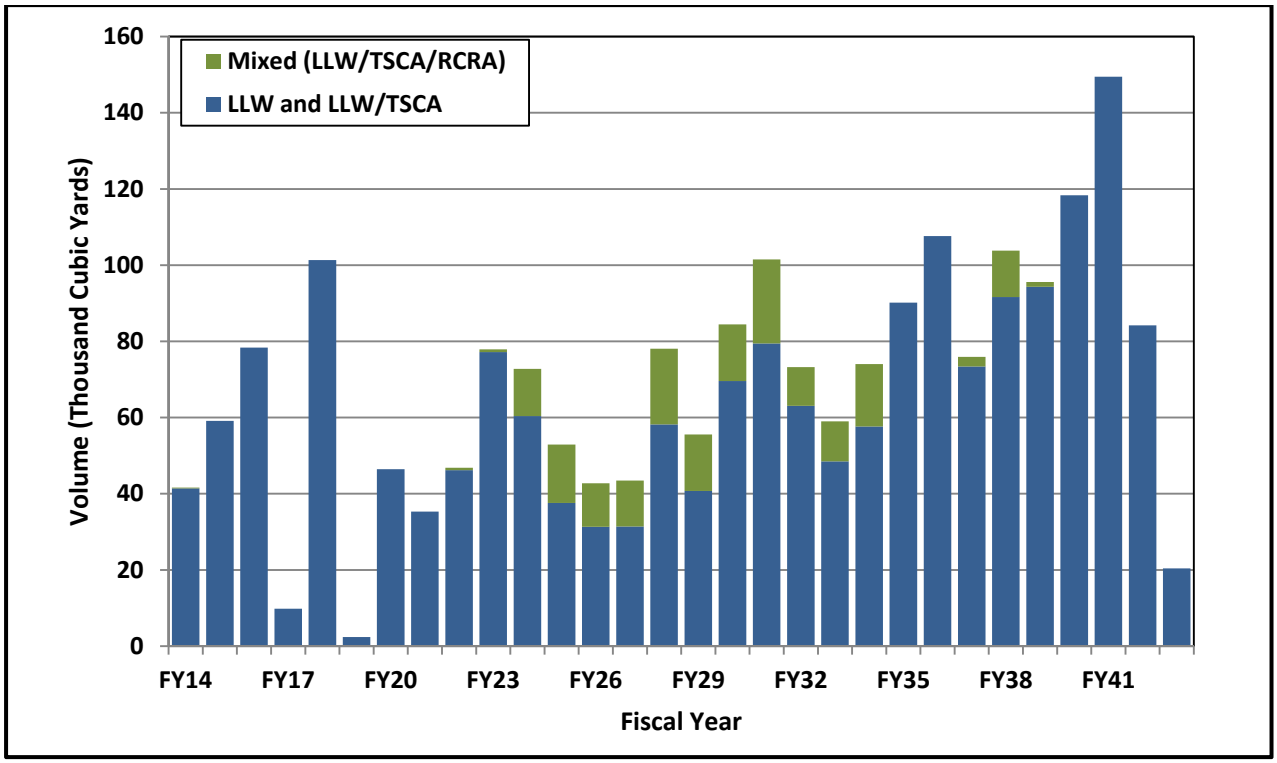



**Figure A-2. Base As-generated Waste Volume Estimate by Waste Type (FY 2014 to FY 2043)**

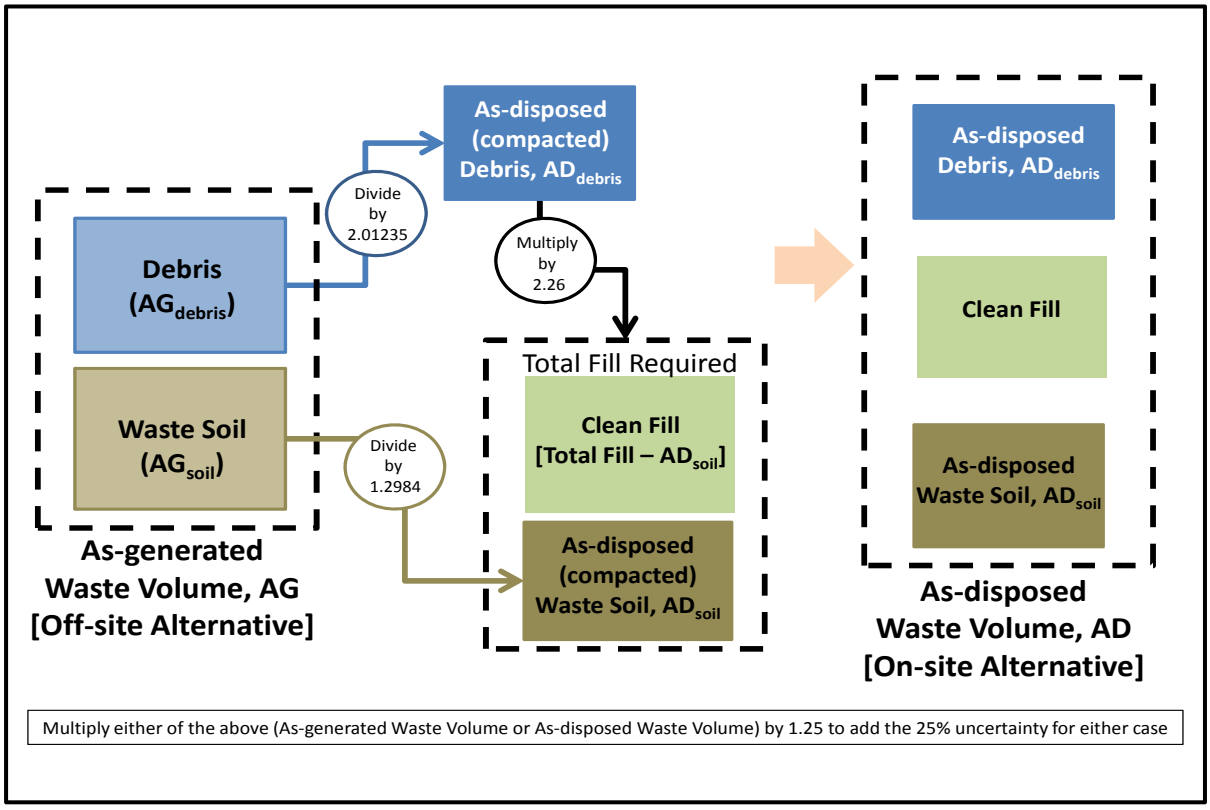



**Figure A-3. Schematic of Calculations to Determine As-disposed Waste Volumes**

## 1.3 WASTE CHARACTERIZATION DATA

The waste characterization results are in the form of a derived data set for radionuclide contaminants. The data set forms the basis for calculating transportation risk for the On- and Off-site Disposal Alternatives, and risk associated with natural phenomena (wind-borne [tornadic] contamination risk) for the On-site Disposal Alternative.

### 1.3.1 Radionuclide Characterization

A contaminant data set of mass-weighted average radionuclide concentrations was developed for use in evaluation of natural phenomena risk and transportation risk. The process used to develop the data set consisted of the following steps described in Section 1.3.1.1 through Section 1.3.1.3:

- Data collection
- Data set development exceptions
- Development of data set to be used for risk evaluation

A description of the process steps and calculations is provided below.

#### 1.3.1.1 Data Collection

The data collection process is described below.

1. Identified waste lots (WLs) for waste disposed at EMWMF: Using a Waste Transportation Management System[2] (WTMS) EMWMF Disposition Summary Report, a list of 134 WLs were identified.
2. Collected radionuclide contaminants of potential concern (COPCs) and expected value[3] concentration data for identified WLs:[4] The expected concentration value used for each radionuclide COPC is listed in Table A-5. Data were obtained from the following sources:
   a) The Waste Acceptance Criteria Forecast Analysis Capability Systems (WACFACS)[5] output report for the identified WL. WACFACS output reports contain values for COPCs that have a numerical limit in the EMWMF analytic waste acceptance criteria (WAC). These reports do not contain values for COPCs that have an unlimited EMWMF analytic WAC (e.g., Cs-137). In order to obtain concentration data for Cs-137 and other COPCs that are predominantly present in the Oak Ridge National Laboratory (ORNL) waste streams but have an unlimited EMWMF analytic WAC, data sources described in (b) and (c) below were used to obtain ORNL expected value concentration data.
   b) The auditable safety analysis-derived WAC section of the waste profile for the identified WL.
   c) Summary statistics from WL profiles.
3. Collected net weight data for identified WLs: As-disposed net weight data were obtained from the WTMS EMWMF Disposition Summary Report. Net weight data for each identified WL are shown in Table A-5.

#### 1.3.1.2 Data Set Development Exceptions

Exceptions to the process were made for the following WLs that were merged or split out from the original approved WL profile and therefore shipped under a different WL number. These WLs are:

- WL #6.998 is a commingled WL that includes wastes from WL # 6.49, 6.50, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57.
- WL #6.999 is a commingled WL that includes wastes from WL # 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47 and 6.48.
- WL #149.11 was shipped as WL #149.4.
- WL #200.999 is a commingled WL that includes wastes from WL # 200.01, 200.02, and 200.04.

---

[2] WTMS is a web-based tool that provides a central source for manually compiling and printing shipping documents required for the transport of waste and materials generated by the EM contractor.

[3] Symbolized by E(x) in waste lot summary statistics.

[4] Some radionuclide data values were reported as radionuclide concentration values for radionuclide pairs (e.g., Cm-243/244, Cm-245/246, Pu-239/240, Ru-106/Rh-106, U-233/234, and U-235/236). The radionuclide concentration values for Cm-243/244 were assigned to Cm-243, Cm-245/246 were assigned to Cm-245, Pu-239/240 were assigned to Pu-239, Ru-106/Rh-106 were assigned to Ru-106, U-233/234 were assigned to U-234, and U-235/236 were assigned to U-235.

[5] WACFACS is the primary tool used to ensure analytic WAC compliance at the EMWMF.

For these WLs:

- In Step 3 of Data Collection (see Section 1.3.1.1 above), the as-disposed volumes from the 2012 Capacity Assurance Remedial Action Report (DOE 2012) and reported radionuclide COPC concentrations for each individual WL were used to calculate a volume-weighted average concentration for each radionuclide COPC. The value was substituted as the concentration value C*ij* in Step 1 in Section 1.3.1.3 below for the commingled/shipped WL *j*, where $C_{ij}$ = concentration of radionuclide contaminant *i* in pCi/g, for WL *j*.

### 1.3.1.3 Development of Data Set for Natural Phenomena and Transportation Risk Evaluation

The steps and assumptions to develop the data set for natural phenomenon and transportation risk evaluation (provided in Appendix F) are summarized below:

1. Calculate the activity in pCi of each radionuclide with a reported value in each individual WL data set.

$$\text{Activity}_{ij} = C_{ij} * \text{Weight}_j * 453.6 \text{ g/lb}$$

where:

$\text{Activity}_{ij}$ = Activity of radionuclide *i* in pCi, for WL *j*
$\text{Weight}_j$ = Net weight in lb for WL *j* (all shipments)

2. Calculate the total activity in the data set for each radionuclide *i*.

$$\text{Activity}_i = \sum \text{Activity}_{ij}$$

where:

$\text{Activity}_i$ = Total activity in pCi, for radionuclide *i*, summed for all WLs *j =1 to m* with a reported value for radionuclide *i.*

3. Calculate the average concentration in pCi/g for each radionuclide present in the WL data set.

$$C_i = \text{Activity}_i / [(\text{Weight}_{tot}*(453.6 \text{ g/lb})] \quad \text{and} \quad \text{Weight}_{tot} = \sum \text{Weight}_j$$

where:

$\text{Weight}_{tot}$ = Total net weight in lb, summed for all WLs *j = 1 to m* in the data set with a reported value for radionuclide *i*

$C_i$ = Average concentration of radionuclide *i* in the data set (all WLs with a reported value for radionuclide *i*)

The calculation spreadsheet of mass-weighted average concentrations for radionuclide COPCs is provided in Table A-6.

## Table A-1. Base As-generated Waste Volume Estimate (FY 2014 to FY 2043)[a]

| As-generated Waste Volume Estimate ($yd^3$) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Waste Type** | **Material Type** | **FY 2014** | **FY 2015** | **FY 2016** | **FY 2017** | **FY 2018** | **FY 2019** | **FY 2020** | **FY 2021** | **FY 2022** | **FY 2023** | **FY 2024** |
| **LLW (includes LLW/TSCA)** | Debris | 39,699 | 57,678 | 69,642 | 2,986 | 39,549 | 2,383 | 41,984 | 31,398 | 41,929 | 65,846 | 27,803 |
| | Debris/Classified | 1,263 | 1,451 | 4,331 | 0 | 0 | 0 | 2,006 | 3,892 | 0 | 0 | 0 |
| | Soil | 450 | 0 | 4,375 | 6,820 | 61,803 | 0 | 2,467 | 0 | 4,242 | 11,348 | 32,563 |
| | **TOTAL** | **41,411** | **59,129** | **78,348** | **9,806** | **101,352** | **2,383** | **46,457** | **35,290** | **46,171** | **77,194** | **60,366** |
| **Mixed (LLW/RCRA, LLW/RCRA/TSCA)** | Debris | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 631 | 686 | 12,183 |
| | Debris/Classified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Soil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 224 |
| | **TOTAL** | **200** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **631** | **686** | **12,407** |
| **TOTAL** | | **41,611** | **59,129** | **78,348** | **9,806** | **101,352** | **2,383** | **46,457** | **35,290** | **46,802** | **77,880** | **72,773** |

| **Waste Type** | **Material Type** | **FY 2025** | **FY 2026** | **FY 2027** | **FY 2028** | **FY 2029** | **FY 2030** | **FY 2031** | **FY 2032** | **FY 2033** | **FY 2034** | **FY 2035** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LLW (includes LLW/TSCA)** | Debris | 36,265 | 31,322 | 31,391 | 51,612 | 35,640 | 67,369 | 57,442 | 57,205 | 45,780 | 54,920 | 80,901 |
| | Debris/Classified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Soil | 1,313 | 0 | 20 | 6,582 | 5,107 | 2,197 | 21,998 | 5,855 | 2,727 | 2,743 | 9,271 |
| | **TOTAL** | **37,579** | **31,322** | **31,411** | **58,194** | **40,747** | **69,567** | **79,439** | **63,060** | **48,507** | **57,663** | **90,172** |
| **Mixed (LLW/RCRA, LLW/RCRA/TSCA)** | Debris | 15,340 | 11,416 | 12,034 | 19,859 | 7,259 | 14,866 | 8,515 | 6,103 | 4,124 | 2,635 | 0 |
| | Debris/Classified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Soil | 0 | 0 | 0 | 0 | 7,562 | 0 | 13,537 | 4,073 | 6,372 | 13,739 | 0 |
| | **TOTAL** | **15,340** | **11,416** | **12,034** | **19,859** | **14,821** | **14,866** | **22,052** | **10,176** | **10,497** | **16,375** | **0** |
| **TOTAL** | | **52,918** | **42,738** | **43,445** | **78,052** | **55,568** | **84,433** | **101,491** | **73,236** | **59,003** | **74,038** | **90,172** |

| **Waste Type** | **Material Type** | **FY 2036** | **FY 2037** | **FY 2038** | **FY 2039** | **FY 2040** | **FY 2041** | **FY 2042** | **FY 2043** | **Total FY 2014 to FY 2043** |
|---|---|---|---|---|---|---|---|---|---|---|
| **LLW (includes LLW/TSCA)** | Debris | 42,840 | 36,708 | 58,925 | 67,914 | 54,946 | 64,960 | 30,638 | 8,200 | 1,335,875 |
| | Debris/Classified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12,943 |
| | Soil | 64,787 | 36,694 | 32,722 | 26,410 | 63,394 | 84,517 | 53,539 | 12,217 | 556,160 |
| | **TOTAL** | **107,627** | **73,402** | **91,648** | **94,324** | **118,340** | **149,477** | **84,177** | **20,417** | **1,904,978** |
| **Mixed (LLW/RCRA, LLW/RCRA/TSCA)** | Debris | 0 | 2,527 | 3,790 | 1,263 | 0 | 0 | 0 | 0 | 123,431 |
| | Debris/Classified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Soil | 0 | 0 | 8,375 | 0 | 0 | 0 | 0 | 0 | 53,882 |
| | **TOTAL** | **0** | **2,527** | **12,165** | **1,263** | **0** | **0** | **0** | **0** | **177,313** |
| **TOTAL** | | **107,627** | **75,929** | **103,812** | **95,588** | **118,340** | **149,477** | **84,177** | **20,417** | **2,082,291** |

LLW low-level waste
RCRA Resource Conservation and Recovery Act of 1976
TSCA Toxic Substance Control Act of 1976

[a] The waste generation forecast does not forecast the volume of classified waste other than for East Tennessee Technology Parl (ETTP). Three percent of debris (post-ETTP cleanup) is assumed to be classified (volumes not shown here).

**Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043)[a]**

| Work Breakdown Structure Project | Material Type | LLW and LLW/TSCA ($yd^3$) | | | Mixed- LLW/RCRA and LLW/RCRA/TSCA ($yd^3$) | | | Total EMWMF | Total EMDF | Total All (FY14-43) ($yd^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total LLW | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total Mixed | | | |
| 2026 Complex | Debris | | 10,012 | 10,012 | | | | | 10,012 | **10,012** |
| 2528 Complex | Debris | | 484 | 484 | | | | | 484 | **484** |
| 3019A & Ancillary Facilities | Debris | | 62,263 | 62,263 | | | | | 62,263 | **62,263** |
| 3525 Complex | Debris | | 7,659 | 7,659 | | | | | 7,659 | **7,659** |
| 3544 Complex | Debris | | 295 | 295 | | | | | 295 | **295** |
| 3608 Complex | Debris | | 4,466 | 4,466 | | | | | 4,466 | **4,466** |
| 4501/4505 Comlex | Debris | | 22,814 | 22,814 | | | | | 22,814 | **22,814** |
| 5505 Building | Debris | | 3,689 | 3,689 | | | | | 3,689 | **3,689** |
| 6010 and East BV Complex | Debris | | 44,916 | 44,916 | | | | | 44,916 | **44,916** |
| 9206 Complex | Debris | | 15,490 | 15,490 | | | | | 15,490 | **15,490** |
| 9212 Complex | Debris | | 113,571 | 113,571 | | | | | 113,571 | **113,571** |
| 9213 and 9401-2 Demolition | Debris | | 8,000 | 8,000 | | | | | 8,000 | **8,000** |
| Alpha-2 Complex | Debris | | 62,800 | 62,800 | | 10,190 | 10,190 | | 72,990 | **72,990** |
| Alpha-3 Complex | Debris | | 37,108 | 37,108 | | | | | 37,108 | **37,108** |
| Alpha-4 Complex | Debris | | 41,314 | 41,314 | | 13,771 | 13,771 | | 55,085 | **55,085** |
| Alpha-5 Complex | Debris | 169 | 85,836 | 86,005 | | 36,787 | 36,787 | 169 | 122,623 | **122,792** |
| Balance of Site Facilities | Debris | 25,115 | | 25,115 | | | | 25,115 | | **25,115** |
| BCV S-3 Ponds | Soil | | 1,094 | 1,094 | | | | | 1,094 | **1,094** |
| BCV White Wing Scrap Yard Remedial Action | Debris | | 10,017 | 10,017 | | | | | 10,017 | **10,017** |
| | Soil | | 62,506 | 62,506 | | | | | 62,506 | **62,506** |
| Beta-1 Complex | Debris | | 46,920 | 46,920 | | | | | 46,920 | **46,920** |
| Beta-3 Deactivation Only | Debris | | 19,502 | 19,502 | | | | | 19,502 | **19,502** |
| Beta-4 Complex | Debris | | 54,189 | 54,189 | | 21,598 | 21,598 | | 75,787 | **75,787** |
| Beta-4 LMD | Debris | 387 | | 387 | | | | 387 | | **387** |
| Biology Complex | Debris | | 29,088 | 29,088 | | | | - | 29,088 | **29,088** |
| | Soil | | 5,069 | 5,069 | | | | - | 5,069 | **5,069** |
| BV Chem Dev Lab Facilities | Debris | | 1,189 | 1,189 | | | | - | 1,189 | **1,189** |

**Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043) (Continued)**

| Work Breakdown Structure Project | Material Type | LLW and LLW/TSCA ($yd^3$) | | | Mixed- LLW/RCRA and LLW/RCRA/TSCA ($yd^3$) | | | Total EMWMF | Total EMDF | Total All (FY14-43) ($yd^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total LLW | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total Mixed | | | |
| BV Inactive Tanks & Pipelines | Debris | | 405 | 405 | | | | - | 405 | **405** |
| | Soil | | 158 | 158 | | | | - | 158 | **158** |
| BV Isotope Area Facilities (3038) | Debris | | 1,825 | 1,825 | | | | - | 1,825 | **1,825** |
| BV Reactor Area Facilities | Debris | | 7,076 | 7,076 | | 144 | 144 | - | 7,220 | **7,220** |
| | Soil | | 552 | 552 | | | | - | 552 | **552** |
| BV Remaining Inactive Tanks and Pipeline | Debris | | 23,446 | 23,446 | | | | - | 23,446 | **23,446** |
| BV Remaining Slabs and Soils | Debris | | 30,024 | 30,024 | | | | - | 30,024 | **30,024** |
| | Soil | | 46,660 | 46,660 | | | | - | 46,660 | **46,660** |
| BV Tank Area Facilities | Debris | | 3,433 | 3,433 | | | | - | 3,433 | **3,433** |
| | Soil | | 182 | 182 | | | | - | 182 | **182** |
| Central Neutralization Facility Closure | Debris | 5,743 | | 5,743 | | | | 5,743 | | **5,743** |
| Central Stack East Hot Cell Complex | Debris | | 5,647 | 5,647 | | | | - | 5,647 | **5,647** |
| Central Stack West Hot Cell Complex | Debris | | 4,356 | 4,356 | | | | - | 4,356 | **4,356** |
| Centrifuge Facilities | Debris | 27,229 | | 27,229 | | | | 27,229 | | **27,229** |
| | Debris/ Classified | 5,398 | | 5,398 | | | | 5,398 | | **5,398** |
| EGCR Complex | Debris | | 45,811 | 45,811 | | | | | 45,811 | **45,811** |
| Fire Station Complex | Debris | | 815 | 815 | | | | | 815 | **815** |
| Hot Storage Garden | Debris | | 190 | 190 | | | | | 190 | **190** |
| HPRR Complex | Debris | | 2,553 | 2,553 | | | | | 2,553 | **2,553** |
| K-1037 and K-1037-C | Debris | 35,960 | | 35,960 | | | | 35,960 | | **35,960** |
| | Debris/ Classified | 500 | | 500 | | | | 500 | | **500** |
| K-25 Facility D&D (ETTP) | Debris | 38,228 | | 38,228 | | | | 38,228 | | **38,228** |
| | Debris/ Classified | 1,263 | | 1,263 | | | | 1,263 | | **1,263** |
| K-27 Deactivation Waste | Debris | 1,106 | | 1,106 | | | | 1,106 | | **1,106** |

**Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043) (Continued)**

| Work Breakdown Structure Project | Material Type | LLW and LLW/TSCA ($yd^3$) | | | Mixed- LLW/RCRA and LLW/RCRA/TSCA ($yd^3$) | | | Total EMWMF | Total EMDF | Total All (FY14-43) ($yd^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total LLW | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total Mixed | | | |
| K-27 Demolition Waste | Debris | 65,911 | | 65,911 | | | | 65,911 | | **65,911** |
| | Debris/ Classified | 5,782 | | 5,782 | | | | 5,782 | | **5,782** |
| K-27 Tie Lines | Debris | 540 | | 540 | | | | 540 | | **540** |
| K-31 Facility | Debris | 55,049 | | 55,049 | | | | 55,049 | | **55,049** |
| LLLW Complex | Debris | | 1,773 | 1,773 | | | | | 1,773 | **1,773** |
| Material Difference 114–PBS40 | Debris | 5,010 | | 5,010 | | | | 5,010 | | **5,010** |
| MV HRE Facility | Debris | | 725 | 725 | | | | | 725 | **725** |
| MV LGWO Complex | Debris | | 7,859 | 7,859 | | | | | 7,859 | **7,859** |
| MV Waste Storage Facilities | Debris | | 1,129 | 1,129 | | | | | 1,129 | **1,129** |
| Newly Generated LLW/MLLW and Additional Waste PBS-42 | Debris | 6 | | 6 | | | | 6 | | **6** |
| ORNL Non-HF Well P&A | Debris | | 20 | 20 | | | | | 20 | **20** |
| ORNL Remaining Non-HF Well P&A | Debris | | 14 | 14 | | | | | 14 | **14** |
| ORNL Soils and Sediments | Debris | | 2,053 | 2,053 | | | | | 2,053 | **2,053** |
| | Soil | | 76,563 | 76,563 | | | | | 76,563 | **76,563** |
| ORNL Surveillance & Maintenance / Environmental Monitoring | Debris | 528 | | 528 | | | | 528 | | **528** |
| ORNL Water Quality Program | Debris | 15 | | 15 | | | | 15 | | **15** |
| Poplar Creek Facilities | Debris | 14,687 | | 14,687 | | | | 14,687 | | **14,687** |
| | Soil | 10,934 | | 10,934 | | | | 10,934 | | **10,934** |
| SE Services Group Complex | Debris | | 112 | 112 | | | | | 112 | **112** |
| Sewage Treatment Plant Complex | Debris | | 73 | 73 | | | | | 73 | **73** |
| Southeast Lab Support Complex | Debris | | 39 | 39 | | | | | 39 | **39** |
| Steam Plant Complex Legacy Material Disposition | Debris | | 80 | 80 | | | | | 80 | **80** |
| Tank Facilities Demolition | Debris | | 3,000 | 3,000 | | | | | 3,000 | **3,000** |
| TRU Treatment Contract | Debris | 50 | | 50 | | | | 50 | | **50** |
| | Soil | 450 | | 450 | | | | 450 | | **450** |
| TSCA Incinerator Facilities | Debris | 5,385 | | 5,385 | | | | 5,385 | | **5,385** |

**Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043) (Continued)**

| Work Breakdown Structure Project | Material Type | LLW and LLW/TSCA ($yd^3$) | | | Mixed- LLW/RCRA and LLW/RCRA/TSCA ($yd^3$) | | | Total EMWMF | Total EMDF | Total All (FY14-43) ($yd^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total LLW | FY14-24 (EMWMF) | FY22-43 (EMDF) | Total Mixed | | | |
| TWPC Complex | Debris | | 3,106 | 3,106 | | | | | 3,106 | **3,106** |
| UEFPC Remaining Slabs and Soils | Debris | | 116,354 | 116,354 | | 40,460 | 40,460 | | 156,814 | **156,814** |
| | Soil | | 234,840 | 234,840 | | 41,692 | 41,692 | | 276,532 | **276,532** |
| UEFPC Sediments - Streambed and Lake Reality | Soil | | | | | 11,966 | 11,966 | | 11,966 | **11,966** |
| UEFPC Soils | Soil | | 3,154 | 3,154 | | | | | 3,154 | **3,154** |
| UEFPC Soils 81-10 Area | Debris | | | - | | 280 | 280 | | 280 | **280** |
| | Soil | 31,813 | 1,313 | 33,126 | | 224 | 224 | 31,813 | 1,537 | **33,350** |
| Y-12 Surveillance & Maintenance/ Environmental Monitoring | Debris | | | - | 200 | | 200 | 200 | | **200** |
| Y-12 Salvage Yard | Debris | 20 | | 20 | | | | 20 | | **20** |
| Zone 2 Remedial Action | Debris | 105,096 | | 105,096 | | | | 105,096 | | **105,096** |
| | Soil | 80,871 | | 80,871 | | | | 80,871 | | **80,871** |
| **TOTAL VOLUME** | | **523,245** | **1,381,733** | **1,904,978** | **200** | **177,112** | **177,312** | **523,445** | **1,558,845** | **2,082,291** |

LLW = low-level waste; RCRA = Resource Conservation and Recovery Act of 1976; TSCA = Toxic Substance Control Act of 1976

[a] The waste generation forecast does not forecast the volume of classified waste other than for ETTP. Three percent of debris (post-ETTP cleanup) is assumed to be classified (volumes not separated here).

**Table A-3. As-generated Waste Volume Estimate (FY 2022 to FY 2043)[a] with Uncertainty**

| As-generated Waste Volume Estimate ($yd^3$) with Uncertainty | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Waste Type** | **Material Type** | **FY 2022** | **FY 2023** | **FY 2024** | **FY 2025** | **FY 2026** | **FY 2027** | **FY 2028** | **FY 2029** |
| **LLW (includes LLW/TSCA)** | Debris + 25% | 6,384 | 1,940 | 33,705 | 43,972 | 37,978 | 38,062 | 62,580 | 43,214 |
| | Debris/Classified + 25% | 197 | 60 | 1,042 | 1,360 | 1,175 | 1,177 | 1,935 | 1,337 |
| | Soil + 25% | 0 | 0 | 0 | 1,642 | 0 | 24 | 8,227 | 6,383 |
| | **TOTAL** | **6,581** | **2,000** | **34,748** | **46,973** | **39,152** | **39,263** | **72,742** | **50,934** |
| **Mixed (LLW/RCRA, LLW/RCRA/TSCA)** | Debris +25% | 765 | 832 | 14,771 | 18,599 | 13,842 | 14,591 | 24,079 | 8,802 |
| | Debris/Classified +25% | 24 | 26 | 457 | 575 | 428 | 451 | 745 | 272 |
| | Soil +25% | 0 | 0 | 280 | 0 | 0 | 0 | 0 | 9,453 |
| | **TOTAL** | **788** | **857** | **15,508** | **19,175** | **14,270** | **15,043** | **24,823** | **18,527** |
| **TOTAL with Uncertainty at 25%** | | **7,370** | **2,857** | **50,256** | **66,148** | **53,422** | **54,306** | **97,566** | **69,460** |

| **Waste Type** | **Material Type** | **FY 2030** | **FY 2031** | **FY 2032** | **FY 2033** | **FY 2034** | **FY 2035** | **FY 2036** | **FY 2037** |
|---|---|---|---|---|---|---|---|---|---|
| **LLW (includes LLW/TSCA)** | Debris +25% | 81,685 | 69,648 | 69,361 | 55,508 | 66,590 | 98,092 | 51,944 | 44,508 |
| | Debris/Classified +25% | 2,526 | 2,154 | 2,145 | 1,717 | 2,059 | 3,034 | 1,607 | 1,377 |
| | Soil +25% | 2,747 | 27,497 | 7,318 | 3,408 | 3,429 | 11,589 | 80,984 | 45,868 |
| | **TOTAL** | **86,958** | **99,299** | **78,825** | **60,633** | **72,079** | **112,715** | **134,534** | **91,752** |
| **Mixed (LLW/RCRA, LLW/RCRA/TSCA)** | Debris +25% | 18,025 | 10,325 | 7,400 | 5,001 | 3,195 | 0 | 0 | 3,064 |
| | Debris/Classified +25% | 557 | 319 | 229 | 155 | 99 | 0 | 0 | 95 |
| | Soil +25% | 0 | 16,921 | 5,091 | 7,965 | 17,174 | 0 | 0 | 0 |
| | **TOTAL** | **18,583** | **27,565** | **12,720** | **13,121** | **20,469** | **0** | **0** | **3,158** |
| **TOTAL with Uncertainty at 25%** | | **105,541** | **126,864** | **91,545** | **73,754** | **92,547** | **112,715** | **134,534** | **94,911** |

| **Waste Type** | **Material Type** | **FY 2038** | **FY 2039** | **FY 2040** | **FY 2041** | **FY 2042** | **FY 2043** | **Total (FY 2022 to FY 2043)** |
|---|---|---|---|---|---|---|---|---|
| **LLW (includes LLW/TSCA)** | Debris +25% | 71,447 | 82,346 | 66,622 | 78,764 | 37,148 | 9,943 | 1,151,440 |
| | Debris/Classified +25% | 2,210 | 2,547 | 2,060 | 2,436 | 1,149 | 308 | 35,612 |
| | Soil +25% | 40,903 | 33,013 | 79,242 | 105,646 | 66,924 | 15,271 | 540,115 |
| | **TOTAL** | **114,559** | **117,905** | **147,925** | **186,846** | **105,221** | **25,521** | **1,727,167** |
| **Mixed (LLW/RCRA, LLW/RCRA/TSCA)** | Debris +25% | 4,595 | 1,532 | 0 | 0 | 0 | 0 | 149,418 |
| | Debris/Classified +25% | 142 | 47 | 0 | 0 | 0 | 0 | 4,621 |
| | Soil +25% | 10,468 | 0 | 0 | 0 | 0 | 0 | 67,353 |
| | **TOTAL** | **15,206** | **1,579** | **0** | **0** | **0** | **0** | **221,391** |
| **TOTAL with Uncertainty at 25%** | | **129,765** | **119,485** | **147,925** | **186,846** | **105,221** | **25,521** | **1,948,558** |

LLW = low-level waste; RCRA = Resource Conservation and Recovery Act of 1976; TSCA = Toxic Substance Control Act of 1976

[a] The waste generation forecast does not forecast the volume of classified waste other than for ETTP. Three percent of debris (post-ETTP cleanup) is assumed to be classified (given in Table).

**Table A-4. As-disposed Waste Volume Estimate**

| | Thru FY 2013 | FY 2014 | FY 2015 | FY 2016 | FY 2017 | FY 2018 | FY 2019 | FY 2020 | FY 2021 | FY 2022 | FY 2023 | FY 2024 | FY 2025 | FY 2026 | FY 2027 | FY 2028 | FY 2029 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EMWMF** | **(ACTUAL)** | | | | | | | | | | | | | | | | |
| Clean Fill= | 456,786 | 45,880 | 66,406 | 79,707 | | | 2,676 | 47,504 | 39,633 | 37,909 | 63,413 | | | | | | |
| Excess Waste= | | | | | 1,899 | 3,184 | | | | | | | | | | | |
| Waste Fill= | 369,070 | 347 | | 3,370 | 3,353 | 44,416 | | 1,900 | | 3,267 | 8,740 | 24,946 | | | | | |
| Debris= | 496,075 | 20,454 | 29,383 | 36,760 | 1,484 | 19,653 | 1,184 | 21,860 | 17,537 | 18,220 | 31,926 | 136 | **NA** | **NA** | **NA** | **NA** | **NA** |
| **Total waste plus fill** | 1,321,931 | 66,681 | 95,789 | 119,836 | 6,737 | 67,253 | 3,860 | 71,264 | 57,170 | 59,396 | 104,079 | 25,082 | | | | | |
| **25% Uncertainty** | NA | 16,670 | 23,947 | 29,959 | 1,684 | 16,813 | 965 | 17,816 | 14,292 | 14,849 | 26,020 | 6,271 | | | | | |
| **Total Waste with Uncertainty** | 1,321,931 | 83,352 | 119,736 | 149,796 | 8,421 | 84,066 | 4,826 | 89,080 | 71,462 | 74,245 | 130,098 | 31,353 | | | | | |
| **Cumulative Waste (EMWMF) w/ 25%** | **1,321,931** | **1,405,283** | **1,525,019** | **1,674,814** | **1,683,235** | **1,767,301** | **1,772,127** | **1,861,207** | **1,932,669** | **2,006,913** | **2,137,012** | **2,168,364** | | | | | |
| **EMDF** | | | | | | | | | | | | | | | | | |
| Clean Fill= | | | | | | | | | | 6,621 | 2,567 | 44,293 | 56,945 | 47,997 | 48,754 | 75,198 | 38,422 |
| Excess Waste= | | | | | | | | | | | | | | | | | |
| Waste Fill= | | | | | | | | | | | | 306 | 1,011 | | 15 | 5,069 | 9,757 |
| Debris= | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | 2,930 | 1,136 | 19,734 | 25,644 | 21,238 | 21,579 | 35,516 | 21,318 |
| **Total waste plus fill** | | | | | | | | | | 9,551 | 3,703 | 64,333 | 83,600 | 69,235 | 70,349 | 115,783 | 69,497 |
| **25% Uncertainty** | | | | | | | | | | 2,388 | 926 | 16,083 | 20,900 | 17,309 | 17,587 | 28,946 | 17,374 |
| **Total Waste with Uncertainty** | | | | | | | | | | 11,939 | 4,629 | 80,416 | 104,501 | 86,544 | 87,936 | 144,729 | 86,872 |
| **Cumulative Waste (EMDF) w/ 25%** | | | | | | | | | | **11,939** | **16,567** | **96,983** | **201,484** | **288,028** | **375,964** | **520,693** | **607,564** |
| **Cumulative Waste (All) w/ 25%** | **1,321,931** | **1,405,283** | **1,525,019** | **1,674,814** | **1,683,235** | **1,767,301** | **1,772,127** | **1,861,207** | **1,932,669** | **2,018,852** | **2,153,579** | **2,265,347** | **2,369,848** | **2,456,392** | **2,544,328** | **2,689,057** | **2,775,928** |
| | | | | | | | | | | **(A)** | | **(B)** | | | | | |

| | FY 2030 | FY 2031 | FY 2032 | FY 2033 | FY 2034 | FY 2035 | FY 2036 | FY 2037 | FY 2038 | FY 2039 | FY 2040 | FY 2041 | FY 2042 | FY 2043 | Total (All Time) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EMDF** | | | | | | | | | | | | | | | |
| Clean Fill= | 90,664 | 46,705 | 63,453 | 49,038 | 51,944 | 83,717 | | 15,801 | 38,781 | 57,350 | 12,883 | 7,860 | | | 1,678,908 |
| Excess Waste= | | | | | | | 1,786 | | | | | | 6,827 | 200 | 13,895 |
| Waste Fill= | 1,692 | 27,368 | 7,646 | 7,008 | 12,695 | 7,140 | 48,112 | 28,261 | 31,652 | 20,341 | 48,825 | 65,094 | 34,408 | 9,209 | 825,021 |
| Debris= | 40,866 | 32,776 | 31,460 | 24,799 | 28,601 | 40,202 | 21,289 | 19,497 | 31,165 | 34,377 | 27,305 | 32,281 | 15,225 | 4,075 | 1,227,683 |
| **Total waste plus fill** | 133,222 | 106,850 | 102,559 | 80,845 | 93,239 | 131,059 | 71,187 | 63,559 | 101,598 | 112,068 | 89,013 | 105,235 | 56,460 | 13,484 | 3,745,507 |
| **25% Uncertainty** | 33,305 | 26,712 | 25,640 | 20,211 | 23,310 | 32,765 | 17,797 | 15,890 | 25,400 | 28,017 | 22,253 | 26,309 | 14,115 | 3,371 | 605,894 |
| **Total Waste with Uncertainty** | 166,527 | 133,562 | 128,199 | 101,056 | 116,549 | 163,824 | 88,983 | 79,449 | 126,998 | 140,085 | 111,266 | 131,544 | 70,575 | 16,855 | 4,351,401 (All Waste+Uncert.) |
| **Cumulative Waste (EMDF) w/ 25%** | **774,091** | **907,654** | **1,035,853** | **1,136,909** | **1,253,458** | **1,417,282** | **1,506,265** | **1,585,715** | **1,712,713** | **1,852,797** | **1,964,063** | **2,095,607** | **2,166,182** | **2,183,037** | **2,183,037 (EMDF)** |
| **Cumulative Waste (All) w/ 25%** | **2,942,456** | **3,076,018** | **3,204,217** | **3,305,273** | **3,421,822** | **3,585,646** | **3,674,630** | **3,754,079** | **3,881,077** | **4,021,161** | **4,132,427** | **4,263,971** | **4,334,546** | **4,351,401** | **4,351,401 (All Waste+Uncert.)** |
| | | **(C)** | | | | | | | **(D)** | | | | | **(E)** | |

**Time Line**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **(A)** | FY 2022: | EMDF Cells 1 and 2 start operations | **(D)** | FY 2038: | EMDF Cells 3 and 4 reach capacity (951,180 $yd^3$); Cells 5 and 6 start operations | | |
| | **(B)** | FY 2024: | EMWMF reaches capacity (~ 2.18 M $yd^3$) | **(E)** | FY 2043: | ORR Cleanup complete; EMDF closure begins | | |
| | **(C)** | FY 2031: | EMDF Cells 1 and 2 reach capacity (822,900 $yd^3$); Cells 3 and 4 start operations | | | | | |

**Table A-5. Radionuclide Concentration Data Set**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | | 1.80E-01 | | | | | | | | | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | | 2.18E+01 | | | 2.10E+00 | | | | | | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | | 2.00E-01 | | | | | | | | | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | | | | | | | | | | | |
| ETTP | 4.05 | K-710 | 2.80E+08 | | | | | | | | | | | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | | 3.08E-01 | | | | | | | | | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | | 3.20E-01 | | | | | | | | | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | | | | | | | | | | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | | | | | | | | | | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | | 4.42E-01 | | | 2.31E+00 | | | | | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | | 7.75E-02 | | | | | | | | | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | | 8.45E-02 | | | | | | | | | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | | 4.23E-01 | | | | | | | | | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | | 5.28E-02 | | | | | | | | | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | | | | | | | | | | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | | 2.35E-02 | | | | | | | | | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | | | | | | | | | | | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | | | | | | | | | | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | | | | | | | | | | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | | 1.79E-01 | | | | | | | | | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | | 1.20E-01 | | | 7.98E+00 | | | | | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | | 3.17E-01 | | | | | | | | | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | | 6.60E-01 | | | | | | | | | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | | | | | | | | | | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | | | | | | | | | | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | | | | | | | | | | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | | 4.33E-03 | | | | | | | | | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | | | | | | | | | | | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | | 2.01E-02 | | | | | | | | | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | | 1.61E-01 | | | | | | | | | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | | 4.93E+00 | | | | | | | | | |
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | | 1.67E-01 | | | | | | | | | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | | 3.52E+02 | | | 8.95E+01 | | | | | | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | | | | | | | | | | | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | | 5.00E-02 | | | | | | | | | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | | 1.50E-01 | | | | | | | | | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | | | | | | | | | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | | 2.00E-02 | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | | 1.00E-02 | | | | | | | | | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | | 1.00E-02 | | | | | | | | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | | 1.75E+00 | | | | | | | | | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | | | | | | | | | | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | | 8.67E-02 | | | | | | | | | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | | 6.74E-01 | | | | | | | | | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | | | | | | | | | | | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | | | | | | | | | | | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | | | | | | | | | | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | | | | | | | | | | | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | | | | | | | | | | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | | | | | 8.60E-02 | | | | | | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | | 4.82E+01 | | | 6.02E+00 | | | | | | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | | | | | | | | | | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | | 4.79E+02 | | | | | | | | | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | | 5.13E-01 | | | | | | | | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | | 1.35E-01 | | | | | | | | | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | | 4.02E-01 | | | | | | | | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | | | | | | | | | | | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | | | | | | | | | | | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | | | | | | | | | | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | | | | | | | | | | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | | | | | 1.32E+00 | | | | | | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | | 5.35E-01 | | | | | | | | | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | | | | | | | | | | | |
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | | 2.45E+00 | | | | | | | | | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | | | | | | | | | | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | | | | | | | | | | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | | 1.32E+01 | | | 6.77E+00 | | | | | | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | | 5.33E+01 | | | 8.19E-01 | | | | | | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | | 1.82E+00 | | | | | | | | | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | | 6.91E+01 | | | 1.21E+01 | | | | | | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | | 2.39E+02 | 8.56E+00 | | 8.97E-02 | | 1.28E+02 | 1.83E+04 | 2.57E+00 | 5.43E+00 | 2.68E-05 |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | | 9.98E+02 | | | 9.75E+00 | | | | | | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | | 3.94E+03 | | | 1.23E+01 | | | | | | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | | 3.41E+01 | | | 5.44E-03 | | | | | | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | | 8.47E+02 | 6.46E+00 | | 7.28E-02 | | 9.74E+01 | 4.58E+04 | 1.93E+00 | 4.23E+00 | 2.09E-05 |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | | 2.84E+02 | | | 3.23E+02 | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | | 2.89E+01 | | | 3.27E+01 | | | | | | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | | 4.12E+01 | | | | | | | | | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | | | | | 2.00E+00 | | | | | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | | 8.57E+00 | | | 7.79E+00 | | | | | | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | | | | | | | | | | | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | | 2.63E-01 | | | 7.57E+00 | | | | | | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | | | | | | | | | | | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | | 1.78E-01 | | | 7.40E+00 | | | | | | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | | 3.89E-01 | | | | | | | | | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | | 2.80E+00 | | | | | | | | | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | | 2.80E+00 | | | | | | | | | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | | 6.67E+01 | | | 3.29E+00 | | | | | | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | | 1.00E+03 | | | 1.12E+01 | | | | | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | | | | | | | | | | | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | | | | | 5.30E-02 | | | | | | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | | 6.18E+00 | | | 2.77E-01 | | | | | | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | | 1.69E+03 | | | 1.39E+02 | | | | | | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | | 7.40E+02 | 6.12E-01 | | 4.50E+00 | 1.63E-01 | | 9.44E+03 | | | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | | 2.41E+03 | | | 1.78E-03 | | | | | | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | | 1.08E+00 | | | | | | | | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | | 2.47E+00 | | | | | | | | | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | | 1.31E+00 | | | | | | | | | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | | 1.18E-01 | | | | | | | | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | | | | | | | | | | | |
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | | 6.51E-02 | | | | | | | | | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | | 3.76E+00 | | | | | | | | | |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | | 6.59E+00 | | | 1.90E-01 | | | | | | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | | | | | | | | | | | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | | 1.27E+01 | | | 6.19E+00 | | | | | | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | | 3.17E-01 | 3.95E-01 | | 3.73E+00 | | | | | | |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | | 3.47E-01 | 4.35E-01 | | 2.27E+00 | | | | | | |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | | 1.32E-01 | 1.45E-01 | 3.89E-01 | 1.60E+00 | | 7.00E-02 | | 4.00E-03 | | 4.00E-03 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | | | | | | | | | | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | 4.76E-01 | 1.83E-01 | | | 1.10E+00 | | 1.40E-01 | | 7.00E-02 | | 1.47E-01 |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | | | | | 1.34E+01 | | | | | | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | | 1.63E-01 | | | | | | | | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | | | | | | | | | | | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | | 8.77E-02 | | | | | | | | | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | | | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | | | | | | | | | | | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | | | | | | | | | 5.31E+01 | 2.10E+00 | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | | | | | | | | | | | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | | | | | | | | | | | |
| ETTP | 4.05 | K-710 | 2.80E+08 | | | | | | | | | | | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | | | | | | | | | | | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | | | | | | | | | | | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | | | | | | | | | | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | | | | | | | | | | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | | | | | | | | | 2.95E+01 | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | | | | | | | | | | | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | | | | | | | | | | | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | | | | | | | | | | | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | | | | | | | | | | | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | | | | | | | | | | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | | | | | | | | | | | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | | | | | | | | | | | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | | | | | | | | | | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | | | | | | | | | | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | | | | | | | | | | | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | | | | | | | | | | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | | | | | | | | | | | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | | | | | | | | | | | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | | | | | | | | | | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | | | | | | | | | | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | | | | | | | | | | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | | | | | | | | | | | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | | | | | | | | | | | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | | | | | | | | | | | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | | | | | | | | | | | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | | | | | | | | | | | |
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | | | | | | | | | | | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | | | | | | | | | 7.45E+00 | 1.53E-02 | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | | | | | | | | | | | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | | | | | | | | | | | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | | | | | | | | | | | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | | | | | | | | | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | | | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | | | | | | | | | | | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | | | | | | | | | | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | | | | | | | | | | | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | | | | | | | | | | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | | | | | | | | | | | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | | | | | | | | | | | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | | | | | | | | | | | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | | | | | | | | | | | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | | | | | | | | | | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | | | | | | | | | | | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | | | | | | | | | | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | | | | | | | | | 4.58E+00 | | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | | | | | | | | | 2.23E+02 | | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | | | | | | | | | | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | | | | | | | | | | 4.50E-03 | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | | | | | | | | | | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | | | | | | | | | | | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | | | | | | | | | | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | | | | | | | | | | | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | | | | | | | | | | | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | | | | | | | | | | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | | | | | | | | | | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | | | | | | | | | | 6.33E-01 | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | | | | | | | | | | | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | | | | | | | | | | | |
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | | | | | | | | | | | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | | | | | | | | | | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | | | | | | | | | | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | | | | | | | | | 6.98E+02 | | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | | | | | | | | | 1.22E-02 | 5.26E-05 | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | | | | | | | | | | | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | | | | | | | | | 1.80E-01 | 7.71E-04 | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | | 1.82E+02 | | 1.98E+03 | 7.08E+02 | 5.51E+02 | 1.35E+03 | | 1.02E-02 | 1.49E-05 | |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | | | | | | | | | | | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | | | | | | | | | | | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | | | | | | | | | 5.94E-04 | 7.89E-07 | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | | 1.88E+00 | | 8.93E+03 | 2.98E+01 | 6.64E+00 | 8.93E+00 | | 7.95E-03 | 1.05E-05 | |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | | | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | | | | | | | | | | | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | | | | | | | | | 3.78E+03 | 9.46E-02 | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | | | | | | | | | 2.67E+00 | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | | 6.57E+03 | | 3.83E+03 | | | | | 6.06E+02 | | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | | | | | | | | | | | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | | | | | | | | | | | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | | | | | | | | | | | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | | | | | | | | | | | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | | | | | | | | | | | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | | | | | | | | | | | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | | | | | | | | | | | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | | | | | | | | | | | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | | | | | | | | | 5.14E+00 | 4.36E-02 | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | | | | 4.36E-01 | | | | | | | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | | 6.16E+00 | | 1.69E+04 | | | | | 1.68E+00 | 5.73E-03 | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | | | | | | | | | 1.95E-04 | 1.69E-05 | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | | | | | | | | | 2.07E-01 | 8.85E-03 | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | | 2.94E+02 | 2.48E+04 | 4.03E+04 | 4.57E+04 | 3.46E+04 | 9.44E+03 | | 6.47E+00 | 1.04E-02 | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | | | | | | | | | 3.42E-02 | 4.06E+01 | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | | | | | | | | | | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | | | | | | | | | | | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | | | | | | | | | | | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | | | | | | | | | | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | | | | | | | | | | | |
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | | | | | | | | | | | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | | 4.93E+00 | | 2.39E+04 | | 1.46E+00 | | | | | 9.70E+00 |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | | | | | | | | | 3.90E+03 | | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | | | | | | | | | | | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | | | | | | | | | | | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | | 1.26E-01 | | 4.81E-01 | 6.16E-01 | 6.44E-01 | 2.70E-01 | | 9.23E-01 | | 1.60E+00 |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | | 1.11E-01 | | 1.23E+00 | 5.10E-01 | 5.27E-01 | 2.28E-01 | | 5.16E-01 | | 1.40E+00 |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | | 7.30E-02 | | 7.30E-02 | 2.13E-01 | 2.42E-01 | 1.18E-01 | | 3.42E+00 | 2.28E+00 | 4.78E+00 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | | | | | | | | | 6.28E+01 | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | 1.48E-01 | 1.92E+01 | | 6.04E+00 | 1.08E+00 | 1.33E+00 | | 1.49E+00 | 3.32E+02 | 1.51E+00 | |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | | | | | | | | | 3.37E+01 | | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | | | | | | | | | 1.81E+00 | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | | | | | | | | | | | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | | | | | | | | | | | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | | | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | | | | | | 3.55E-01 | | | | | 1.00E-01 |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | | | | | | 7.60E-01 | | | | | 5.61E+01 |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | | | | | | 1.95E-01 | | | | | 1.00E-01 |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | | | | | | 6.23E-01 | | | | | 4.35E-02 |
| ETTP | 4.05 | K-710 | 2.80E+08 | | | | | | 6.26E-02 | | | | | 6.00E-02 |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | | | | | | | | | | | 1.06E-01 |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | | | | | | 4.50E-01 | | | | | 1.37E+00 |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | | | | | | | | | | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | | | | | | | | | | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | | | | | | | | | | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | | | | | | 1.32E-01 | | | | | 2.79E-02 |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | | | | | | 1.62E-01 | | | | | 5.67E-02 |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | | | | | | 5.38E-01 | | | | | 4.22E-01 |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | | | | | | 4.80E-02 | | | | | 5.87E-02 |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | | | | | | 3.63E-01 | | | | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | | | | | | 1.60E-02 | | | | | 1.00E-02 |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | | | | | | 8.90E-01 | | | | | 5.62E-02 |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | | | | | | | | | | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | | | | | | | | | | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | | | | | | | | | | | 1.71E-01 |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | | | | | | 1.40E-01 | | | | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | | | | | | 2.96E-01 | | | | | 2.92E-01 |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | | | | | | 1.71E-01 | | | | | 2.74E+00 |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | | | | | | | | | | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | | | | | | | | | | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | | | | | | 2.58E-01 | | | | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | | | | | | 1.28E-01 | | | | | 7.21E-03 |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | | | | | | | | | | | 2.33E-01 |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | | | | | | 3.91E-01 | | | | | 8.43E-02 |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | | | | | | 1.32E-02 | | | | | 3.20E-02 |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | | | | | | 6.83E-02 | | | | | 2.52E+00 |
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | | | | | | 3.83E-01 | | | | | 8.33E-02 |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | | | | | | 1.49E+00 | | | | | 1.05E+01 |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | | | | | | | | | | | 6.00E-02 |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | | | | | | 4.00E-02 | | | | | 4.00E-02 |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | | | | | | 3.00E-02 | | | | | 8.00E-02 |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | | | | | | | | | | | 6.00E-02 |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | | | | | | 1.60E-01 | | | | | 5.00E-02 |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | | | | | | 9.00E-02 | | | | | 4.30E-01 |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | | | | | | | | | | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | | | | | | 1.62E+00 | | | | | 4.40E-01 |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | | | | | | | | | | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | | | | | | 2.26E-01 | | | | | 3.93E-02 |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | | | | | | 9.67E+00 | | | | | 6.71E+00 |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | | | | | | | | | | | 1.63E-01 |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | | | | | | 1.96E+00 | | | | | 8.01E-01 |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | | | | | | 6.41E+00 | | | | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | | | | | | 2.80E-02 | | | | | 3.00E-03 |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | | | | | | 2.75E-01 | | | | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | | | | | | | | | | | 6.80E-01 |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | | | | | | 1.13E+01 | | | | | 2.29E+00 |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | | | | | | 1.35E-01 | | | | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | | | | | | 1.68E-02 | | | | | 4.94E+01 |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | | | | | | 1.17E+02 | | | | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | | | | | | 2.20E-02 | | | | | 1.22E-02 |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | | | | | | 6.80E-02 | | | | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | | | | | | | | | | | 2.43E-02 |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | | | | | | | | | | | 6.29E-02 |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | | | | | | | | | | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | | | | | | | | | | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | | | | | | 3.74E-01 | | | | | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | | | | | | 7.44E+00 | | | | | 2.71E-01 |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | | | | | | | | | | | |
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | | | | | | 1.45E-01 | | | | | 1.17E+00 |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | | | | | | | | | | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | | | | | | | | | | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | | | | | | | | | | | 4.19E+00 |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | | | | | | 1.43E-02 | | | | | 3.28E+01 |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | | | | | | | | | | | 2.00E-01 |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | | | | | | 2.12E-01 | | | | | 4.54E+01 |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | | | | | | 2.33E-02 | | | | 6.62E+02 | 1.18E+02 |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | | | | | | 6.16E+00 | | | | | 1.03E+03 |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | | | | | | 1.31E+01 | | | | | 4.05E+03 |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | | | | | | 1.54E-03 | | | | | 3.99E+01 |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | | | | | | 2.06E-02 | | | | 1.24E+04 | 1.05E+03 |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | | | | | | 1.42E+00 | | | | | 6.93E+02 |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | | | | | | 1.45E-01 | | | | | 8.95E+01 |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | | | | | | 5.52E-01 | | | | | 1.17E+02 |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | | | | | | | | | | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | | | | | | | | | | 9.50E-01 | 4.24E+00 |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | | | | | | 2.51E-01 | | | | | 1.14E-01 |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | | | | | | | | | | | 1.32E+00 |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | | | | | | | | | | | 9.82E-02 |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | | | | | | 9.00E-02 | | | | | 3.21E-01 |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | | | | | | 8.48E-02 | | | | | 1.74E+00 |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | | | | | | 8.48E-02 | | | | | 1.91E-01 |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | | | | | | 8.48E-02 | | | | | 1.91E-01 |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | | | | | | | | | | | 3.25E+02 |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | | | | | | 4.25E+00 | | | | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | | | | | | | | | | 1.79E-01 | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | | | | | | | | | | 5.10E+00 | 3.34E+00 |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | | | | | | 4.70E-03 | | | | | 1.35E+00 |
| ORNL | 149.07 | NHF Process | 2.90E+07 | | | | | | 2.43E+00 | | | | | 1.34E+03 |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | | | | | 1.26E+02 | 5.43E-01 | | | | 2.31E+02 | 1.41E+02 |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | | | | | | 1.07E-01 | | | | | 1.39E+03 |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | | | | | | | | | | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | | | | | | | | | | | 1.17E+00 |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | | | | | | 1.14E-01 | | | | | 1.52E+00 |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | | | | | | | | | | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | | | | | | | | | | | |
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | | | | | | 6.73E-02 | | | | | 3.93E-02 |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | | | | | | | 1.35E+02 | | | 3.06E+00 | 1.63E+01 |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | | | | | | | | | | | 4.66E+00 |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | | | | | | | | | | | 1.56E+00 |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | | | | | | | | | | | 9.12E+01 |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | | | 1.08E-01 | | | 3.70E-01 | | | | 2.62E-01 | 3.13E-01 |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | | | | | | 4.01E-01 | | | | 2.96E-01 | 4.57E-01 |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | | | 6.20E-02 | | | 1.28E-01 | 1.76E+00 | 4.02E-01 | | 1.13E-01 | 1.26E-01 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | | | | | | | | | | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | 1.04E+02 | 8.47E-01 | 4.69E-01 | 4.04E+01 | 6.23E+00 | 3.74E-01 | | | 1.00E+01 | 1.07E-01 | 4.65E-01 |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | | | | | | 2.15E-01 | | | | | 1.81E-01 |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | | | | | | | | | | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | | | | | | | | | | | 2.28E-01 |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | | | | | | 2.16E-01 | | | | | 4.21E-02 |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | | | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | | | | | | | | | 2.13E+01 | | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | | | | | | | | | 2.83E+00 | | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | | | | | | | | | 6.34E+00 | | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | | | | | | | | | 1.29E+00 | | |
| ETTP | 4.05 | K-710 | 2.80E+08 | | | | | | | | | 7.71E+00 | | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | | | | | | | | | | | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | | | | | | | | | | | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | | | | | | | | | 1.48E+00 | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | | | | | | | | | 1.08E+02 | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | | | | | | | | | 2.57E+01 | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | | | | | | | | | 1.22E+01 | | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | | | | | | | | | 2.85E+01 | | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | | | | | | | | | 1.64E+02 | | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | | | | | | | | | 1.92E+02 | | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | | | | | | | | | 6.65E+01 | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | | | | | | | | | 3.67E+00 | | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | | | | | | | | | 2.89E+00 | | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | | | | | | | | | 8.48E-01 | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | | | | | | | | | 1.08E+01 | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | | | | | | | | | 1.66E+00 | | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | | | | | | | | | 7.37E-01 | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | | | | | | | | | 1.87E+01 | | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | | | | | | | | | 1.23E+01 | | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | | | | | | | | | 2.03E+00 | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | | | | | | | | | 1.20E+02 | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | | | | | | | | | 2.88E+02 | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | | | | | | | | | 1.45E+02 | | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | | | | | | | | | 2.17E+00 | | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | | | | | | | | | 9.30E+01 | | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | | | | | | | | | 3.92E+00 | | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | | | | | | | | | 7.35E+00 | | |
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | | | | | | | | | 4.75E+01 | | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | | | | | | | | | 3.31E+00 | | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | | | | | | | | | 4.92E+00 | | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | | | | | | | | | 1.44E+00 | | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | | | | | | | | | 1.29E+01 | | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | | | | | | | | | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | | | | | | | | | 4.79E+00 | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | | | | | | | | | 6.38E+01 | | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | | | | | | | | | 3.50E-01 | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | | | | | | | | | 1.01E+01 | | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | | | | | | | | | 4.89E+01 | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | | | | | | | | | 1.28E+01 | | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | | | | | | | | | 3.75E+02 | | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | | | | | | | | | 3.44E+00 | | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | | | | | | | | | 1.98E+00 | | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | | | | | | | | | 3.00E+01 | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | | | | | | | | | 1.71E-01 | | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | | | | | | | | | 3.82E+01 | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | | | | | | | | | 2.86E+01 | | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | | | | | | | | | 6.56E+02 | | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | | | | | | | | | 4.83E+02 | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | 1.08E+01 | | | | | | | | 2.65E+01 | | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | 1.83E+00 | | | | | | | | 1.29E+02 | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | | | | | | | | | 2.98E+01 | | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | 1.38E-01 | | | | | | | | 2.50E+00 | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | | | | | | | | | 3.22E+00 | | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | | | | | | | | | 5.97E+00 | | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | | | | | | | | | 1.79E+01 | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | | | | | | | | | 4.85E+01 | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | | | | | | | | | 7.98E+01 | | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | | | | | | | | | 8.27E-01 | | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | | | | | | | | | | | |
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | | | | | | | | | 1.12E+02 | | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | | | | | | | | | 6.33E+00 | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | | | | | | | | | 6.33E+00 | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | | | | | | | | | | | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | | | | | | | | | 6.43E-01 | | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | | | | | | | | | | | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | 4.77E+00 | | | | | | | | 9.51E+00 | | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | 4.15E+02 | 5.98E+01 | 7.90E-02 | 1.63E-08 | | | | 8.26E+03 | 1.02E-02 | | |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | 5.54E+02 | | | | | | | | 1.90E+00 | | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | 2.18E+03 | | | | | | | | 3.07E+00 | | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | 1.11E+02 | | | | | | | | 1.07E-02 | | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | 5.69E+02 | 4.67E+01 | 6.40E-02 | 1.30E-08 | | | | 2.75E+03 | 1.44E-01 | | |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | 1.31E+02 | | | | | | | | 5.64E+00 | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | | | | | | | | | 5.63E-01 | | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | 4.51E+01 | | | | | | | | 3.80E+02 | | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | | | | | | | | | 7.44E+00 | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | | | | | | | | 2.25E+01 | | 9.45E-01 | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | | | | | | | | | 6.14E+01 | | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | | | | | | | | | 2.58E+00 | | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | | | | | | | | | 3.61E+00 | | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | | | | | | | | | 1.60E+00 | | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | | | | | | | | | 1.60E+00 | | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | | | | | | | | | 3.43E+00 | | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | | | | | | | | | 3.43E+00 | | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | | | | | | | | | 1.87E+00 | | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | | | | | | | | | 1.62E-04 | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | | | | | | | | 7.07E-01 | | 3.50E-01 | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | | | | | | | | 1.52E+03 | 6.50E-02 | | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | 1.31E+00 | | | | | | | | 1.05E-01 | | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | 8.53E+01 | | | | | | | | 1.53E+02 | | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | | 1.21E+03 | 4.59E-01 | 4.08E-02 | | | 6.27E+04 | 7.52E+04 | 2.06E+02 | | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | 1.06E+03 | | | | | | | | 5.82E-02 | | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | | | | | | | | | 1.37E+01 | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | | | | | | | | | 1.18E+01 | | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | | | | | | | | | 3.33E+00 | | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | | | | | | | | | 7.31E+00 | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | | | | | | | | | | | |
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | | | | | | | | | 3.00E+02 | | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | | | | | | 1.82E+00 | | 1.50E+03 | | | |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | | | | | | | | | | | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | | | | | | | | | 4.35E+00 | | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | | | | | | | | | 1.18E+01 | | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | | | | | 3.48E-01 | | | 3.57E+00 | 1.27E+00 | 6.07E-01 | |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | | | | | 9.87E-01 | | | 5.25E-01 | 1.61E+00 | 5.75E-01 | |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | | 2.54E-01 | | | 8.94E-01 | 7.89E-01 | | 6.53E-01 | 4.46E+00 | 3.35E-01 | 4.00E-03 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | | | | | | | | | 1.68E+00 | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | | 2.19E+01 | | | | | | 1.40E+02 | 5.51E+00 | | |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | | | | | | | | | 1.67E+00 | | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | | | | | | | | | 3.15E+00 | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | | | | | | | | | 8.53E+00 | | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | | | | | | | | | 1.30E+01 | | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | | | | | | | | | | | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | | | | | 4.70E+02 | 1.97E+01 | 7.38E+00 | 7.78E+02 | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | | | | | 1.44E+01 | 2.32E+00 | 1.40E-01 | 5.51E+00 | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | | | | | 3.26E+02 | 9.79E+00 | 5.71E+00 | 1.98E+02 | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | | | | | 1.31E+01 | 9.22E-01 | | 4.65E+00 | |
| ETTP | 4.05 | K-710 | 2.80E+08 | | | | | 1.19E+01 | 4.57E-01 | | 9.97E+00 | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | | | | | 9.83E+01 | 4.73E+00 | | 2.60E+02 | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | | | | | 2.85E+02 | 1.45E+01 | | 7.32E+01 | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | | | | | 8.39E-01 | 3.67E-01 | | 3.51E+00 | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | | | | | 2.95E+01 | 3.44E+00 | | 2.50E+01 | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | | | | | 8.00E+00 | 4.12E-01 | | 3.62E+00 | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | | | | | 4.43E+01 | 2.82E+00 | 1.28E-01 | 4.67E+01 | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | | | | | 1.08E+01 | 6.78E-01 | 3.68E-01 | 9.71E+00 | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | | | | | 1.46E+02 | 2.14E+01 | 1.15E-01 | 1.01E+02 | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | | | | | 3.63E+00 | 2.96E-01 | 2.54E-01 | 2.96E+00 | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | | | | | 5.15E+02 | 2.24E+01 | 3.46E+00 | 1.87E+01 | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | | | | | 4.87E+01 | 2.52E+00 | 4.70E-01 | 1.37E+00 | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | | | | | 6.74E+02 | 2.34E+01 | 2.19E+00 | 2.11E+00 | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | | | | | 1.08E+01 | 1.11E+00 | | 1.14E+01 | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | | | | | 1.87E+01 | 1.03E+00 | | 5.20E+00 | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | | | | | 6.93E-01 | 1.88E-01 | | 1.41E+00 | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | | | | | 7.43E-01 | 1.36E-01 | | 6.76E-01 | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | | | | | 5.38E+02 | 2.61E+01 | 7.47E-01 | 5.44E+01 | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | | | | | 2.21E+00 | | | 5.44E+01 | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | | | | | 2.15E+00 | 1.38E+00 | | 1.28E+00 | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | | | | | 8.20E-01 | | | 3.53E-01 | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | | | | | 3.26E+03 | 1.31E+02 | | 1.49E+01 | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | | | | | 3.52E+03 | 1.79E+02 | | 2.38E+01 | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | | | | | 1.26E+03 | 6.33E+01 | | 5.38E+00 | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | | | | | 8.92E+02 | 4.76E+01 | | 2.64E+01 | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | | | | | 2.95E+03 | 1.59E+02 | | 8.38E+01 | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | | | | | 2.84E+03 | 1.44E+02 | | 1.80E+01 | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | | | | | 1.41E+03 | 9.13E+01 | 1.26E+01 | 5.49E+01 | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | | | | | 1.57E+02 | 1.23E+01 | | 2.44E+01 | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | | | | | 2.17E+00 | 1.08E-01 | 1.08E-02 | 2.17E+00 | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | | | | | 1.05E+02 | 5.45E+00 | | 1.75E+02 | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | | | | | 7.08E-01 | 7.40E-02 | | 8.42E-01 | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | | | | | | 7.27E-01 | | 4.33E+00 | |
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | | | | | 6.44E+00 | 4.47E+00 | | 4.52E+01 | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | | | | | 1.22E+02 | 4.03E+00 | 7.05E-06 | 2.58E+02 | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | | | | | 2.43E+00 | 7.00E-02 | 3.25E+01 | 1.73E+00 | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | | | | | 1.61E+01 | 8.00E-01 | 3.30E-01 | 3.50E+00 | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | | | | | 6.40E+00 | 5.00E-01 | 7.31E+00 | 9.60E+00 | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | | | | | 2.00E-02 | 1.00E-02 | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | | | | | 4.46E+02 | 2.25E+01 | 9.29E+00 | 1.02E+02 | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | | | | | 1.04E+02 | 1.06E+01 | 4.85E+00 | 3.42E+02 | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | | | | | 5.50E-01 | 8.00E-02 | 5.00E-02 | 5.30E-01 | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | | | | | 5.63E+01 | 3.30E+00 | 5.29E+00 | 4.62E+01 | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | | | | | 4.18E+01 | 5.51E+00 | | 7.26E+00 | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | | | | | 1.82E+01 | 1.42E+00 | | 1.71E+01 | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | | | | | 5.70E+03 | 3.56E+02 | | 2.65E+03 | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | | | | | 2.72E-01 | 5.34E-02 | | 2.56E-01 | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | | | | | 1.08E-01 | | | 3.04E-01 | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | | | | | 2.74E+00 | 2.45E-01 | | 7.33E+00 | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | | | | | 2.09E+01 | 2.10E+00 | | 2.31E+01 | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | | | | | 4.89E+02 | 2.76E+01 | | 5.91E+02 | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | | | | | 5.37E-03 | 3.10E-04 | | 5.51E-03 | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | | | | | 1.47E+02 | 4.18E+00 | 3.67E-01 | 5.95E+01 | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | | | | | 2.72E+02 | 1.87E+01 | 4.07E+00 | 1.47E+02 | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | | | | | 3.33E+01 | 6.08E-01 | 1.98E-01 | 2.98E+01 | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | | | | | 3.47E+02 | 2.26E+01 | 5.06E+01 | 2.15E+02 | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | | | | | 1.83E+02 | 7.37E+00 | | 2.58E+02 | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | | | | | 1.56E+03 | 6.40E+01 | | 2.78E+03 | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | | | | | 3.55E+03 | 1.16E+02 | 1.37E+01 | 1.63E+03 | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | | | | 1.10E+01 | 1.40E+02 | 7.99E+00 | 6.35E-01 | 1.68E+02 | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | | | | | 5.37E+02 | 3.26E+01 | 7.35E+00 | 7.29E+02 | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | | | | | 4.60E+01 | 2.61E+00 | 7.63E-01 | 1.96E+02 | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | | | | | 3.09E+01 | 1.71E+00 | | 1.99E+01 | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | | | | | 5.97E+00 | 2.01E+00 | | 2.87E+00 | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | | | | | 4.82E+00 | 2.12E-01 | | 4.47E-01 | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | | | | | 6.00E-02 | 1.07E+00 | 2.00E-02 | 1.82E+01 | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | | | | | 1.27E-01 | 1.32E+00 | | 2.22E+01 | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | | | | 2.50E+02 | | 1.45E+01 | 1.09E+01 | 2.57E+01 | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | | | | | 5.92E-01 | 6.90E-02 | | 7.49E-01 | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | | | | | 2.69E+02 | 1.47E+01 | 1.19E+01 | 1.08E+02 | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | | | | | 7.95E+00 | 4.46E-01 | | 6.04E+00 | |
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | | | | | 5.42E+02 | 1.81E+01 | | 4.59E+02 | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | | | | | 1.05E+03 | 6.14E+01 | 2.38E+01 | 5.24E+02 | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | | | | | 1.05E+03 | 6.14E+01 | 2.38E+01 | 5.24E+02 | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | | | | | 1.84E+00 | | | 1.10E+00 | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | | | | | 2.10E+00 | | | 1.20E+00 | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | | | | 3.08E-01 | 2.69E-01 | 4.24E-03 | 4.71E-02 | 5.24E-01 | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | | | | | 1.11E+00 | 1.25E-01 | | 8.22E-01 | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | | | | 7.53E+00 | 4.99E+00 | 2.33E-01 | 1.03E-02 | 5.31E+00 | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | | | | 6.12E-02 | 1.12E+00 | 1.38E-07 | 4.17E-08 | 1.94E-02 | |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | | | | | 3.17E+02 | 1.19E+00 | 4.82E-01 | 3.83E+00 | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | | | | | 4.07E+02 | 4.66E+00 | 1.92E+00 | 6.96E+00 | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | | | | 8.17E-03 | 3.77E-01 | 7.45E-09 | 4.72E-09 | 1.18E-03 | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | | | | 1.10E-01 | 5.06E+00 | 1.00E-07 | 6.32E-08 | 1.57E-02 | |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | | | | | 8.21E+01 | 4.05E+00 | 2.44E+00 | 4.63E+01 | |

**Table A-5. Radionuclide Concentration Data Set (Continued)**

**Units in pCi/g*

| Site | Waste Lot | WL Name | Net Weight (g) | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | | | | | 8.21E+00 | 4.25E-01 | 2.90E-01 | 4.36E+00 | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | | | | 3.09E+03 | 1.77E+02 | 2.11E-02 | 2.47E-02 | 7.61E-03 | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | | | | | 6.13E-01 | | | 5.18E-01 | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | 5.90E-01 | 7.60E-01 | | | 1.94E+00 | | | 2.67E+00 | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | | | | | 2.40E+02 | 8.07E+00 | 3.68E+00 | 5.41E+01 | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | | | | | 2.48E+02 | 1.93E+01 | 6.27E+00 | 2.41E+02 | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | | | | | 7.07E+00 | 3.56E-01 | | 7.83E+00 | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | | | | | 2.00E+01 | 1.18E+00 | 6.08E-01 | 1.72E+01 | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | | | | | 1.27E+02 | 4.86E+00 | 1.65E+00 | 6.26E+01 | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | | | | | 4.20E+02 | 6.07E+00 | 2.81E+01 | 4.11E+02 | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | | | | | 4.20E+02 | 6.07E+00 | 2.81E+01 | 4.11E+02 | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | | | | | 5.05E+00 | | | 4.36E+01 | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | | | | | | | | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | 5.42E-01 | 2.45E-01 | | | 3.15E-01 | | | 3.28E-01 | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | | 1.69E-04 | | | 3.01E+01 | 8.15E-01 | 3.21E-01 | 2.57E-02 | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | | | | 3.44E+00 | 4.71E-02 | 9.55E-04 | 1.55E-09 | 1.32E-02 | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | | | | 2.09E+02 | 1.96E+01 | 3.43E-01 | | 9.63E+00 | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | 8.52E+00 | 1.11E+01 | 1.65E+00 | 8.17E+02 | 1.34E+01 | 1.19E+00 | 1.08E+00 | 1.30E+02 | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | | | | 1.42E+00 | 9.47E-01 | 1.15E-03 | 1.01E-02 | 2.47E-02 | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | | | | | 5.30E+02 | 6.01E+01 | | 2.60E+02 | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | | | | | 2.21E+02 | 1.33E+01 | | 2.44E+02 | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | | | | | 8.39E+00 | 4.12E-01 | | 6.48E+00 | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | | | | | 6.98E+00 | 4.24E-01 | | 1.61E+00 | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | | | | | 9.80E+00 | 6.28E-01 | | 1.77E+00 | |
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | | | | | 8.44E+01 | 4.58E+00 | | 1.99E+01 | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | 3.16E+00 | 6.95E-01 | | | 1.21E+01 | 3.62E+00 | | 1.28E+01 | |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | | | | | 4.58E+00 | 2.14E-01 | 7.00E-02 | 2.91E-01 | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | | | | | 4.66E+00 | | | 4.61E-01 | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | | | | | 3.03E+02 | 1.29E+00 | | 1.19E+01 | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | 8.21E-01 | 1.98E-01 | | | 5.24E-01 | 3.99E-01 | | 4.52E-01 | |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | 7.48E-01 | 2.09E-01 | | | 5.58E-01 | 3.97E-01 | | 4.48E-01 | |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | 3.96E-01 | 2.50E-01 | | 1.57E+01 | 6.54E+00 | 1.09E-01 | 1.08E-01 | 1.25E+00 | |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | | | | | 9.03E+00 | 4.37E-01 | | 5.66E-01 | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | 6.78E-01 | 4.17E-01 | | | 2.74E+00 | 1.96E-01 | | 4.23E-01 | 1.46E+00 |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | | | | | 2.11E+01 | 1.64E-02 | 2.19E-01 | 6.60E-01 | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | | | | | | 4.59E-02 | | 2.67E-01 | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | | | | | | 1.70E+00 | 8.80E-01 | 1.35E+02 | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | | | | 1.10E+00 | 1.55E+02 | 8.72E+00 | 4.32E+00 | 6.72E+02 | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | | | | | 1.03E+04 | 6.23E+02 | 1.45E+02 | 8.07E+03 | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | | | | | 9.65E+01 | 3.56E+00 | | 5.12E+01 | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | | | | | 3.27E+01 | | 2.71E+00 | 2.51E+01 | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | | | | | 8.17E+00 | 3.99E-01 | | 5.88E+00 | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | | | | | 1.81E+01 | 1.42E+00 | | 1.71E+01 | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | | | | | 1.38E+00 | | 5.36E-01 | 1.28E+00 | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | *pCi* | | 1.56E+10 | | | | | | | | | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | *pCi* | | 4.84E+11 | | | 4.66E+10 | | | | | | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | *pCi* | | 5.17E+09 | | | | | | | | | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 4.05 | K-710 | 2.80E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | *pCi* | | 4.66E+06 | | | | | | | | | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | *pCi* | | 4.69E+07 | | | | | | | | | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | *pCi* | | 2.93E+08 | | | 1.53E+09 | | | | | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | *pCi* | | 2.64E+08 | | | | | | | | | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | *pCi* | | 3.27E+07 | | | | | | | | | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | *pCi* | | 8.07E+07 | | | | | | | | | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | *pCi* | | 3.12E+06 | | | | | | | | | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | *pCi* | | 1.60E+07 | | | | | | | | | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | *pCi* | | 1.63E+08 | | | | | | | | | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | *pCi* | | 1.02E+08 | | | 6.79E+09 | | | | | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | *pCi* | | 6.10E+08 | | | | | | | | | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | *pCi* | | 1.81E+09 | | | | | | | | | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | *pCi* | | 2.00E+08 | | | | | | | | | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | *pCi* | | 1.18E+07 | | | | | | | | | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | *pCi* | | 7.43E+08 | | | | | | | | | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | *pCi* | | 1.12E+10 | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | *pCi* | | 4.43E+07 | | | | | | | | | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | *pCi* | | 2.48E+11 | | | 6.30E+10 | | | | | | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | *pCi* | | 1.53E+07 | | | | | | | | | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | *pCi* | | 1.65E+08 | | | | | | | | | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | *pCi* | | 3.95E+06 | | | | | | | | | |
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | *pCi* | | 7.78E+05 | | | | | | | | | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | *pCi* | | 2.60E+05 | | | | | | | | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | *pCi* | | 1.59E+07 | | | | | | | | | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | *pCi* | | 2.11E+09 | | | | | | | | | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | *pCi* | | 3.59E+07 | | | | | | | | | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | *pCi* | | | | | | | | | | | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | *pCi* | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | *pCi* | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | *pCi* | | | | | 1.37E+08 | | | | | | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | *pCi* | | 2.32E+10 | | | 2.90E+09 | | | | | | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | *pCi* | | 8.55E+10 | | | | | | | | | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | *pCi* | | 9.37E+07 | | | | | | | | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | *pCi* | | 4.77E+07 | | | | | | | | | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | *pCi* | | 2.60E+07 | | | | | | | | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | *pCi* | | | | | 1.16E+09 | | | | | | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | *pCi* | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | *pCi* | | 7.03E+07 | | | | | | | | | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | *pCi* | | 2.40E+10 | | | | | | | | | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | *pCi* | | | | | | | | | | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | *pCi* | | 1.12E+11 | | | 5.74E+10 | | | | | | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | *pCi* | | 5.37E+10 | | | 8.25E+08 | | | | | | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | *pCi* | | 1.50E+07 | | | | | | | | | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | *pCi* | | 8.40E+10 | | | 1.47E+10 | | | | | | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | *pCi* | | 7.52E+10 | 2.69E+09 | | 2.82E+07 | | 4.03E+10 | 5.76E+12 | 8.08E+08 | 1.71E+09 | 8.43E+03 |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | *pCi* | | 3.18E+11 | | | 3.10E+09 | | | | | | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | *pCi* | | 7.08E+11 | | | 2.21E+09 | | | | | | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | *pCi* | | 6.19E+07 | | | 9.87E+03 | | | | | | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | *pCi* | | 3.86E+09 | 2.95E+07 | | 3.32E+05 | | 4.44E+08 | 2.09E+11 | 8.81E+06 | 1.93E+07 | 9.54E+01 |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | *pCi* | | 1.78E+12 | | | 2.02E+12 | | | | | | |
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | *pCi* | | 2.90E+10 | | | 3.28E+10 | | | | | | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | *pCi* | | 1.93E+09 | | | | | | | | | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | *pCi* | | | | | 1.71E+09 | | | | | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | *pCi* | | 5.68E+09 | | | 5.17E+09 | | | | | | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | *pCi* | | | | | | | | | | | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | *pCi* | | 3.52E+09 | | | 1.01E+11 | | | | | | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | *pCi* | | | | | | | | | | | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | *pCi* | | 8.73E+07 | | | 3.62E+09 | | | | | | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | *pCi* | | 2.84E+10 | | | | | | | | | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | *pCi* | | 3.78E+11 | | | | | | | | | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | *pCi* | | 1.39E+09 | | | | | | | | | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | *pCi* | | 3.10E+11 | | | 1.53E+10 | | | | | | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | *pCi* | | 5.98E+10 | | | 6.70E+08 | | | | | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | *pCi* | | | | | 1.12E+07 | | | | | | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | *pCi* | | 3.67E+08 | | | 1.64E+07 | | | | | | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | *pCi* | | 4.90E+10 | | | 4.03E+09 | | | | | | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | *pCi* | | 8.86E+11 | 7.33E+08 | | 5.39E+09 | 1.95E+08 | | 1.13E+13 | | | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | *pCi* | | 2.39E+10 | | | 1.76E+04 | | | | | | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | *pCi* | | 1.21E+11 | | | | | | | | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | *pCi* | | 4.51E+09 | | | | | | | | | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | *pCi* | | 2.04E+08 | | | | | | | | | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | *pCi* | | 1.79E+07 | | | | | | | | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Ag-110m | Am-241 | Am-243 | Bi-214 | C-14 | Cm-242 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | *pCi* | | 2.37E+09 | | | | | | | | | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | *pCi* | | 1.17E+08 | | | | | | | | | |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | *pCi* | | 5.09E+09 | | | 1.47E+08 | | | | | | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | *pCi* | | | | | | | | | | | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | *pCi* | | 3.51E+10 | | | 1.71E+10 | | | | | | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | *pCi* | | 2.88E+06 | 3.58E+06 | | 3.38E+07 | | | | | | |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | *pCi* | | 4.13E+08 | 5.18E+08 | | 2.70E+09 | | | | | | |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | *pCi* | | 7.36E+08 | 8.09E+08 | 2.17E+09 | 8.92E+09 | | 3.90E+08 | | 2.23E+07 | | 2.23E+07 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | *pCi* | 1.18E+08 | 4.53E+07 | | | 2.72E+08 | | 3.46E+07 | | 1.73E+07 | | 3.64E+07 |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | *pCi* | | | | | 1.21E+11 | | | | | | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | *pCi* | | 3.03E+08 | | | | | | | | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | *pCi* | | 2.21E+08 | | | | | | | | | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | *pCi* | | | | | | | | | | | |
| | | | **1.29E+12** | ***pCi*** | **1.18E+08** | **5.98E+12** | **4.78E+09** | **2.17E+09** | **2.55E+12** | **1.95E+08** | **4.11E+10** | **1.73E+13** | **8.57E+08** | **1.73E+09** | **5.87E+07** |
| | | | | ***g*** | **2.47E+08** | **6.52E+11** | **8.29E+09** | **5.58E+09** | **8.74E+10** | **1.20E+09** | **6.14E+09** | **1.52E+09** | **6.14E+09** | **3.19E+08** | **6.14E+09** |
| | | | | ***pCi/g*** | **4.76E-01** | **9.18E+00** | **5.77E-01** | **3.89E-01** | **2.91E+01** | **1.63E-01** | **6.69E+00** | **1.14E+04** | **1.39E-01** | **5.41E+00** | **9.55E-03** |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | *pCi* | | | | | | | | | | | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | *pCi* | | | | | | | | | 1.18E+12 | 4.66E+10 | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 4.05 | K-710 | 2.80E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | *pCi* | | | | | | | | | 1.95E+10 | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | *pCi* | | | | | | | | | 5.25E+09 | 1.08E+07 | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | *pCi* | | | | | | | | | | | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | *pCi* | | | | | | | | | | | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | *pCi* | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | *pCi* | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | *pCi* | | | | | | | | | 7.32E+09 | | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | *pCi* | | | | | | | | | 1.07E+11 | | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | *pCi* | | | | | | | | | | 8.03E+05 | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | *pCi* | | | | | | | | | | 5.57E+08 | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | *pCi* | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | *pCi* | | | | | | | | | | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | *pCi* | | | | | | | | | 5.92E+12 | | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | *pCi* | | | | | | | | | 1.23E+07 | 5.30E+04 | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | *pCi* | | | | | | | | | | | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | *pCi* | | | | | | | | | 2.19E+08 | 9.38E+05 | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | *pCi* | | 5.72E+10 | | 6.23E+11 | 2.23E+11 | 1.73E+11 | 4.25E+11 | | 3.21E+06 | 4.69E+03 | |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | *pCi* | | | | | | | | | 1.08E+03 | 1.43E+00 | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | *pCi* | | 8.58E+06 | | 4.07E+10 | 1.36E+08 | 3.03E+07 | 4.07E+07 | | 3.63E+04 | 4.79E+01 | |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | *pCi* | | | | | | | | | 1.77E+11 | 4.44E+06 | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | *pCi* | | | | | | | | | 2.28E+09 | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | *pCi* | | 4.36E+12 | | 2.54E+12 | | | | | 4.02E+11 | | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | *pCi* | | | | | | | | | | | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | *pCi* | | | | | | | | | | | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | *pCi* | | | | | | | | | | | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | *pCi* | | | | | | | | | | | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | *pCi* | | | | | | | | | | | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | *pCi* | | | | | | | | | | | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | *pCi* | | | | | | | | | 3.08E+08 | 2.61E+06 | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | *pCi* | | | | 5.06E+07 | | | | | | | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | *pCi* | | 1.31E+09 | | 3.59E+12 | | | | | 3.56E+08 | 1.22E+06 | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | *pCi* | | | | | | | | | 1.16E+04 | 1.00E+03 | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | *pCi* | | | | | | | | | 6.01E+06 | 2.57E+05 | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | *pCi* | | 3.52E+11 | 2.97E+13 | 4.82E+13 | 5.47E+13 | 4.14E+13 | 1.13E+13 | | 7.74E+09 | 1.24E+07 | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | *pCi* | | | | | | | | | 3.39E+05 | 4.03E+08 | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Co-57 | Co-60 | Cs-134 | Cs-137 | Eu-152 | Eu-154 | Eu-155 | F-59 | H-3 | I-129 | K-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | *pCi* | | | | | | | | | | | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | *pCi* | | 1.54E+08 | | 7.46E+11 | | 4.56E+07 | | | | | 3.03E+08 |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | *pCi* | | | | | | | | | 3.01E+12 | | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | *pCi* | | | | | | | | | | | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | *pCi* | | 1.14E+06 | | 4.36E+06 | 5.59E+06 | 5.84E+06 | 2.45E+06 | | 8.37E+06 | | 1.45E+07 |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | *pCi* | | 1.32E+08 | | 1.46E+09 | 6.07E+08 | 6.27E+08 | 2.71E+08 | | 6.14E+08 | | 1.67E+09 |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | *pCi* | | 4.07E+08 | | 4.07E+08 | 1.19E+09 | 1.35E+09 | 6.58E+08 | | 1.91E+10 | 1.27E+10 | 2.67E+10 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | *pCi* | | | | | | | | | 3.98E+10 | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | *pCi* | 3.66E+07 | 4.75E+09 | | 1.49E+09 | 2.67E+08 | 3.29E+08 | | 3.68E+08 | 8.21E+10 | 3.73E+08 | |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | *pCi* | | | | | | | | | 3.05E+11 | | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | *pCi* | | | | | | | | | 3.36E+09 | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | *pCi* | | | | | | | | | | | |
| | | | **1.29E+12** | ***pCi*** | **3.66E+07** | **4.77E+12** | **2.97E+13** | **5.58E+13** | **5.49E+13** | **4.16E+13** | **1.17E+13** | **3.68E+08** | **1.13E+13** | **6.07E+10** | **2.86E+10** |
| | | | | ***g*** | **2.47E+08** | **9.45E+09** | **1.20E+09** | **9.56E+09** | **8.54E+09** | **8.57E+09** | **8.29E+09** | **2.47E+08** | **5.91E+10** | **3.40E+10** | **6.81E+09** |
| | | | | ***pCi/g*** | **1.48E-01** | **5.05E+02** | **2.48E+04** | **5.83E+03** | **6.43E+03** | **4.85E+03** | **1.41E+03** | **1.49E+00** | **1.91E+02** | **1.79E+00** | **4.21E+00** |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | *pCi* | | | | | | 3.08E+10 | | | | | 8.66E+09 |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | *pCi* | | | | | | 1.69E+10 | | | | | 1.25E+12 |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | *pCi* | | | | | | 5.04E+09 | | | | | 2.59E+09 |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | *pCi* | | | | | | 8.42E+09 | | | | | 5.88E+08 |
| ETTP | 4.05 | K-710 | 2.80E+08 | *pCi* | | | | | | 1.75E+07 | | | | | 1.68E+07 |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | *pCi* | | | | | | | | | | | 1.60E+06 |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | *pCi* | | | | | | 6.60E+07 | | | | | 2.01E+08 |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | *pCi* | | | | | | 4.49E+08 | | | | | 9.50E+07 |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | *pCi* | | | | | | 6.26E+07 | | | | | 2.19E+07 |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | *pCi* | | | | | | 1.03E+08 | | | | | 8.04E+07 |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | *pCi* | | | | | | 2.83E+06 | | | | | 3.47E+06 |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | *pCi* | | | | | | 7.72E+07 | | | | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | *pCi* | | | | | | 1.09E+07 | | | | | 6.82E+06 |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | *pCi* | | | | | | 1.21E+08 | | | | | 7.62E+06 |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | *pCi* | | | | | | | | | | | 1.56E+08 |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | *pCi* | | | | | | 1.19E+08 | | | | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | *pCi* | | | | | | 5.68E+08 | | | | | 5.61E+08 |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | *pCi* | | | | | | 4.69E+08 | | | | | 7.50E+09 |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | *pCi* | | | | | | 5.36E+08 | | | | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | *pCi* | | | | | | 5.91E+09 | | | | | 3.34E+08 |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | *pCi* | | | | | | | | | | | 2.65E+09 |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | *pCi* | | | | | | 2.30E+08 | | | | | 4.97E+07 |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | *pCi* | | | | | | 6.07E+07 | | | | | 1.47E+08 |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | *pCi* | | | | | | 1.55E+08 | | | | | 5.73E+09 |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | *pCi* | | | | | | 1.02E+08 | | | | | 2.22E+07 |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | *pCi* | | | | | | 1.05E+09 | | | | | 7.37E+09 |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | *pCi* | | | | | | | | | | | 1.15E+08 |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | *pCi* | | | | | | 1.22E+07 | | | | | 1.22E+07 |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | *pCi* | | | | | | 3.30E+07 | | | | | 8.80E+07 |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | *pCi* | | | | | | | | | | | 9.64E+06 |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | *pCi* | | | | | | 3.16E+07 | | | | | 9.86E+06 |
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | *pCi* | | | | | | 7.00E+06 | | | | | 3.35E+07 |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | *pCi* | | | | | | 1.47E+07 | | | | | 3.99E+06 |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | *pCi* | | | | | | 5.50E+09 | | | | | 9.55E+08 |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | *pCi* | | | | | | 5.15E+08 | | | | | 3.57E+08 |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | *pCi* | | | | | | | | | | | 8.36E+07 |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | *pCi* | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | *pCi* | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | *pCi* | | | | | | 4.06E+09 | | | | | 1.66E+09 |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | *pCi* | | | | | | 5.37E+09 | | | | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | *pCi* | | | | | | 1.68E+06 | | | | | 1.80E+05 |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | *pCi* | | | | | | 3.24E+08 | | | | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | *pCi* | | | | | | | | | | | 1.09E+09 |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | *pCi* | | | | | | 5.46E+09 | | | | | 1.10E+09 |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | *pCi* | | | | | | 2.95E+07 | | | | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | *pCi* | | | | | | 3.00E+06 | | | | | 8.82E+09 |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | *pCi* | | | | | | 2.14E+10 | | | | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | *pCi* | | | | | | 7.77E+06 | | | | | 4.31E+06 |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | *pCi* | | | | | | 4.39E+06 | | | | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | *pCi* | | | | | | | | | | | 1.74E+07 |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | *pCi* | | | | | | | | | | | 1.06E+08 |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | *pCi* | | | | | | | | | | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | *pCi* | | | | | | 3.29E+08 | | | | | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | *pCi* | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | *pCi* | | | | | | 9.78E+08 | | | | | 3.56E+07 |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | *pCi* | | | | | | 1.42E+09 | | | | | 1.14E+10 |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | *pCi* | | | | | | | | | | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | *pCi* | | | | | | | | | | | 3.56E+10 |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | *pCi* | | | | | | 1.45E+07 | | | | | 3.31E+10 |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | *pCi* | | | | | | | | | | | 1.65E+06 |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | *pCi* | | | | | | 2.58E+08 | | | | | 5.52E+10 |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | *pCi* | | | | | | 7.33E+06 | | | | 2.08E+11 | 3.71E+10 |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | *pCi* | | | | | | 1.96E+09 | | | | | 3.28E+11 |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | *pCi* | | | | | | 2.34E+09 | | | | | 7.26E+11 |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | *pCi* | | | | | | 2.79E+03 | | | | | 7.24E+07 |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | *pCi* | | | | | | 9.40E+04 | | | | 5.66E+10 | 4.79E+09 |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | *pCi* | | | | | | 8.89E+09 | | | | | 4.34E+12 |
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | *pCi* | | | | | | 1.45E+08 | | | | | 8.98E+10 |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | *pCi* | | | | | | 2.59E+07 | | | | | 5.48E+09 |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | *pCi* | | | | | | | | | | 6.30E+08 | 2.81E+09 |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | *pCi* | | | | | | 4.92E+06 | | | | | 2.23E+06 |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | *pCi* | | | | | | | | | | | 1.77E+10 |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | *pCi* | | | | | | | | | | | 1.78E+08 |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | *pCi* | | | | | | 4.41E+07 | | | | | 1.57E+08 |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | *pCi* | | | | | | 6.18E+09 | | | | | 1.27E+11 |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | *pCi* | | | | | | 1.15E+10 | | | | | 2.58E+10 |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | *pCi* | | | | | | 4.21E+07 | | | | | 9.48E+07 |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | *pCi* | | | | | | | | | | | 1.51E+12 |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | *pCi* | | | | | | 2.54E+08 | | | | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | *pCi* | | | | | | | | | | 2.08E+07 | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | *pCi* | | | | | | | | | | 1.08E+09 | 7.07E+08 |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | *pCi* | | | | | | 2.79E+05 | | | | | 8.01E+07 |
| ORNL | 149.07 | NHF Process | 2.90E+07 | *pCi* | | | | | | 7.05E+07 | | | | | 3.89E+10 |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | *pCi* | | | | | 1.51E+11 | 6.50E+08 | | | | 2.77E+11 | 1.69E+11 |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | *pCi* | | | | | | 1.06E+06 | | | | | 1.38E+10 |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | *pCi* | | | | | | | | | | | 2.14E+09 |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | *pCi* | | | | | | 1.78E+07 | | | | | 2.37E+08 |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Kr-85 | Mn-54 | Nb-94 | Ni-59 | Ni-63 | Np-237 | Pb-210 | Pb-214 | Pm-147 | Pu-238 | Pu-239 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | *pCi* | | | | | | 2.45E+09 | | | | | 1.43E+09 |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | *pCi* | | | | | | | 4.21E+09 | | | 9.53E+07 | 5.09E+08 |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | *pCi* | | | | | | | | | | | 3.60E+09 |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | *pCi* | | | | | | | | | | | 7.94E+07 |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | *pCi* | | | | | | | | | | | 2.52E+11 |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | *pCi* | | | 9.80E+05 | | | 3.36E+06 | | | | 2.38E+06 | 2.84E+06 |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | *pCi* | | | | | | 4.77E+08 | | | | 3.52E+08 | 5.44E+08 |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | *pCi* | | | 3.46E+08 | | | 7.14E+08 | 9.82E+09 | 2.24E+09 | | 6.30E+08 | 7.03E+08 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | *pCi* | 2.57E+10 | 2.09E+08 | 1.16E+08 | 9.99E+09 | 1.54E+09 | 9.25E+07 | | | 2.47E+09 | 2.65E+07 | 1.15E+08 |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | *pCi* | | | | | | 1.94E+09 | | | | | 1.64E+09 |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | *pCi* | | | | | | | | | | | 4.55E+10 |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | *pCi* | | | | | | 5.44E+08 | | | | | 1.06E+08 |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | *pCi* | | | | | | | | | | | |
| | | | **1.29E+12** | *pCi* | **2.57E+10** | **2.09E+08** | **4.63E+08** | **9.99E+09** | **1.52E+11** | **1.55E+11** | **1.40E+10** | **2.24E+09** | **2.47E+09** | **5.44E+11** | **9.18E+12** |
| | | | | *g* | **2.47E+08** | **2.47E+08** | **5.83E+09** | **2.47E+08** | **1.44E+09** | **5.34E+11** | **5.61E+09** | **5.58E+09** | **2.47E+08** | **9.56E+09** | **7.81E+11** |
| | | | | *pCi/g* | **1.04E+02** | **8.47E-01** | **7.93E-02** | **4.04E+01** | **1.05E+02** | **2.91E-01** | **2.50E+00** | **4.02E-01** | **1.00E+01** | **5.69E+01** | **1.17E+01** |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | *pCi* | | | | | | | | | 1.85E+12 | | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | *pCi* | | | | | | | | | 6.28E+10 | | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | *pCi* | | | | | | | | | 1.64E+11 | | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | *pCi* | | | | | | | | | 1.74E+10 | | |
| ETTP | 4.05 | K-710 | 2.80E+08 | *pCi* | | | | | | | | | 2.16E+09 | | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | *pCi* | | | | | | | | | 7.95E+08 | | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | *pCi* | | | | | | | | | 9.51E+12 | | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | *pCi* | | | | | | | | | 1.71E+10 | | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | *pCi* | | | | | | | | | 4.15E+10 | | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | *pCi* | | | | | | | | | 1.10E+10 | | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | *pCi* | | | | | | | | | 3.13E+10 | | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | *pCi* | | | | | | | | | 1.13E+10 | | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | *pCi* | | | | | | | | | 1.41E+10 | | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | *pCi* | | | | | | | | | 2.50E+09 | | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | *pCi* | | | | | | | | | 3.92E+08 | | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | *pCi* | | | | | | | | | 6.67E+07 | | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | *pCi* | | | | | | | | | 1.16E+10 | | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | *pCi* | | | | | | | | | 1.51E+09 | | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | *pCi* | | | | | | | | | 6.27E+08 | | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | *pCi* | | | | | | | | | 3.60E+10 | | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | *pCi* | | | | | | | | | 3.38E+10 | | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | *pCi* | | | | | | | | | 1.13E+09 | | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | *pCi* | | | | | | | | | 3.63E+11 | | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | *pCi* | | | | | | | | | 5.98E+11 | | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | *pCi* | | | | | | | | | 6.69E+12 | | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | *pCi* | | | | | | | | | | | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | *pCi* | | | | | | | | | 2.46E+10 | | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | *pCi* | | | | | | | | | 5.48E+10 | | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | *pCi* | | | | | | | | | 1.81E+10 | | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | *pCi* | | | | | | | | | 1.67E+10 | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | *pCi* | | | | | | | | | 1.26E+10 | | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | *pCi* | | | | | | | | | 2.33E+09 | | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | *pCi* | | | | | | | | | 9.42E+09 | | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | *pCi* | | | | | | | | | 4.40E+08 | | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | *pCi* | | | | | | | | | 1.41E+10 | | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | *pCi* | | | | | | | | | 9.45E+08 | | |
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | *pCi* | | | | | | | | | 4.96E+09 | | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | *pCi* | | | | | | | | | 9.09E+06 | | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | *pCi* | | | | | | | | | 9.14E+07 | | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | *pCi* | | | | | | | | | 2.58E+11 | | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | *pCi* | | | | | | | | | 3.11E+11 | | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | *pCi* | | | | | | | | | 1.99E+10 | | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | *pCi* | | | | | | | | | | | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | *pCi* | | | | | | | | | | | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | *pCi* | | | | | | | | | 1.76E+09 | | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | *pCi* | | | | | | | | | | | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | *pCi* | | | | | | | | | | | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | *pCi* | | | | | | | | | | | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | *pCi* | | | | | | | | | 4.10E+09 | | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | *pCi* | | | | | | | | | 2.52E+10 | | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | *pCi* | | | | | | | | | 1.03E+07 | | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | *pCi* | | | | | | | | | 4.50E+10 | | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | *pCi* | | | | | | | | | 4.57E+10 | | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | *pCi* | | | | | | | | | 3.16E+11 | | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | *pCi* | | | | | | | | | 1.06E+11 | | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | *pCi* | 1.94E+09 | | | | | | | | 4.73E+09 | | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | *pCi* | 3.34E+08 | | | | | | | | 2.36E+10 | | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | *pCi* | | | | | | | | | 1.05E+10 | | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | *pCi* | 8.91E+06 | | | | | | | | 1.61E+08 | | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | *pCi* | | | | | | | | | 2.31E+09 | | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | *pCi* | | | | | | | | | 1.00E+10 | | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | *pCi* | | | | | | | | | 7.43E+11 | | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | *pCi* | | | | | | | | | 4.64E+10 | | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | *pCi* | | | | | | | | | 7.03E+10 | | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | *pCi* | | | | | | | | | | | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | *pCi* | | | | | | | | | 1.09E+08 | | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | *pCi* | | | | | | | | | 1.10E+12 | | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | *pCi* | | | | | | | | | 5.42E+08 | | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | *pCi* | | | | | | | | | 6.16E+08 | | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | *pCi* | | | | | | | | | | | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | *pCi* | | | | | | | | | 6.48E+08 | | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | *pCi* | | | | | | | | | | | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | *pCi* | 5.80E+09 | | | | | | | | 1.16E+10 | | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | *pCi* | 1.31E+11 | 1.88E+10 | 2.49E+07 | 5.13E+00 | | | | 2.60E+12 | 3.21E+06 | | |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | *pCi* | 1.76E+11 | | | | | | | | 6.06E+08 | | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | *pCi* | 3.91E+11 | | | | | | | | 5.51E+08 | | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | *pCi* | 2.01E+08 | | | | | | | | 1.94E+04 | | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | *pCi* | 2.60E+09 | 2.13E+08 | 2.92E+05 | 5.93E-02 | | | | 1.25E+10 | 6.57E+05 | | |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | *pCi* | 8.19E+11 | | | | | | | | 3.53E+10 | | |
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | *pCi* | | | | | | | | | 5.65E+08 | | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | *pCi* | 2.12E+09 | | | | | | | | 1.79E+10 | | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | *pCi* | | | | | | | | | 6.35E+09 | | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | *pCi* | | | | | | | | 1.49E+10 | | 6.27E+08 | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | *pCi* | | | | | | | | | 1.20E+09 | | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | *pCi* | | | | | | | | | 3.46E+10 | | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | *pCi* | | | | | | | | | 6.54E+09 | | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | *pCi* | | | | | | | | | 7.83E+08 | | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | *pCi* | | | | | | | | | 1.17E+11 | | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | *pCi* | | | | | | | | | 4.64E+11 | | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | *pCi* | | | | | | | | | 1.70E+09 | | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | *pCi* | | | | | | | | | 8.68E+09 | | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | *pCi* | | | | | | | | | 9.70E+03 | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | *pCi* | | | | | | | | 8.20E+07 | | 4.06E+07 | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | *pCi* | | | | | | | | 3.22E+11 | 1.38E+07 | | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | *pCi* | 7.78E+07 | | | | | | | | 6.23E+06 | | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | *pCi* | 2.47E+09 | | | | | | | | 4.44E+09 | | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | *pCi* | | 1.45E+12 | 5.49E+08 | 4.88E+07 | | | 7.51E+13 | 9.00E+13 | 2.47E+11 | | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | *pCi* | 1.05E+10 | | | | | | | | 5.76E+05 | | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | *pCi* | | | | | | | | | 1.53E+12 | | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | *pCi* | | | | | | | | | 2.15E+10 | | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | *pCi* | | | | | | | | | 5.19E+08 | | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | *pCi* | | | | | | | | | 1.11E+09 | | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | *pCi* | | | | | | | | | | | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Pu-240 | Pu-241 | Pu-242 | Pu-244 | Ra-226 | Ra-228 | Ru-106 | Sr-90 | Tc-99 | Th-228 | Th-229 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | *pCi* | | | | | | | | | 1.09E+13 | | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | *pCi* | | | | | | 5.68E+07 | | 4.67E+10 | | | |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | *pCi* | | | | | | | | | | | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | *pCi* | | | | | | | | | 2.22E+08 | | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | *pCi* | | | | | | | | | 3.26E+10 | | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | *pCi* | | | | | 3.16E+06 | | | 3.24E+07 | 1.15E+07 | 5.51E+06 | |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | *pCi* | | | | | 1.18E+09 | | | 6.25E+08 | 1.92E+09 | 6.85E+08 | |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | *pCi* | | 1.42E+09 | | | 4.99E+09 | 4.40E+09 | | 3.64E+09 | 2.49E+10 | 1.87E+09 | 2.23E+07 |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | *pCi* | | | | | | | | | 1.07E+09 | | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | *pCi* | | 5.42E+09 | | | | | | 3.46E+10 | 1.36E+09 | | |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | *pCi* | | | | | | | | | | | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | *pCi* | | | | | | | | | | | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | *pCi* | | | | | | | | | 1.51E+10 | | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | *pCi* | | | | | | | | | 5.85E+09 | | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | *pCi* | | | | | | | | | 1.71E+12 | | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | *pCi* | | | | | | | | | 3.27E+10 | | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | *pCi* | | | | | | | | | | | |
| | | | **1.29E+12** | *pCi* | **1.54E+12** | **1.47E+12** | **5.75E+08** | **4.88E+07** | **6.17E+09** | **4.46E+09** | **7.51E+13** | **9.30E+13** | **3.80E+13** | **3.23E+09** | **2.23E+07** |
| | | | | *g* | **8.87E+09** | **7.34E+09** | **1.52E+09** | **1.52E+09** | **6.78E+09** | **5.61E+09** | **1.20E+09** | **9.56E+09** | **1.04E+12** | **7.56E+09** | **5.58E+09** |
| | | | | *pCi/g* | **1.74E+02** | **2.01E+02** | **3.79E-01** | **3.22E-02** | **9.10E-01** | **7.95E-01** | **6.27E+04** | **9.73E+03** | **3.67E+01** | **4.27E-01** | **4.00E-03** |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-12 | 1.0 | BYBY RA | 8.66E+10 | *pCi* | | | | | 4.07E+13 | 1.71E+12 | 6.39E+11 | 6.74E+13 | |
| ORNL | 2.01 | SWSA 4 Remedial Action IHP-1 RA | 2.22E+10 | *pCi* | | | | | 3.20E+11 | 5.15E+10 | 3.11E+09 | 1.22E+11 | |
| ETTP | 3.00 | K-1070-A RA | 2.59E+10 | *pCi* | | | | | 8.42E+12 | 2.53E+11 | 1.48E+11 | 5.12E+12 | |
| ETTP | 4.02 | PWR K-1085-401 RA | 5.93E+07 | *pCi* | | | | | | | | | |
| ETTP | 4.03 | Blair Quarry Soils | 1.35E+10 | *pCi* | | | | | 1.77E+11 | 1.25E+10 | | 6.28E+10 | |
| ETTP | 4.05 | K-710 | 2.80E+08 | *pCi* | | | | | 3.33E+09 | 1.28E+08 | | 2.79E+09 | |
| ETTP | 4.06 | K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils | 1.51E+07 | *pCi* | | | | | 1.49E+09 | 7.16E+07 | | 3.94E+09 | |
| ETTP | 4.08 | Duct Island Soil Mounds | 1.47E+08 | *pCi* | | | | | 4.18E+10 | 2.13E+09 | | 1.07E+10 | |
| ETTP | 4.11 | K-711/K-766 Debris and Soils | 5.37E+08 | *pCi* | | | | | 4.51E+08 | 1.97E+08 | | 1.89E+09 | |
| ETTP | 4.12 | K-770 Scrap Yard Soils | 8.81E+10 | *pCi* | | | | | 2.60E+12 | 3.03E+11 | | 2.20E+12 | |
| ETTP | 4.14 | K-1093 Scrap Yard Debris | 6.63E+08 | *pCi* | | | | | 5.30E+09 | 2.73E+08 | | 2.40E+09 | |
| ETTP | 6.01 | K25 HMA-1 DD R2 | 3.41E+09 | *pCi* | | | | | 1.51E+11 | 9.60E+09 | 4.36E+08 | 1.59E+11 | |
| ETTP | 6.02 | K27 Units 1-7 ACM R2 (ARRA) | 3.87E+08 | *pCi* | | | | | 4.19E+09 | 2.63E+08 | 1.43E+08 | 3.76E+09 | |
| ETTP | 6.03 | K25 HMA-2 DD Rev 2 | 1.91E+08 | *pCi* | | | | | 2.78E+10 | 4.09E+09 | 2.19E+07 | 1.93E+10 | |
| ETTP | 6.04 | K-27 Units 402-8 & 402-9 Hazardous Materials Abatement | 5.90E+07 | *pCi* | | | | | 2.14E+08 | 1.75E+07 | 1.50E+07 | 1.75E+08 | |
| ETTP | 6.06 | K-25 Bldg Area 6 PER R1 | 2.13E+08 | *pCi* | | | | | 1.10E+11 | 4.77E+09 | 7.37E+08 | 3.97E+09 | |
| ETTP | 6.12 | K-25 Bldg Non-Purge Ext. Transite | 6.80E+08 | *pCi* | | | | | 3.31E+10 | 1.71E+09 | 3.20E+08 | 9.35E+08 | |
| ETTP | 6.13 | K-25 Bldg Area 5.1 PER R0 | 1.36E+08 | *pCi* | | | | | 9.15E+10 | 3.18E+09 | 2.97E+08 | 2.87E+08 | |
| ETTP | 6.14 | K-1232 Tank Farm Miscellaneous Debris R0 | 7.86E+07 | *pCi* | | | | | 8.46E+08 | 8.69E+07 | | 8.97E+08 | |
| ETTP | 6.16 | K-601 Misc Debris | 1.07E+09 | *pCi* | | | | | 2.00E+10 | 1.10E+09 | | 5.56E+09 | |
| ETTP | 6.17 | Building K-1030 Debris | 9.11E+08 | *pCi* | | | | | 6.31E+08 | 1.71E+08 | | 1.28E+09 | |
| ETTP | 6.18 | Building K-1024 Debris | 8.51E+08 | *pCi* | | | | | 6.32E+08 | 1.16E+08 | | 5.75E+08 | |
| ETTP | 6.19 | K-25/K-27 Bldg Struc Debris | 1.92E+09 | *pCi* | | | | | 1.03E+12 | 5.01E+10 | 1.44E+09 | 1.05E+11 | |
| ETTP | 6.27 | K-25/K-27 EMR Debris Material (K-27 ARRA) | 2.74E+09 | *pCi* | | | | | 6.05E+09 | | | 1.49E+11 | |
| ETTP | 6.28 | K-25 Lead Based Pain Debris | 5.54E+08 | *pCi* | | | | | 1.19E+09 | 7.63E+08 | | 7.10E+08 | |
| ETTP | 6.31 | K-25 Building Northwest Bridge | 5.25E+08 | *pCi* | | | | | 4.30E+08 | | | 1.85E+08 | |
| ETTP | 6.41 | K-25 West Side Compressors Group 1 R1 | 6.11E+09 | *pCi* | | | | | 1.99E+13 | 8.03E+11 | | 9.08E+10 | |
| ETTP | 6.42 | K-25 West Side Converters Group 1 R1 | 1.02E+09 | *pCi* | | | | | 3.60E+12 | 1.83E+11 | | 2.44E+10 | |
| ETTP | 6.43 | K-25 West Side Converters Group 1 R1 | 3.49E+09 | *pCi* | | | | | 4.39E+12 | 2.21E+11 | | 1.88E+10 | |
| ETTP | 6.58 | K25 East and North Low-Risk Converters | 3.03E+09 | *pCi* | | | | | 2.70E+12 | 1.44E+11 | | 8.00E+10 | |
| ETTP | 6.59 | Building K-25 East Wing and North End Low-Risk Compressors | 2.08E+09 | *pCi* | | | | | 6.14E+12 | 3.30E+11 | | 1.74E+11 | |
| ETTP | 6.60 | K-25 West Wing Post Mined Low-Risk Compressors | 8.48E+07 | *pCi* | | | | | 2.41E+11 | 1.22E+10 | | 1.52E+09 | |
| ETTP | 6.998 | Comingled waste lot that inlcudes WL's 6.49-6.57 | 4.63E+10 | *pCi* | | | | | 6.54E+13 | 4.23E+12 | 5.82E+11 | 2.54E+12 | |
| ETTP | 6.999 | Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48 | 1.66E+11 | *pCi* | | | | | 2.62E+13 | 2.05E+12 | | 4.06E+12 | |
| ETTP | 8.02 | Building K-33 Concrete Pedestal | 1.14E+10 | *pCi* | | | | | 2.46E+10 | 1.23E+09 | 1.23E+08 | 2.46E+10 | |
| ETTP | 8.05 | BNFL Compressor Blades | 5.89E+08 | *pCi* | | | | | 6.18E+10 | 3.21E+09 | | 1.03E+11 | |
| ETTP | 8.07 | BNFL K-31 Concrete Pedestal Waste Lot | 4.61E+09 | *pCi* | | | | | 3.26E+09 | 3.41E+08 | | 3.88E+09 | |
| ETTP | 8.08 | K-33 Concrete Floor Scabble | 2.27E+09 | *pCi* | | | | | | 1.65E+09 | | 9.85E+09 | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 8.11 | Non-PG/Non-Fissile Components | 2.66E+08 | *pCi* | | | | | 1.71E+09 | 1.19E+09 | | 1.20E+10 | |
| ORNL | 10.01 | Old Hydrofracture Facility Remediation Wastes (Containers) | 7.04E+08 | *pCi* | | | | | 8.57E+10 | 2.84E+09 | 4.96E+03 | 1.82E+11 | |
| ETTP | 14.01 | K-1303 Building Debris | 1.92E+09 | *pCi* | | | | | 4.65E+09 | 1.34E+08 | 6.22E+10 | 3.31E+09 | |
| ETTP | 14.02 | K-1302 Building Debris | 3.06E+08 | *pCi* | | | | | 4.91E+09 | 2.45E+08 | 1.01E+08 | 1.07E+09 | |
| ETTP | 14.03 | K-1413 Building Debris | 1.10E+09 | *pCi* | | | | | 7.04E+09 | 5.50E+08 | 8.04E+09 | 1.06E+10 | |
| ETTP | 14.04 | K-1303 Metal Debris | 1.61E+08 | *pCi* | | | | | 3.21E+06 | 1.61E+06 | | | |
| ETTP | 14.05 | K-1300 Stack Debris | 1.97E+08 | *pCi* | | | | | 8.81E+10 | 4.44E+09 | 1.83E+09 | 2.02E+10 | |
| ETTP | 14.06 | K-1413 Process Piping and Equipment | 7.78E+07 | *pCi* | | | | | 8.09E+09 | 8.22E+08 | 3.77E+08 | 2.66E+10 | |
| ETTP | 14.07 | Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris | 2.60E+07 | *pCi* | | | | | 1.43E+07 | 2.08E+06 | 1.30E+06 | 1.38E+07 | |
| ETTP | 14.08 | K-1301, K-1405, and K-1407 Asbestos | 9.08E+06 | *pCi* | | | | | 5.11E+08 | 3.00E+07 | 4.80E+07 | 4.19E+08 | |
| ETTP | 14.11 | K-1420 Equipment and Building Debris | 5.28E+09 | *pCi* | | | | | 2.21E+11 | 2.91E+10 | | 3.83E+10 | |
| ETTP | 14.14 | K-1401/K-723 R4 | 2.43E+10 | *pCi* | | | | | 4.42E+11 | 3.45E+10 | | 4.16E+11 | |
| ETTP | 14.15 | K-1420 Calciner | 5.32E+07 | *pCi* | | | | | 3.03E+11 | 1.90E+10 | | 1.41E+11 | |
| ETTP | 14.16 | Main Plant D&D Housekeeping R0 | 1.53E+07 | *pCi* | | | | | 4.16E+06 | 8.14E+05 | | 3.91E+06 | |
| ETTP | 14.17 | UF6 Cylinders Wooden Saddles | 2.88E+08 | *pCi* | | | | | 3.13E+07 | | | 8.78E+07 | |
| ETTP | 14.21 | K-1066-G Scrap, Debris and Abandoned Equipment | 5.12E+08 | *pCi* | | | | | 1.40E+09 | 1.25E+08 | | 3.75E+09 | |
| Offsite | 24.0 | ACAP RA | 3.87E+10 | *pCi* | | | | | 8.08E+11 | 8.13E+10 | | 8.94E+11 | |
| Offsite | 24.01 | ACAP Debris | 2.46E+06 | *pCi* | | | | | 1.20E+09 | 6.79E+07 | | 1.45E+09 | |
| Offsite | 24.02 | ACAP Soil | 1.30E+09 | *pCi* | | | | | 6.99E+06 | 4.03E+05 | | 7.17E+06 | |
| ETTP | 30.01 | ETTP OD RSM1 R1 | 2.07E+09 | *pCi* | | | | | 3.04E+11 | 8.65E+09 | 7.59E+08 | 1.23E+11 | |
| ETTP | 30.02 | ETTP OD CD | 8.38E+08 | *pCi* | | | | | 2.28E+11 | 1.57E+10 | 3.41E+09 | 1.23E+11 | |
| ETTP | 30.03 | ETTP OD RSM 5 | 6.00E+07 | *pCi* | | | | | 2.00E+09 | 3.65E+07 | 1.19E+07 | 1.79E+09 | |
| ETTP | 30.06 | ETTP OD DAW R1 | 1.18E+09 | *pCi* | | | | | 4.09E+11 | 2.66E+10 | 5.96E+10 | 2.53E+11 | |
| ETTP | 30.07 | OD VRR-1 | 1.60E+09 | *pCi* | | | | | 2.92E+11 | 1.18E+10 | | 4.11E+11 | |
| ETTP | 30.08 | OD VRR-2 | 4.81E+08 | *pCi* | | | | | 7.49E+11 | 3.08E+10 | | 1.34E+12 | |
| ETTP | 30.09 | ETTP OD DAW-2 R1 | 2.19E+08 | *pCi* | | | | | 7.77E+11 | 2.53E+10 | 3.01E+09 | 3.57E+11 | |
| ETTP | 30.10 | ETTP OD DAW-3 | 1.78E+08 | *pCi* | | | | 1.96E+09 | 2.50E+10 | 1.43E+09 | 1.13E+08 | 3.01E+10 | |
| Offsite | 30.12 | DWI 901 Stored Soils | 1.83E+08 | *pCi* | | | | | 9.81E+10 | 5.95E+09 | 1.34E+09 | 1.33E+11 | |
| ETTP | 30.13 | ETTP Outdoor Solids | 3.53E+08 | *pCi* | | | | | 1.63E+10 | 9.22E+08 | 2.70E+08 | 6.93E+10 | |
| ETTP | 62.01 | Poplar Creek Process Facilities Building Debris and Miscellaneous Materials | 6.46E+07 | *pCi* | | | | | 2.00E+09 | 1.10E+08 | | 1.29E+09 | |
| ETTP | 62.04 | K-413 Building Debris and Process Equipment | 7.17E+08 | *pCi* | | | | | 4.28E+09 | 1.44E+09 | | 2.06E+09 | |
| ETTP | 62.05 | K-1231 and K-1233 Demolition Debris | 1.68E+09 | *pCi* | | | | | 8.09E+09 | 3.56E+08 | | 7.50E+08 | |
| ETTP | 65.01 | K-770 Scrap Yard | 4.16E+10 | *pCi* | | | | | 2.50E+09 | 4.45E+10 | 8.33E+08 | 7.58E+11 | |
| ETTP | 65.02 | K-770 14 Series Piles | 9.56E+08 | *pCi* | | | | | 1.21E+08 | 1.26E+09 | | 2.12E+10 | |
| ETTP | 65.03 | K-770 B-25 Boxes | 8.81E+08 | *pCi* | | | | 2.20E+11 | | 1.28E+10 | 9.60E+09 | 2.26E+10 | |
| ETTP | 66.01 | KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project | 2.86E+06 | *pCi* | | | | | 1.69E+06 | 1.97E+05 | | 2.14E+06 | |
| ETTP | 66.04 | K-1064 Peninsula Area | 1.31E+08 | *pCi* | | | | | 3.54E+10 | 1.93E+09 | 1.56E+09 | 1.42E+10 | |
| ETTP | 66.06 | K-1025 Buildings Structural Wood | 3.40E+07 | *pCi* | | | | | 2.70E+08 | 1.51E+07 | | 2.05E+08 | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 66.07 | DBOS Building Debris and Misc Materials R2 | 9.78E+09 | *pCi* | | | | | 5.30E+12 | 1.77E+11 | | 4.49E+12 | |
| ETTP | 73.01 | Centrifuge Equipment U | 8.57E+07 | *pCi* | | | | | 9.00E+10 | 5.26E+09 | 2.04E+09 | 4.49E+10 | |
| ETTP | 73.02 | Centrifuge Equipment C | 9.73E+07 | *pCi* | | | | | 1.02E+11 | 5.97E+09 | 2.32E+09 | 5.10E+10 | |
| ORNL | 80.01 | HFIR Impoundments | 8.49E+09 | *pCi* | | | | | 1.56E+10 | | | 9.33E+09 | |
| ORNL | 80.02 | HRE Pond Sediments | 6.88E+09 | *pCi* | | | | | 1.44E+10 | | | 8.25E+09 | |
| ORNL | 81.01 | T1/T2 R4 HFIR Tanks Debris R5 | 1.01E+09 | *pCi* | | | | 3.10E+08 | 2.71E+08 | 4.27E+06 | 4.74E+07 | 5.28E+08 | |
| ORNL | 81.02 | 22-Trench Debris & Secondary Waste | 8.24E+06 | *pCi* | | | | | 9.14E+06 | 1.03E+06 | | 6.77E+06 | |
| ORNL | 84.01 | GAAT RA Waste R3 | 1.22E+09 | *pCi* | | | | 9.16E+09 | 6.07E+09 | 2.83E+08 | 1.25E+07 | 6.46E+09 | |
| ORNL | 84.02 | ITRA Waste R1 | 3.15E+08 | *pCi* | | | | 1.93E+07 | 3.52E+08 | 4.34E+01 | 1.31E+01 | 6.10E+06 | |
| ORNL | 84.03 | W1-A B12 Box Soil | 3.18E+08 | *pCi* | | | | | 1.01E+11 | 3.80E+08 | 1.53E+08 | 1.22E+09 | |
| ORNL | 84.04 | W1-A B12 Box Soil-1 | 1.79E+08 | *pCi* | | | | | 7.31E+10 | 8.36E+08 | 3.45E+08 | 1.25E+09 | |
| ORNL | 84.05 | RASW Inactive Tanks Secondary Equipment | 1.81E+06 | *pCi* | | | | 1.48E+04 | 6.84E+05 | 1.35E-02 | 8.56E-03 | 2.14E+03 | |
| ORNL | 84.06 | HIC-1 FFA Inactive Tanks | 4.56E+06 | *pCi* | | | | 5.02E+05 | 2.31E+07 | 4.56E-01 | 2.88E-01 | 7.16E+04 | |
| ORNL | 87.01 | SIOU Bricks | 6.26E+09 | *pCi* | | | | | 5.14E+11 | 2.54E+10 | 1.53E+10 | 2.90E+11 | |
| ORNL | 87.02 | SIOU Debris R2 | 1.00E+09 | *pCi* | | | | | 8.23E+09 | 4.26E+08 | 2.91E+08 | 4.37E+09 | |
| ORNL | 89.01 | MSRE Remedial Action | 4.69E+07 | *pCi* | | | | 1.45E+11 | 8.29E+09 | 9.88E+05 | 1.16E+06 | 3.57E+05 | |
| ORNL | 102.01 | Building 3026 Debris and Misc Material | 8.53E+08 | *pCi* | | | | | 5.23E+08 | | | 4.42E+08 | |
| ORNL | 111.01 | Melton Valley Weir Cleanout and Bank Stabilization Project | 6.63E+08 | *pCi* | 3.91E+08 | 5.04E+08 | | | 1.29E+09 | | | 1.77E+09 | |
| Y-12 | 114.01 | Jack Case Center Contaminated Force Main | 1.96E+07 | *pCi* | | | | | 4.70E+09 | 1.58E+08 | 7.21E+07 | 1.06E+09 | |
| Offsite | 145.01 | David Witherspoon, Inc. 901 Site- Candora Soil | 1.34E+10 | *pCi* | | | | | 3.32E+12 | 2.58E+11 | 8.40E+10 | 3.23E+12 | |
| Offsite | 145.02 | DWI 901 Scrap Metal and Debris R2 | 1.81E+09 | *pCi* | | | | | 1.28E+10 | 6.45E+08 | | 1.42E+10 | |
| Offsite | 145.03 | DWI 901 Site Building and Miscellaneous Debris | 4.90E+08 | *pCi* | | | | | 9.79E+09 | 5.78E+08 | 2.98E+08 | 8.42E+09 | |
| Offsite | 145.04 | David Witherspoon, Inc. 901 Site Soil | 7.29E+10 | *pCi* | | | | | 9.26E+12 | 3.54E+11 | 1.20E+11 | 4.57E+12 | |
| Offsite | 146.01 | DWI 1630 Soil and Incidental Debris R6 | 1.35E+11 | *pCi* | | | | | 5.68E+13 | 8.20E+11 | 3.80E+12 | 5.56E+13 | |
| Offsite | 146.02 | DWI 1630 Site: Drums and Drum Soils | 4.96E+08 | *pCi* | | | | | 2.09E+11 | 3.01E+09 | 1.40E+10 | 2.04E+11 | |
| ORNL | 149.01 | NHF D&D | 4.64E+09 | *pCi* | | | | | 2.35E+10 | | | 2.02E+11 | |
| ORNL | 149.02 | NHF Well P&A Debris R2 | 5.98E+07 | *pCi* | | | | | | | | | |
| ORNL | 149.03 | HRE Ancillary Facilities | 1.16E+08 | *pCi* | 6.29E+07 | 2.84E+07 | | | 3.65E+07 | | | 3.80E+07 | |
| ORNL | 149.04 | HRE Waste Evaporator System and Sampling Station Waste R2 | 2.12E+08 | *pCi* | | 3.58E+04 | | | 6.38E+09 | 1.73E+08 | 6.81E+07 | 5.45E+06 | |
| ORNL | 149.06 | NHF Well P&A Primary Waste | 5.94E+07 | *pCi* | | | | 2.04E+08 | 2.80E+06 | 5.67E+04 | 9.20E-02 | 7.84E+05 | |
| ORNL | 149.07 | NHF Process | 2.90E+07 | *pCi* | | | | 6.06E+09 | 5.69E+08 | 9.95E+06 | | 2.79E+08 | |
| ORNL | 149.09 | 7841 Scrap Yard Debris and Equipment | 1.20E+09 | *pCi* | 1.02E+10 | 1.33E+10 | 1.98E+09 | 9.78E+11 | 1.60E+10 | 1.42E+09 | 1.29E+09 | 1.56E+11 | |
| ORNL | 149.10 | MV Tanks 454 and 455 | 9.91E+06 | *pCi* | | | | 1.41E+07 | 9.38E+06 | 1.13E+04 | 1.00E+05 | 2.44E+05 | |
| ORNL | 155.01 | K-1070-B Burial Ground Remediation | 1.12E+11 | *pCi* | | | | | 5.93E+13 | 6.73E+12 | | 2.91E+13 | |
| ETTP | 155.02 | BOS Lab Facilities Miscellaneous Wastes | 1.83E+09 | *pCi* | | | | | 4.04E+11 | 2.43E+10 | | 4.46E+11 | |
| ETTP | 155.03 | BOS Lab Area Soil | 1.56E+08 | *pCi* | | | | | 1.31E+09 | 6.43E+07 | | 1.01E+09 | |
| ETTP | 155.04 | BOS Lab Area Acid Pits and Piping | 1.52E+08 | *pCi* | | | | | 1.06E+09 | 6.45E+07 | | 2.45E+08 | |
| ETTP | 155.05 | K-1015-A Laundry Pit | 1.33E+08 | *pCi* | | | | | 1.30E+09 | 8.34E+07 | | 2.35E+08 | |

**Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)**

| Site | Waste Lot | WL Name | Net Weight (g) | Units | Th-230 | Th-232 | U-232 | U-233 | U-234 | U-235 | U-236 | U-238 | Zn-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETTP | 157.01 | K-29 Building D&D | 3.63E+10 | *pCi* | | | | | 3.07E+12 | 1.66E+11 | | 7.23E+11 | |
| ORNL | 164.01 | Hot Storage Garden R1 | 3.12E+07 | *pCi* | 9.86E+07 | 2.17E+07 | | | 3.78E+08 | 1.13E+08 | | 4.00E+08 | |
| ORNL | 167.01 | Epicor II Lysimeters, MV Soils & Sediments | 7.73E+08 | *pCi* | | | | | 3.54E+09 | 1.65E+08 | 5.41E+07 | 2.25E+08 | |
| ORNL | 200.03 | Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material | 5.09E+07 | *pCi* | | | | | 2.37E+08 | | | 2.35E+07 | |
| ORNL | 200.999 | Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4 | 2.76E+09 | *pCi* | | | | | 8.37E+11 | 3.56E+09 | | 3.29E+10 | |
| ORNL | 201.01 | Miscellaneous Materials from Buildings 2001, 2019 and 2024 | 9.07E+06 | *pCi* | 7.45E+06 | 1.80E+06 | | | 4.75E+06 | 3.62E+06 | | 4.10E+06 | |
| ORNL | 201.02 | Building 2000 Structure and Contents | 1.19E+09 | *pCi* | 8.91E+08 | 2.49E+08 | | | 6.64E+08 | 4.73E+08 | | 5.33E+08 | |
| ORNL | 201.03 | Slabs - Drains, Pipes and Slabs | 5.58E+09 | *pCi* | 2.21E+09 | 1.39E+09 | | 8.76E+10 | 3.65E+10 | 6.08E+08 | 6.02E+08 | 6.97E+09 | |
| ORNL | 203.01 | Buildings 2011, 2017 and 3044 | 6.34E+08 | *pCi* | | | | | 5.72E+09 | 2.77E+08 | | 3.59E+08 | |
| ORNL | 207.01 | 3026 Hot Cells | 2.47E+08 | *pCi* | 1.68E+08 | 1.03E+08 | | | 6.78E+08 | 4.85E+07 | | 1.05E+08 | 3.61E+08 |
| Y-12 | 301.01 | Capability Unit 29 Legacy Material Bldg 9201-5 | 1.05E+08 | *pCi* | | | | | 2.22E+09 | 1.72E+06 | 2.30E+07 | 6.94E+07 | |
| Y-12 | 301.02 | Legacy Material from Building 9201-5 | 4.98E+07 | *pCi* | | | | | | 2.28E+06 | | 1.33E+07 | |
| Y-12 | 301.04 | Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas | 1.10E+09 | *pCi* | | | | | | 1.87E+09 | 9.67E+08 | 1.48E+11 | |
| Y-12 | 303.01 | Old Salvage Yard Piles SY-HI (Areas 1 and 2) | 7.39E+09 | *pCi* | | | | 8.13E+09 | 1.14E+12 | 6.44E+10 | 3.19E+10 | 4.96E+12 | |
| Y-12 | 303.02 | Old Salvage Yard SY-H1 Area 1 Pile, Rev 1 | 1.41E+09 | *pCi* | | | | | 1.46E+13 | 8.81E+11 | 2.05E+11 | 1.14E+13 | |
| Y-12 | 304.01 | Building 9211 D&D | 9.04E+09 | *pCi* | | | | | 8.72E+11 | 3.22E+10 | | 4.63E+11 | |
| Y-12 | 304.02 | Building 9769 D&D | 1.86E+09 | *pCi* | | | | | 6.08E+10 | | 5.03E+09 | 4.66E+10 | |
| ETTP | 401.01 | K-33 Building Debris and Misc Material | 2.00E+11 | *pCi* | | | | | 1.63E+12 | 7.97E+10 | | 1.18E+12 | |
| ETTP | 997.01 | Main Plant LR/LC Buildings | 2.52E+09 | *pCi* | | | | | 4.56E+10 | 3.58E+09 | | 4.31E+10 | |
| ETTP | 997.02 | K-1035 Demolition Debris | 5.90E+09 | *pCi* | | | | | 8.15E+09 | | 3.16E+09 | 7.56E+09 | |
| | | | **1.29E+12** | *pCi* | **1.40E+10** | **1.56E+10** | **1.98E+09** | **1.46E+12** | **3.45E+14** | **2.04E+13** | **5.81E+12** | **2.05E+14** | **3.61E+08** |
| | | | | *g* | **9.03E+09** | **9.24E+09** | **1.20E+09** | **1.79E+10** | **1.28E+12** | **1.25E+12** | **5.10E+11** | **1.29E+12** | **2.47E+08** |
| | | | | *pCi/g* | **1.55E+00** | **1.69E+00** | **1.65E+00** | **8.13E+01** | **2.69E+02** | **1.63E+01** | **1.14E+01** | **1.60E+02** | **1.46E+00** |

# 2. REFERENCES

DOE 2012. *Environmental Management Waste Management Facility 2012 Capacity Assurance Remedial Action Report*, March 2012, DOE/OR/01-2567&D1.

DOE 2013. *Fiscal Year 2013 Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Waste Management Facility*, February 2013, DOE/OR/01-2603&D0.

This page intentionally left blank.

# APPENDIX B:
# WASTE VOLUME REDUCTION

This page intentionally left blank.

# CONTENTS


ACRONYMS ..... B-4
1. INTRODUCTION ..... B-6
2. SCOPE ..... B-7
3. APPROACH ..... B-7
4. WASTE MATERIALS ..... B-8
5. VOLUME REDUCTION METHODS AND BENEFITS ..... B-12
5.1 RECYCLING ..... B-12
5.1.1 Regulatory Climate ..... B-12
5.1.2 Recycling Potential ..... B-13
5.2 PROJECT SEQUENCING ..... B-15
5.3 IMPROVED SEGREGATION ..... B-16
5.4 DEBRIS SIZE REDUCTION ..... B-17
5.4.1 Size Reduction Equipment ..... B-17
5.4.1.1 Shredders ..... B-17
5.4.1.2 Crushers ..... B-18
5.4.1.3 Compactors ..... B-19
5.4.1.4 Shearing Machines ..... B-20
5.4.2 Evaluation of Size Reduction Methods ..... B-21
5.4.2.1 Size Reduction of Equipment and Structural Steel ..... B-22
5.4.2.2 Size Reduction of Concrete and General Demolition Debris ..... B-24
5.4.2.3 ROM Cost for Size Reduction Facility ..... B-26
5.4.2.4 Cost Effectiveness of Size Reduction ..... B-30
5.4.2.5 Evaluation of Alternative Locations for Size Reduction Facility ..... B-30
5.4.2.6 Size Reduction Evaluation Conclusions for the On-site Disposal Alternative ..... B-34
5.4.2.7 Volume Reduction for Off-Site Disposal ..... B-36
6. PREVIOUS VOLUME REDUCTION EVALUATIONS ..... B-43
7. LESSONS LEARNED ..... B-43
8. SUMMARY ..... B-44
9. REFERENCES ..... B-45
APPENDIX B - ATTACHMENT A: VENDOR INFORMATION ..... B-48
APPENDIX B - ATTACHMENT B: VOLUME REDUCTION PROCESSING COST ESTIMATE ..... B-55

# FIGURES

Figure B-1. Hierarchy for Waste Disposal on the ORR ..... B-6
Figure B-2. Shredder Cutter Assembly (SSI Shredding Systems, Inc.) ..... B-18
Figure B-3. Rotary Impact Crusher Components (Striker Crushing and Screening Co.) ..... B-19
Figure B-4. BSH Shear by Harris ..... B-20
Figure B-5. EMDF Site Plan with Potential Location for Size Reduction Facility ..... B-33

# TABLES

Table B-1. Forecasted As-generated CERCLA Waste Volume ..... B-9
Table B-2. Waste Streams for Representative Buildings by Material Type ..... B-10
Table B-3. Predicted Debris Types and Quantities for Volume Reduction ..... B-11
Table B-4. Cost Summary for Clean Concrete Crusher Operations ..... B-14
Table B-5. Projected EMDF Waste Types and Volume with 25% Uncertainty ..... B-15
Table B-6. Disposal Capacity Gained Through Size Reduction of Equipment and Heavy Steel Debris ..... B-23
Table B-7. Disposal Capacity Gained Through Size Reduction of Concrete and General Demolition Debris ..... B-25
Table B-8. Capital Costs for EMDF Size Reduction Facility ..... B-27
Table B-9. Operations Personnel for Size Reduction Facility ..... B-28
Table B-10. Total Life-cycle Costs for Size Reduction Facility ..... B-29
Table B-11. Avoided EMDF Construction Costs Through Size Reduction ..... B-30
Table B-12. Cost Comparison for Size Reduction Facility Deployment at EMDF and at Two Facilities in Existing Buildings at ORNL and Y-12 ..... B-32
Table B-13. Cost Comparison between Size Reduction Facility Installations at EMDF and within the EMDF Landfill Site ..... B-35
Table B-14. Summary of Size Reduction Cost/Benefit Study Results for the On-site Disposal Alternative ..... B-36
Table B-15. Volume Reduction Analysis for the Off-Site Disposal Alternative ..... B-38
Table B-16. Total Life-cycle Costs for Off-Site Alternative Size Reduction Facility ..... B-39
Table B-17. Cost Benefit of Size Reduction for Off-site Disposal Alternative (Option 1) ..... B-40
Table B-18. Unit Cost Determination for On-site Disposal Cost by Waste Type without Volume Reduction ..... B-42
Table B-19. Basis for Size Reduction Cost Estimate ..... B-56
Table B-20. Cost Data for Shredder Operation ..... B-56
Table B-21. Cost Data for Crusher Operation ..... B-57
Table B-22. Cost Data for Excavator Operation ..... B-58

# ACRONYMS

| | |
|---|---|
| ACM | asbestos-containing material |
| ANSI | American National Standards Institute |
| BJC | Bechtel Jacobs Company LLC |
| BNFL | British Nuclear Fuels Limited |
| C&D | construction and demolition |
| CARAR | Capacity Assurance Remedial Action Reports |
| CERCLA | Comprehensive Response, Compensation, and Liability Act of 1980 |
| D&D | deactivation and decommissioning |
| DAW | dry active waste |
| DOE | U.S. Department of Energy |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| ETTP | East Tennessee Technology Park |
| FEMP | Fernald Environmental Management Project |
| FTE | full-time equivalent |
| HPS | Health Physics Society |
| K | Thousand |
| IAEA | International Atomic Energy Agency |
| LANL | Los Alamos National Laboratory |
| LLNL | Lawrence Livermore National Laboratory |
| LLW | low-level waste |
| M | Million |
| NNSS | Nevada National Security Site |
| NRC | Nuclear Regulatory Commission |
| ORNL | Oak Ridge National Laboratory |
| ORR | Oak Ridge Reservation |
| PPE | personal protective equipment |
| RA | remedial action |
| RI/FS | Remedial Investigation/Feasibility Study |
| TDEC | Tennessee Department of Environment and Conservation |
| U.S. | United States |
| VR | volume reduction |
| WAC | waste acceptance criteria |
| WGF | Waste Generation Forecast |

| | |
|---|---|
| WMPP | Waste Management Program Plan |
| WSSRAP | Weldon Spring Site Remedial Action Project |
| Y-12 | Y-12 National Security Complex |

# 1. INTRODUCTION

The Remedial Investigation/Feasibility Study (RI/FS) for Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste evaluates alternatives that will address disposal of waste generated by CERCLA actions on the Oak Ridge Reservation (ORR). Measures that reduce the volume of waste material can potentially reduce disposal costs by reducing the size of the proposed landfill and associated costs for the On-site Disposal Alternative, and reducing the cost of transportation and disposal fees for the Off-site Disposal Alternative. For the On-site Disposal Alternative, consolidated disposal of most future-generated CERCLA waste would utilize a newly-constructed landfill facility in East Bear Creek Valley on the ORR, referred to as the Environmental Management Disposal Facility (EMDF). The Off-site Disposal Alternative would provide for the transportation of future CERCLA candidate waste streams to an approved off-site disposal facility. The purpose of this Appendix is to review and assess different approaches for reducing the volume of the CERCLA waste and evaluate the potential benefits.

Volume reduction (VR) almost always requires additional effort to characterize or process the waste in a manner that reduces volume and cost. Therefore, it is necessary to evaluate VR methods to determine if the additional effort is beneficial. Approaches to VR include the following:

- Those that divert waste materials from the EMDF or from off-site landfill disposal.
- Methods that reduce the quantity of clean fill required for EMDF landfill operations.
- Physical methods to reduce the volume of waste prior to placement in the EMDF landfill or prior to off-site waste transportation.

The Oak Ridge Office of Environmental Management follows a hierarchy for dispositioning waste generated through cleanup projects to minimize disposition volumes and costs, and reduce needed landfill capacity (see Figure B-1). The foundation of the strategy is built on evaluating waste materials for recycle or beneficial reuse instead of disposing of them as waste. The second priority is to make use of onsite Subtitle D landfills for final disposal instead of the CERCLA landfill.

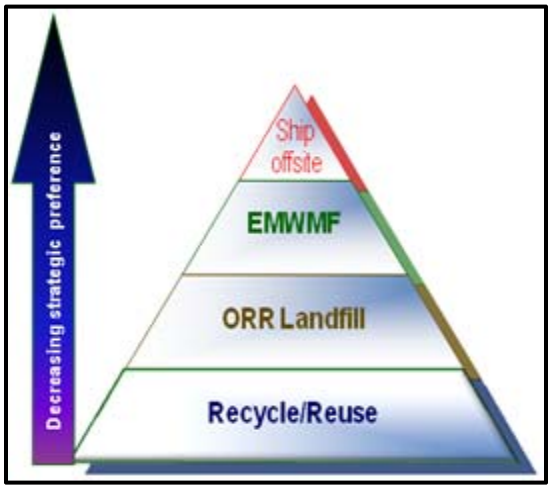



**Figure B-1. Hierarchy for Waste Disposal on the ORR**

One of the purposes of facility characterization prior to demolition is to identify materials for potential recycle and to plan for the separation of contaminated and clean waste material (segregation). Clean materials to be recycled are removed prior to demolition and, if it is feasible and safe to do so, highly contaminated sections of a facility may be selectively removed and disposed of separately in the CERLA landfill or off-site. Clean or lightly contaminated waste materials may be disposed in the Subtitle D ORR Landfill.

Clean fill occupies a substantial fraction of landfill space. It is used to fill debris void space and to provide structural stability to the landfill. Remedial action projects that involve removal of contaminated soil are evaluated for the potential to use waste soil in place of clean fill. Size-reduction processing of waste can be considered as a way to reduce debris void space and reduce the fill requirements for waste placement. The additional effort and cost for each of these methods was evaluated to determine the potential benefits for CERCLA waste disposal.

# 2. SCOPE

The scope of the study is limited to a preliminary evaluation of various approaches that have potential or have proven to be effective in reducing the volume of CERCLA materials requiring disposal. The study evaluates recycling possibilities, enhanced segregation of waste, modified project sequencing, and physical size-reducing methods for volume reduction. The study estimates potential cost savings and identifies challenges, both technical and administrative, associated with implementing the approaches. In order to define a basis, it was necessary to use waste generation forecast data to estimate potential quantities of the types of waste materials that could be recycled, segregated, or size reduced. The evaluations are thus dependent on the accuracy of these predictions. In addition, implementation of the methods is dependent on the availability of funding and the ability to implement broad programmatic approaches for VR efforts.

The issues associated with recycling materials from the United States (U.S.) Department of Energy (DOE) nuclear facilities are discussed herein and the potential benefits explored. Improved segregation of waste materials involves additional waste characterization to verify that the wastes meet the criteria for disposal at the ORR Landfill, thus conserving disposal capacity at the EMDF. The possibility and potential benefits of project sequencing, whereby projects are scheduled in order to make optimal use of waste soil as fill material during placement of debris, are examined. The physical treatment methods evaluated include those that are typically used for commercial construction and demolition (C&D) projects or at recycling facilities by private industry. Estimates developed for deployment of size-reduction equipment are preliminary only and would require additional effort to increase confidence in the potential cost of implementation. The study utilizes the waste volume estimates in Chapter 2 and Appendix A of this RI/FS and information from the Environmental Management Waste Management Facility (EMWMF) Capacity Assurance Remedial Action Reports (CARAR) (DOE 2004, DOE 2011a, and DOE 2012a) to determine waste volumes, waste types, and clean fill requirements.

VR costs were estimated and potential gains determined as a consequence of reduced debris void space, reduced clean fill requirement, and reduced landfill size. Methods that divert CERCLA waste from disposal operations include both recycle and segregation based on contamination level. Project sequencing allows for efficient utilization of waste soil to replace clean fill while size reduction processing reduces debris void space and also reduces clean fill requirements. Assumptions were made and documented during the study to account for uncertainties that exist due to lack of information or inability to predict future conditions.

# 3. APPROACH

Evaluation of VR methods was performed through literature reviews, reliable internet sources, budgetary cost information from commercial vendors, interviews with VR equipment operations personnel, and information from previous estimates. Applicability and timeliness of the information for current economic conditions was considered.

The study utilized estimated waste volumes and waste material types from several representative buildings that are scheduled for deactivation and decommissioning (D&D) in the future at Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12). These facilities also represent a significant fraction of the future D&D work load. This information was used to determine an overall breakdown of waste types to apply against the total estimated volume of CERCLA waste. Information from CARAR reports was used to estimate the benefits of VR in terms of reduced clean fill required to isolate and fill voids in the wastes.

The cost effectiveness of physical VR options was evaluated by comparing the cost of implementing the VR method to the cost of on-site and off-site disposal of unprocessed material. The On-site and Off-site

Disposal Alternative cost estimates developed for EMDF and described in Appendix G of this RI/FS were used to determine potential VR cost benefits.

# 4. WASTE MATERIALS

The benefits of VR depend upon the volume and characteristics of the waste materials. Descriptions of types and quantities available from demolition planning activities for several facilities from ORNL and Y-12 were used to predict the composition and volume of materials to be managed as CERCLA waste. For the purposes of the VR evaluation, this composition was assumed to be representative for the total volume forecasted for the 2022 to 2043 time frame given in Table B-1. It was assumed that only debris that was not either classified or mixed with materials regulated under the Resource Conservation and Recovery Act (RCRA) or the Toxic Substance Control Act (TSCA) would be considered for VR actions. The values in the table are in terms of as-generated volumes; that is, they include estimated void space dependent upon the type of material. Table B-2 is a summary of waste types and volumes for the selected facilities. The waste materials from all the buildings were summed to provide a representative percentage by waste type for materials to be disposed. The representative fractional quantities given in the table were applied against the projected as-generated debris volume from Table B-1 to determine the total quantity of debris material that could possibly benefit from application of VR methods.

A large fraction of the waste generated by building demolition is amenable to VR. Only items that are highly contaminated and hazardous materials such as lead brick and asbestos-containing materials (ACM) do not lend themselves easily to VR measures. Materials that are highly contaminated with radioactive constituents, mercury, or beryllium would be addressed prior to facility demolition using existing infrastructure and localized containment in order to extract these materials prior to open-air demolition of the remaining structure. Lead brick and sheet would be separated for either recycling as shield materials or transported for off-site treatment. ACM cannot be recycled or size reduced by shredding or compaction due to the hazards of spreading and dispersing airborne asbestos particles. ACM can be vitrified if necessary; however, vitrification processing is very expensive and would not be a cost effective VR option.

Concrete rubble including reinforced concrete, block, and brick masonry can be crushed and possibly recycled for construction or used as fill material in landfill operations. Light steel materials such as ventilation duct, conduit, thin-walled pipe, and sheet metal siding can potentially be recycled. These materials along with siding, flooring, wood materials, and roof materials can be shredded to reduce landfill volume and to reduce transportation costs. Heavy gauge metal materials (structural steel, large diameter, thick walled piping, process vessels, and equipment items that have a large void fraction) are also good candidates for recycle, although the effort required for decontamination of these materials could be significant. Shearing machines such as those used in shipyards and commercial metal recycling facilities may be used to size-reduce heavy steel items to reduce transportation costs or to reduce landfill space requirements. The three building project (BNFL 2001) performed at the East Tennessee Technology Park (ETTP) in 2001 successfully used a “supercompactor” shearing machine to size-reduce large equipment items and heavy gauge steel for disposal. Additional segregation of the materials discussed above could be considered for alternative, lower-cost, disposal options. Segregation would involve additional contamination surveys to verify that the materials meet appropriate disposal criteria for an alternative landfill.

As shown in Table B-3, about 98.8% of D&D debris materials could be considered for VR. The waste soil quantities given in Table B-1 are an important element of VR because they can be used to replace clean fill soil that is used to fill the void space inherent in demolition debris. EM projects must be sequenced such that the waste soil is available to replace clean fill at the time that the debris is placed in the landfill. The quantity of debris generated during this time period is 1,341,090 $yd^3$ including 25% uncertainty. Classified debris and debris that is mixed with hazardous constituents would not be

considered for VR, reducing the total for VR actions to 1,151,440 $yd^3$. Table B-3 applies a fractional value for debris volumes based on the assumption that a lower fraction of the debris would not be processed by VR due to logistical limitations, contamination issues, or other unexpected circumstances. After applying these factors, the final estimated volume for VR processing is 758,299 $yd^3$.

**Table B-1. Forecasted As-generated CERCLA Waste Volume**

| Waste Type | Material Type | Total FY 2022–FY 2043 $yd^3$ |
|---|---|---|
| LLW (includes LLW/TSCA) | Debris | 921,152 |
| | Debris/Classified | 28,489 |
| | Soil | 432,092 |
| Mixed (LLW/RCRA, LLW/RCRA/TSCA) | Debris | 119,534 |
| | Debris/Classified | 3,697 |
| | Soil | 53,882 |
| Subtotal | | **1,558,847** |
| 25% Uncertainty | | 389,712 |
| Total Waste Volume with Uncertainty | | 1,948,558 |
| Total Debris Volume with Uncertainty | | 1,341,090 |
| Total Debris Volume with Uncertainty (not including Classified or Mixed LLW) | | **1,151,440** |

**Table B-2. Waste Streams for Representative Buildings by Material Type**

| Debris Type | Description | ORNL Facilities | | | Y-12 Facilities | | | | | Total Volume ($yd^3$) | Fraction of Total Volume (%) | Debris Volume* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4501 & 4505 ($yd^3$) | 7600 ($yd^3$) | Isotopes ($yd^3$) | 9201-4 Alpha-4 ($yd^3$) | 9201-5 Alpha-5 ($yd^3$) | 9204-4 Beta-4 ($yd^3$) | 9207 Biology Complex ($yd^3$) | 9212 ($yd^3$) | | | |
| Asbestos containing materials | Insulation, floor tiles | 457 | 47 | 266 | 310 | 550 | 550 | 2,041 | 355 | 4,576 | 0.99% | 11,354 |
| Transite | Transite | 8 | 165 | 0 | 148 | 265 | 120 | 0 | 146 | 853 | 0.18% | 2,117 |
| Lead | Bricks, sheet | 0 | 0 | 94 | 0 | 0 | | 2 | 0 | 96 | 0.02% | 239 |
| Equipment | Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes | 3,234 | 2,334 | 1,028 | 5,279 | 25,736 | 5,030 | 2,609 | 39,609 | 84,859 | 18.28% | 210,539 |
| Heavy steel | Pipe, tanks, structural steel | 1,174 | 7,584 | 1,314 | 14,215 | 31,972 | 32,489 | 3,793 | 21,074 | 113,616 | 24.48% | 281,886 |
| Concrete and masonry | Reinforced concrete, block, brick, shield walls | 16,363 | 34,380 | 437 | 27,688 | 46,298 | 26,741 | 17,118 | 27,122 | 196,147 | 42.26% | 486,647 |
| Demolition (general) | Small buildings, cooling towers, structural framing, interior and exterior finishes, floors, wood | 0 | 0 | 0 | 0 | 11,609 | 14,212 | 0 | 6,749 | 32,570 | 7.02% | 80,807 |
| Light gauge metals and siding | Air ductwork, small diameter pipe, siding, panels | 770 | 860 | 599 | 1,432 | 3,565 | 2,501 | 97 | 4,154 | 13,979 | 3.01% | 34,683 |
| Roofing materials (asphalt) | Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt | 703 | 440 | 342 | 2,808 | 2,630 | 1,619 | 3,296 | 4,511 | 16,349 | 3.52% | 40,562 |
| Legacy material | Containers, furniture, trash | 0 | 0 | 27 | 838 | 0 | 0 | 0 | 48 | 913 | 0.20% | 2,265 |
| Packaged for EMWMF | Legacy containerized waste | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 0 | 84 | 0.02% | 209 |
| Off-site disposal | Mixed waste designated for off-site disposal | 0 | 0 | 53 | 0 | 0 | 0 | 0 | 0 | 53 | 0.01% | 132 |
| | **Total** | **22,709** | **45,811** | **4,245** | **52,720** | **122,624** | **83,262** | **28,956** | **103,770** | **464,129** | **100%** | 1,151,440 |

* Debris volume based on Table A-3, Appendix A as-generated debris forecast including 25% contingency (1,536,610 $yd^3$)

**Table B-3. Predicted Debris Types and Quantities for Volume Reduction**

| Debris Type | Fraction of Total | Total Volume Projected ($yd^3$) | Fraction for Processing | Volume for Processing ($yd^3$) | Bulk Density ($lb/yd^3$) | Weight for Processing (tons) |
|---|---|---|---|---|---|---|
| Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes* | 18.28% | 210,539 | 0.3 | 63,162 | 680 | 21,475 |
| Piping, tanks, structural steel* | 24.48% | 281,886 | 0.75 | 211,415 | 1,040 | 109,936 |
| Concrete and masonry: reinforced concrete, block, brick, shield walls | 42.26% | 486,647 | 0.75 | 364,985 | 2,600 | 474,481 |
| Small structures: small cooling towers, structural framing, interior and exterior finishes, wood | 7.02% | 80,807 | 0.75 | 60,605 | 1,620 | 49,090 |
| Metal (light gauge): ventilation ductwork, small diameter piping, siding, panels* | 3.01% | 34,683 | 0.75 | 26,012 | 1,040 | 13,526 |
| Roofing materials: shingles, built-up roofs, vapor barrier, insulation, roof vents, flashing | 3.52% | 40,562 | 0.75 | 30,422 | 1,520 | 23,121 |
| Legacy material: containers, furniture, trash, wood | 0.20% | 2,265 | 0.75 | 1,698 | 640 | 544 |
| **Total** | 98.8% | **1,137,389** | | **758,299** | | **692,172** |

*Considered for recycle (see Section 5.1.2).

# 5. VOLUME REDUCTION METHODS AND BENEFITS

Volume reduction methods evaluated in this report include recycling, project sequencing, improved segregation, and physical size reduction. Advantages and disadvantages are discussed along with cost data collected from various sources. The discussion considers administrative aspects, technical applicability, the cost of implementing, and the magnitude of VR that can potentially be achieved. This information is used to determine the viability and cost of VR and the amount of landfill space that could be gained or the number of waste shipments that could be avoided. Using EMDF cost information from the On-site Disposal Alternative, the impact of VR to various cost elements associated with construction, operations, and maintenance was estimated. In addition, the cost of transporting and disposing of debris at an off-site facility was evaluated to determine potential benefits of VR for the Off-site Disposal Alternative.

## 5.1 RECYCLING

### 5.1.1 Regulatory Climate

The U.S. Environmental Protection Agency (EPA) has raised awareness and promoted C&D debris recycling through many initiatives and programs that provide information, incentives, research funding, and guidance to resolve technical issues and increase nationwide recycling of C&D materials. Many states, including Tennessee, have adopted these principals and encouraged C&D recycling efforts. In some states and cities, where landfill space is limited, regulations have been adopted that require recycling of C&D materials. California Law AB 939 requires recycling of 50% of waste materials of all types and many cities, such as San Francisco, mandate the recycling of all C&D materials in order to conserve limited landfill space. New Jersey municipalities must meet the State Recycling Mandate which requires all C&D waste to be recycled.

There are several examples that document DOE's efforts to recycle D&D materials. During demolition of a 149,987 $ft^2$ building at Lawrence Livermore National Laboratory (LLNL) in 2007, 89% of demolished materials were either recycled or reused (LLNL 2008). This included 1,665 tons of metals, 7,399 tons of concrete, and 14,580 gallons (gal) of dielectric fluid. Recycling reportedly reduced the project cost by 11%. Since 2002, LLNL has recycled or reused 32,075 tons of asphalt/concrete, more than 5,000 tons of metal, 673 lbs of freon, and 201 $yd^3$ of wood. A DOE Inspector General audit report reviewing ORNL's waste diversion effort reported that in 2011, ORNL successfully diverted over 5,100 of 9,500 metric tons of solid waste through recycling and reuse (DOE 2012c). At Los Alamos National Laboratory (LANL), more than 136 tons of metal saved from demolished buildings were recycled during demolition projects under the American Recovery and Reinvestment Act of 2009 (LANL 2009). This was largely due to efforts by heavy equipment operators to remove recyclable materials from the buildings before they were demolished.

The majority of the facilities identified for D&D in Oak Ridge were used for nuclear energy research and development and thus are categorized under DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* (DOE 1992) as Nuclear or Radiological facilities. In 2000, DOE placed a moratorium on the recycling of volumetrically contaminated metals and a suspension on the recycling of metals located within Radiological facilities. This moratorium seeks to prevent public exposure to radiation above background resulting from recycling/reuse of contaminated DOE material in consumer products. The moratorium will continue until the U.S. Nuclear Regulatory Commission (NRC) establishes a set of national standards regarding allowable contamination levels in recycled steel. The moratorium does allow for reuse of demolition materials for specific purposes by DOE-authorized nuclear facilities, the commercial nuclear industry, and NRC licensees authorized to possess the material. Restricting recycled materials usage to sites and facilities owned by DOE is a potential, albeit limited alternative.

In 2005, the NRC completed an exhaustive study and proposed rule: Radiological Criteria for Controlling the Disposition of Solid Materials, RIN 3150-AH18 (NRC 2005a). The rule is an effort by NRC to develop a basis to support decisions on rules that would set specific requirements on controlling releases of solid materials from NRC licensed nuclear facilities. The materials include metals, concrete, soils, equipment, furniture, etc., which are present at licensed nuclear facilities during routine operations. Historically, these materials have been released on a case-by-case basis, without a consistent approach for clearance surveys. The report provides information regarding the measurement of residual radioactivity in materials that are to be cleared, including guidance about designing, performing, and documenting radiological surveys to address the need for survey consistency. The rule was disapproved in 2005, although not for technical reasons, but rather to defer the rulemaking until additional resources are available (NRC 2005b).

An option routinely considered when planning D&D work for nuclear facilities involves selectively removing materials from contaminated zones first, then re-characterizing the facility and performing an additional hazard screening to downgrade the facility to the "Other Industrial" category. This would allow for unrestricted recycle of demolition materials, however, the cost of characterization and hazard analysis reduces the cost effectiveness of this approach. A manual that provides guidance for survey and assessment of materials and equipment for release, Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual was developed by DOE, the U.S. Department of Defense, EPA, and NRC (DOE 2009a). The manual currently refers to the release criteria given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993), later replaced by DOE Order 458.1 (DOE 2011b) though the new order refers to DOE 5400.5 for the release criteria. The release criteria require survey of 100% of the surface of the material being evaluated for release, which is a labor intensive and costly effort.

In 1999, American National Standards Institute (ANSI)/Health Physics Society (HPS) N13.12 *Surface and Volume Radioactivity Standards for Clearance* (ANSI-1999) was issued to provide a technically sound basis for release of solid materials containing trace levels of activity. However, the standard was not fully adopted by U.S. Federal agencies because the technical basis was considered inadequate to be applied on a broad basis. The International Atomic Energy Agency (IAEA) published RS-G-1.7, *Application of the Concepts of Exclusion, Exemption and Clearance*, along with *Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance* (IAEA-2004). An ongoing effort has been initiated to revise ANSI/HPS N13.12 to complement the guidance provided in the IAEA publications and become the new basis for the DOE Order 458.1 release criteria. The recycling of demolition materials from radiological facilities remains a complex issue that is not fully resolved, but should continue to be evaluated on a case-by-case basis.

### 5.1.2 Recycling Potential

The two materials that would be most likely to be beneficial for recycle would be concrete and metals. Clean concrete could be recycled to use as aggregate for new concrete or for base material or roads or new facilities. Demolition concrete that is clean and cleared for release could be crushed and screened on site to be used for other DOE applications in close proximity to the demolition site. The commercial value of aggregate is about $4.41 per ton in Tennessee (USGS 2011). The crushing operations would require the use of an industrial crushing machine and an excavator for placing the concrete debris in the crusher feed hopper and for managing the crushed product. Table B-4 provides estimated costs for a concrete crushing operation. This operation assumes the concrete is clean and the quantity is equal to the estimated quantity given in Table B-3. Based on this estimate, the cost of processing alone at $7.15/lb is higher than the commercial value of aggregate. With additional costs added for storage and transportation, it is even less likely that concrete recycling would be cost effective.

**Table B-4. Cost Summary for Clean Concrete Crusher Operations**

| Cost Element | Crusher | Excavator |
|---|---|---|
| Equipment | $512,400 | $228,479 |
| Operations labor | $711,721 | $626,315 |
| Fuel and maintenance | $553,591 | $ 268,937 |
| Engineering/procurement | $17,500 | $17,500 |
| Indirect costs | $309,297 | $146,411 |
| Total cost | $2,104,509 | $1,287,642 |
| Cost per hr, including capital | $222 | $136 |
| Cost/ton (474,481 tons) | $4.44 | $2.71 |
| Total cost/ton for crusher operations | | $7.15 |

Recycling metals is a potential option for demolition materials. Metal recyclers in Tennessee purchase steel materials at about $0.10 per lb. The U.S. market value for steel beams is about $0.32 per lb and the value of shredded scrap metal is about $0.07 per lb according to RecycleInMe.com, a worldwide scrap metal trading web site. According to Table B-3, the quantity of metallic waste (equipment, heavy steel, and light gauge metals) to consider for recycle is about 300,588 $yd^3$ total. Of this total, it is assumed that 50% of the material is targeted for recycle. This material is surveyed for contamination and it is assumed that 80% of the material meets the clean release criteria. After applying bulk density values, the total weight of metal for recycle is 57,975 tons. Bechtel Jacobs Company LLC (BJC) developed a cost estimate for contamination surveys that would be required for clean release of metals from D&D projects (BJC 2004). The approach is based on DOE 5400.5 requirements and includes radiation control technician support, personal protective equipment (PPE), survey instruments, and scanning operations. The estimated cost is $32 per $yd^3$ of recycled material. For the 150,294 $yd^3$ targeted for recycle, the cost of contamination surveys would be $4.8M. At an average value of $0.15 per lb, the commercial value of the metals (57,975 tons) would be about $17.4M. Transporting the metals to a local recycler would cost about $220 per 10 $yd^3$ or about $2.6M. EMDF capacity gains would be realized from metal recycling including the as-disposed volume that would have been required for the metals along with the required clean-fill. For the 57,975 tons of metal estimated for recycle, the clean fill required if disposed at the EMDF would be approximately 72,903 $yd^3$ based on CARAR requirements. The value of clean fill is $6.5 per ton, so at 1.24 tons per $yd^3$ the cost savings would be about $588K. After deducting survey and transportation costs, the net gain for recycling would be about $9.9M.

Metal melt provides another opportunity to recycle contaminated metals. This technology is available at the Energy*Solutions* Bear Creek facility in Oak Ridge at a (FY 2011) cost of approximately $3 per lb. An induction furnace is used to melt the material before being poured into blocked forms for controlled reuse, usually in high-energy accelerator facilities around the world. To date, this process has not been utilized by DOE facilities because of the relatively high cost compared to disposal.

There is a potential for significant cost savings from metal recycle, although without a clear set of approved regulations regarding survey of materials for clean release, there is a significant risk associated with the cost of certifying metals for clean release. Effective regulations would reduce the risk of accidentally releasing contaminated materials into the commercial market place and unintentionally

exposing the public to radiation, however, public concern would need to be addressed and the ban on DOE metal recycling would have to be lifted before recycling could be considered.

## 5.2 PROJECT SEQUENCING

As shown in Table B-5 (derived from Table A-4 of Appendix A), clean fill occupies over 1 M $yd^3$ of the landfill capacity and is a major cost element of landfill operations. As such, it is important that measures be taken to avoid exceeding the predicted clean fill requirement. Project sequencing involves the scheduling of EM projects so that waste soil is available to replace clean fill soil at the time that debris is placed in the landfill. Information from the RI/FS waste volume forecast was reviewed to verify that future D&D and remedial action (RA) projects are projected to be sequenced such that virtually all RA soil waste can be used for filling the voids of waste materials and not become "excess waste fill." In order to eliminate excess fill and minimize the quantity of clean fill required, the ratio of soil to debris generated in a particular time period should be at a level that ensures that all of the waste soil is utilized as fill. Sequencing of planned projects is based on assumptions such as funding level, project prioritization, and contracting schedules that can be uncertain and subject to change.

**Table B-5. Projected EMDF Waste Types and Volume with 25% Uncertainty**

| Waste Type | Total As-Disposed Waste Volume ($yd^3$) |
|---|---|
| Debris | 666,264 |
| Waste soil | 468,030 |
| Clean fill | 1,048,743 |
| **Total with Uncertainty** | **2,183,037** |

Table B-5 indicates an as-disposed volume of waste soil of 468,030 $yd^3$ (including 25% uncertainty) will be generated during the operational life of the EMDF along with 666,264 $yd^3$ of debris. The quantity of fill needed for this quantity of debris is approximately 1,048,743 $yd^3$. Current predictions for clean fill demand assume that nearly all of the waste soil is used to replace clean fill that would otherwise be needed for placement of the debris.

Sequencing projects in a way that makes use of waste soil as fill material results in cost benefits and conserves disposal capacity of the landfill. It is recommended that, as much as possible, demolition work be sequenced with soil remediation work to take advantage of using waste soil as fill material for debris. The OREM baseline sequencing of projects intersperses demolition and remediation projects to take advantage of this approach. The current remediation schedule and sequencing plan indicates that only a minor amount (~8,800 $yd^3$) of soil waste would not be available as fill material. In practice, it is challenging to implement sequencing for a number of reasons: (1) demolition of a facility must occur first in order to access the soils underneath/beside the facility, (2) demolition and soil remediation are generally awarded as two separate contracts, and (3) the amount of soil that may be staged in a working cell(s) is limited due to safety basis requirements, equipment limitations, and double-handling logistics. EMWMF operating personnel report that the use of waste soil to replace clean fill is performed when possible. To the extent possible, project sequencing will continue to be used as a way to conserve landfill capacity.

## 5.3 IMPROVED SEGREGATION

Waste segregation is an important element of waste minimization that is emphasized in planning of all DOE D&D projects. Significant effort and funding is provided for initial characterization of nuclear facilities in order to provide health and safety information for worker protection, to determine the disposal path for waste materials of all types, to identify areas that are not contaminated and have not been exposed to radiological materials, to separate highly contaminated materials that require costly treatment and disposal options, and to develop waste lot information for disposal. Improved segregation involves the additional effort required to separate clean from contaminated materials in order to divert a greater volume of clean materials to the ORR Landfill.

Both construction and operating costs for the ORR Landfill are lower than CERCLA disposal facility costs and overall disposal costs would be reduced by segregating more waste material to the ORR Landfills which use Class II and Class IV design as defined by the Tennessee Department of Environment and Conservation (TDEC) Division of Solid and Hazardous Waste Management. Design of the CERCLA landfill requires a much more substantial liner and capping system with additional geomembrane layers, an additional biointrusion layer, and an additional leachate leak detection system. These requirements more than double the construction costs of the CERCLA landfill compared to the ORR Landfill.

When waste generation forecasts (WGFs) are developed for D&D projects, facility type and characterization data are used to determine waste disposition. D&D materials from facilities that are classified "other industrial" in accordance with DOE-EM-STD-5502-94, *DOE Limited Standard, Hazard Baseline Documentation* (DOE 1994) are assumed to be acceptable at the ORR Landfill. In most cases, D&D materials from facilities that are classified as "nuclear" in accordance with DOE-STD-1027-92 (DOE 1992) or "radiological" per DOE-EM-STD-5502-94 are assumed to be disposed at the EMWMF. However, there may be clean areas associated with contaminated facilities that could possibly be demolished in a manner that avoids co-mingling with materials from potentially contaminated zones, thus creating an opportunity for disposing at least a portion of debris at the ORR Landfill. Additional segregation may be performed in these cases, if it is considered safe and cost effective. Radiological or nuclear facilities that include relatively small contaminated zones can be downgraded to a non-radiological category if the contaminated area can be selectively removed. After downgrading, the balance of the facility demolition materials can be disposed at the ORR Landfill. In many cases, the size of the contaminated area or degree of contamination in the facility makes it either unsafe or not cost effective to attempt to selectively remove contamination. In these cases, clean, but potentially contaminated demolition materials associated with radiological facilities are disposed at the EMWMF. Enhanced segregation activities would require more intensive characterization efforts to verify that waste materials meet the ORR Landfill waste acceptance criteria (WAC). As discussed in Section 5.1.2 on recycling, contamination surveys of demolition material would be a labor intensive and costly effort that should be evaluated to determine the benefits prior to executing during a demolition project. This approach may also involve an effort to revise the ORR Landfill WAC to accept slightly contaminated debris and soil from CERCLA projects. While potentially beneficial from a cost standpoint, additional segregation would carry the risk of releasing contaminated materials into the landfill that exceed the ORR Landfill WAC and cause contamination of leachate with associated treatment and disposal complications.

An expansion of the ORR Industrial Landfill V that provided an additional 384,500 $yd^3$ of disposal capacity was completed with American Recovery and Reinvestment Act of 2009 funding in 2011. The need for the expansion was identified based on analysis of WGF projections. Capacity at the ORR Landfills is now sufficient for the near term and will be monitored for future capacity needs.

Plans for segregating clean materials for disposal at the ORR landfill will continue to be part of D&D planning activities and should include a cost/benefit evaluation that balances potential cost savings

against the cost of additional facility safety analysis and contamination surveys, and the risk of negative consequences brought about by placing contaminated material in the ORR landfill.

## 5.4 DEBRIS SIZE REDUCTION

The physical treatment methods evaluated were limited to those that are typically used for commercial demolition projects or at recycling facilities by private industry. Commercially available size reduction equipment is capable of reducing the size and void space associated with bulk demolition materials of all kinds. Many models with various production capacities are available as stationary units or mobile units that can be located at the demolition site or at the landfill site. Deployment at the demolition site takes advantage of reduced costs for transporting processed materials from the demolition site to the landfill, however, the infrastructure costs for multiple deployments of size reduction equipment would be cost prohibitive.

### 5.4.1 Size Reduction Equipment

Equipment used to size-reduce debris materials includes crushers, shredders, compactors, and shears. These machines are capable of processing at sufficiently high rates so as not to significantly impact the overall demolition project schedule. Demolition equipment such as excavators with cutting and crushing attachments are normally used to size-reduce materials to meet the requirements for transportation and placement in a landfill. The same equipment and size requirements are applicable for preparing the materials for VR processors. Excavators with various boom attachments may be used to manage the product. Alternatively, the VR machines can be equipped with conveyors to move the processed materials to a waste container or collection area.

Shredder and crusher controls may be adjusted for sizes in a range that allows for elimination of void space while maximizing output and ease of transport and handling. Crushers are typically designed to produce a range of product size distributions. If they are equipped with screens, concrete can be processed to meet specific material specifications for recycle as aggregate for construction base material or to be mixed with new concrete.

#### 5.4.1.1 Shredders

Shredder design depends on the application. Demolition debris shredders are typically low-speed, high-torque machines that utilize dual shaft counter-rotating, custom-designed cutter blades that interlace in a way that optimizes shearing, tearing, and impact forces (see Figure B-2). The design of the cutters depends on the application. New designs have been developed that minimize repair costs through simple and speedy replacement of cutter components or the entire cutter/shaft assembly. Electrically driven stationary units generally cost less to operate, but are more prone to jamming situations and more likely to incur mechanical damage if unacceptable materials enter the feed. On-site track-mounted mobile units can be equipped with conveyors and magnets to separate metals for possible recycle. They can be controlled remotely by the excavator operator who provides feed material for the unit. Maintenance requirements include routine filter and lubrication of the drive system and also sharpening (hard-facing) of the cutters. Hard-facing requires about 16 hours per month assuming 40 hours per week operating time. Operational availability is typically 75% for the diesel driven units and about 90% for stationary electric units. Attachment A includes vendor inquiry data for the processors.

Most equipment vendors claim size reduction by up to 80% for C&D debris materials. A manual developed by DOE in 1988 to provide guidance in selection of low-level waste (LLW) VR technologies (DOE 1988) indicates that waste density for a simulated mixture of LLW increased from 13 to 30.8 lbs per $ft^3$ using a standard compaction device which translates to a VR of 58%. When the waste was shredded prior to compaction, the density increased from 13 to 80.3 lbs per $ft^3$, equivalent to an 84% decrease in volume. The increase in density from 30.8 to 80.3 lbs per $ft^3$ indicates about a 60%

decrease in volume realized by shredding alone. An additional study performed at Columbia University (CU 2009) indicated that shredding increases the bulk density of municipal solid waste by two or three times, resulting in reduced transportation costs.

**Figure B-2. Shredder Cutter Assembly**
**(SSI Shredding Systems, Inc.)**

#### 5.4.1.2 Crushers

Impact crushers are generally used for concrete and rubble that don't contain large quantities of metals. Two types are commonly used at demolition sites. The first involves a spinning rotor with "blow-bars" that initially impact the material propelling it against one of several rigid impact or "wear" plates (see Figure B-3). The material bounces between the blow bars and wear plates until it reaches a size that allows it to pass through the machine to the conveyor. The second type uses spinning "swing-hammers" that initially impact the material and propel it against breaking plates that direct the material back into the hammers until it reaches a size that can pass through the preset gap between the hammers and the plates.

Mobile crusher units are readily available on road-ready frames that include a fifth wheel for tractor hauling. Once on site, the units include support legs that allow the unit to be leveled and stabilized for immediate operations. The machines can be equipped with conveyors and magnets to separate metals for possible recycle. They can be controlled remotely by the excavator operator who provides feed material for the unit. Maintenance requirements include routine filter and lubrication of the drive system and also maintaining the crusher mechanism. In the case of the spinning rotor impactor, this involves periodic replacement of blow-bars and the stationary wear plates. Eagle Crusher Company machines use wear plates that can be rotated to increase run time and reduce maintenance costs. Blow-bars (about $3,300 per set) usually require replacement after processing about 20,000 tons of material. Wear plates (about $1,500 for a group of six) are rotated or replaced every 80,000 tons of material. Replacement of blow-bars requires about four hours for two operators and replacement of wear plates requires about one hour for two operators. Operational availability is typically 80% for diesel driven units. Attachment A includes equipment manufacturer inquiry data.

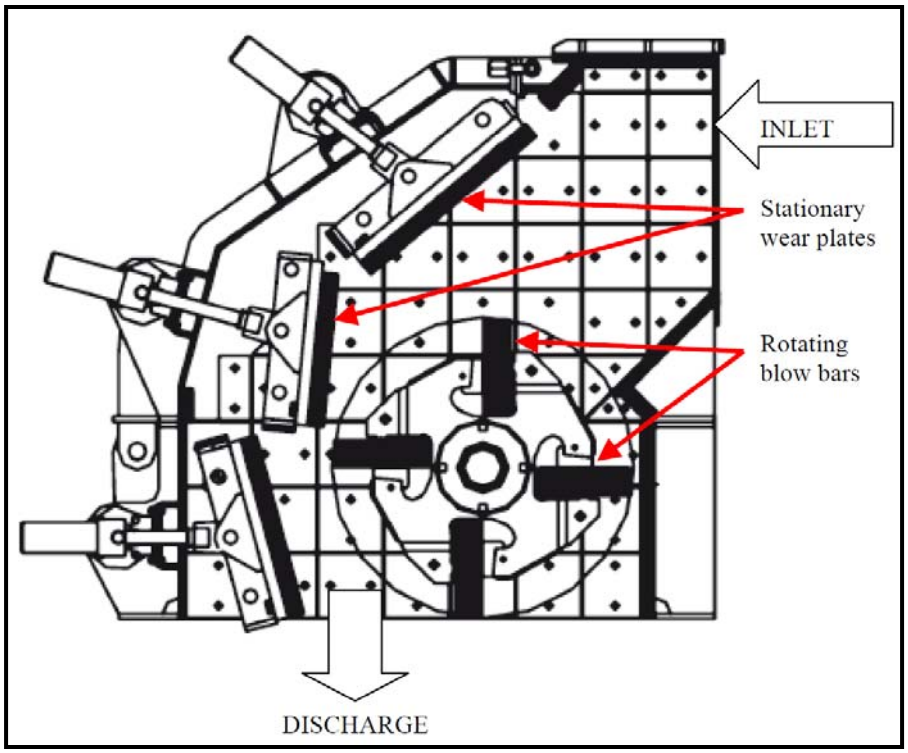



**Figure B-3. Rotary Impact Crusher Components (Striker Crushing and Screening Co.)**

### 5.4.1.3 Compactors

Compactors operate using a hydraulic press to compress materials in a confined area that conforms to a shape and size that is suitable for transportation and disposal. Compactors are typically used for light voluminous materials (wood, paper, plastic, light-gauge metals). Drum compactors are commonly used to crush empty waste drums that were used to store and transport LLW. PPE and dry active waste (DAW), such as mop heads and wipes used in decontamination activities, can become a significant fraction of the waste volume unless VR methods are employed. A typical approach involves the use of empty waste drums as containers for PPE and using a compactor to process the PPE-filled drums. The rigid structure of the compacted drum provides a strong envelope to prevent PPE from re-expanding after compaction. Compacted 55-gallon drums can be over packed in 85-gallon drums with very little void space. PPE is typically bagged and placed in B-25 boxes with very little compaction. At EMWMF, B-25 boxes are placed in the landfill in a sealed condition, whereby the void space within the box could not be filled and would replace landfill capacity with air. Using a compactor for PPE in drums would reduce this void space by about 80%, or about 6 $ft^3$ per drum. Industrial refuse compactors are available that are designed to compact large volumes of light materials into a cubical bale configuration. The shape and size of the resultant compressed form from a compactor could meet landfill size requirements and significant savings in transportation costs would be expected. Void space evaluation would be required to determine the acceptability of the compressed bail waste form.

The size-reduction machine deployed at the K-33 building demolition project at ETTP (BNFL 2001) is referred to as a "supercompactor," but the product is actually heavy gauge steel components that have been sheared into smaller pieces. The compaction component refers to the feed box that bends and molds the heavy steel into a shape that can be indexed into the cutting device. This machine is described in Section 5.4.1.4 as a shearing machine.

#### 5.4.1.4 Shearing Machines

Shearing machines are typically used in shipyards and commercial metal recycling facilities to size-reduce heavy steel items. British Nuclear Fuels Limited (BNFL) used a Harris Model BSH 2205-30 Shear (BSH Shear) designed for size-reducing scrap metal from shipyards and steel mills to process large equipment removed from the K-33 building at the ETTP (BNFL 2001). The size-reduced metal was either to be recycled or shipped to Envirocare in Utah (now Energy*Solutions*) or the Nevada Test Site (now the Nevada National Security Site [NNSS]). BNFL reported that the project saved $100 Million (M) in disposal costs (Platts 2004). It is presumed that most of the cost savings derived from reduced transportation costs and disposal fees. The K-33 shear was capable of cutting solid metal components up to 10 inches thick. A photo of a BHS Shear by Harris is shown in Figure B-4. The $13M facility (including the shear and containment facility) was used for approximately three years to process 70,000 tons of material. K-33 equipment was initially disassembled and hand-cut into sections that were small enough to fit into the charge box of the 1,400 horsepower shear. In the charge box, the materials are compressed using a "tuck and roll" device into 26 ft long laminate sections that were indexed lengthwise into the shear for cutting into 10 inch lengths to meet debris dimensional requirements for NNSS. Discussions with former BNFL operations supervisors indicated the typical net weight of the sheared material loaded into a 25 $ft^3$ intermodal container was 52,500 lb giving a bulk density of 2,100 lb per $yd^3$. This is triple the bulk density normally experienced for large equipment disposed at the EMWMF (per CARAR density data). The compressed and sheared sections were collected in containers for shipment. The K-33 operation required a crew of 20 to operate, including those conducting primary size reduction operations, radiation protection personnel, equipment operators, and supervision. Assuming total personnel costs of $8.7M, and maintenance costs of $150,000, the approximate cost of VR for this operation was about $330 per $yd^3$.

**Figure B-4. BSH Shear by Harris**

### 5.4.2 Evaluation of Size Reduction Methods

Size reduction processing reduces disposal and transportation costs by increasing the density of the debris, which conserves landfill space and allows more material to be loaded per truckload. With continually rising fuel costs and the inherent risk of waste transportation, reducing the number of transport events is a significant benefit, especially for the distances required in the Off-site Disposal Alternative. For EMDF on-site disposal, the principal benefits of VR are the reduction in the quantity of clean fill material required to fill the void spaces within the material being placed in the disposal cell and the reduction in landfill size. The quantity of clean fill used is based on the volume and type of waste received. Once the waste has been placed in the cell with fill material, the heavy equipment (bull dozers) used to place the material is also used to compact the waste mix by driving over the materials. The capacity of the landfill is defined as the space occupied by the compacted waste and fill.

As defined in the CARAR (DOE 2012a) completed annually for the EMWMF based on the WGF, there are two types of quantitative waste volume estimates used in this RI/FS as described below:

- "As-generated" waste volume:
  - Volume estimate based upon excavated bulk volumes of soils, sediments, and demolished building debris that includes void space.
  - Bulk volume of soils, sediments, and demolished building debris that is roughly equivalent to the volume expected to be shipped (i.e., used for Off-site Disposal Alternative).
  - Includes higher amount of void space and has lower bulk density than debris that has been compacted in a landfill.

The as-generated volume is used in project planning to determine the number of truckloads and associated cost and duration necessary to move wastes from the work site to the disposal facility (on-site or off-site).

- "As-disposed" waste volume:
  - Volume estimate of waste after disposal in the disposal facility, at which point debris wastes, waste (soil) suitable for use as fill, and clean (additional) fill have been mixed and processed to meet compaction, void space, and operational requirements (i.e., used to determine the volume required for an on-site disposal facility).
  - Physically equivalent to survey results taken quarterly to estimate disposal facility airspace utilized.
  - Includes lower amount of void space than as-generated waste volumes because voids have been filled with soil and the material has been compacted in the landfill.

The as-disposed waste volume estimate is used as the basis for determining the required capacity of a new disposal facility for the On-site Disposal Alternative. Chapter 2 of this RI/FS includes additional information regarding as-generated and as-disposed waste volume estimates developed for the RI/FS.

Soil used as fill typically has an as-generated void fraction of about 25% and general construction debris has an as-generated void fraction of about 50%. Landfill capacity is referred to in terms of as-disposed volume, while WGF information is typically reported in terms of as-generated volume. To evaluate VR approaches, it was first necessary to determine the projected amount of as-generated debris that could be processed (see Table B-3). Based on this quantity, VR equipment can be sized and the full impact of processing can be determined.

Fill materials are used to reduce settlement of the waste and to ensure long-term stability of the final cap placed on the landfill. Previous experience gained from operating EMWMF indicates a soil-to-debris ratio greater than 1:1 is required to fill voids in bulky building debris (DOE 2004 and 2011a). Additional clean (uncontaminated) soil fill is required for operational purposes (e.g., to construct dump ramps and the

planned clean layer within the middle of the cell) (DOE 2011a). Because of shortfalls in contaminated soils and soil-like waste materials, EMWMF has purchased clean soil from off-site borrow sources to fill void spaces in the landfill (DOE 2011a). Size reduction of certain waste materials, such as bulky building debris, reduces the void space and reduces the volume of fill required for a particular waste stream (DOE 2003 and 2004). Cost effectiveness is determined by comparing the cost of size-reduction processing (capital cost and operating cost) with the cost savings realized through the reduction in fill requirements and reduced landfill size for several waste material types and processing methods.

#### 5.4.2.1 Size Reduction of Equipment and Structural Steel

Since heavy equipment and structural steel debris have relatively large void space and clean fill requirements, an initial evaluation was performed to determine the impact of VR through size reduction of equipment and heavy steel on clean fill requirement and landfill space.

From Table B-3, the volumes of equipment and steel anticipated for VR processing are 63,162 and 211,415 $yd^3$, respectively, or a total of 131,411 tons. It was assumed that the shearing machine described in Section 5.4.1.4 would be used for this application. The productivity of this machine, based on the K-33 project, is about 15.8 tons per hour, the equivalent of about 4.5 years of operation at 40 hours per week for the quantity given. This production rate is judged to be adequate based on a 15 year duration expected for D&D projects that would produce most of the equipment and heavy steel materials for processing. The density information used to develop the CARAR estimates indicates an as-generated void fraction of over 90% for equipment and metals. It is assumed that shearing operations will reduce the void volume of equipment and heavy steel components by 50%, doubling the bulk density. Fill material would still be necessary to occupy void space in the material, although the fill requirement would be lower. The CARAR provides estimates of the clean fill requirement based on the type of debris and density. In the case of equipment debris, it was assumed that the CARAR clean fill requirement would be reduced from a ratio of 9.58:1 (clean fill volume:equipment volume based on the as-disposed debris volume) to the ratio that would normally be required for construction debris or 2.26:1. In the case of structural steel debris, it was assumed that the clean fill requirement would be reduced from a ratio of 6.63:1 (clean fill volume:steel volume based on the as-disposed debris volume) to 2.26:1.

Table B-6 compares the fill requirements for unprocessed material with the anticipated fill requirements for size-reduced equipment and steel. The total quantity of clean fill avoided is 113,455 $yd^3$ which is approximately 27% of a complete landfill cell. The value of clean fill not used at $6.5/ton is $914K. In addition to clean fill savings, there are reductions in the cost of transporting the debris from the generator site to the EMDF. Since the bulk density is greater by a factor of two, the volume of debris per shipment is doubled and the number of shipments reduced by half. At $220 per transport event, the total savings would be about $3M. Landfill construction costs would not be reduced because the anticipated size of the cell and associated labor and materials would be the same, even if the cell is projected to receive a smaller fraction (73%) of the debris it was designed to accommodate. Landfill operating costs would also be the same because the waste generation schedule and resource levels would not change if the same quantity of waste (smaller volume, but same mass) must be managed. The total estimated cost savings from size reduction of equipment and heavy steel is about $3.92M. From the K-33 operation described in Section 5.4.1.4, the approximate cost of the processing equipment and facility is $13M without operating costs. This is $9.1M greater than the estimated savings associated with size-reduction, so it would not be cost effective to implement this process. As discussed previously, this method of VR provided cost savings for the K-33 project because heavy steel debris was shipped off-site for disposal at much greater cost than what would be expected for on-site disposal at the EMDF. The benefits of VR for the Off-site Disposal Alternative are addressed in Section 5.4.2.7.1.

This page intentionally left blank.

**Table B-6. Disposal Capacity Gained Through Size Reduction of Equipment and Heavy Steel Debris**

| Debris Type | Description | As-generated Volume for Processing ($yd^3$) | Weight, Tons | As-disposed Volume ($yd^3$) | Clean Fill Requirement for Unprocessed Material ( $yd^3$) | Basis | Volume after Size Reducing Material ( $yd^3$) | Volume Reduction | Clean Fill Ratio for Processed Material (Soil: Debris) | Clean Fill Requirement for Processed Material ($yd^3$) | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Thick walled steel, glove boxes, hoods, structural components, heavy-walled equipment, cranes structures | 63,162 | 21,475 | 3,821 | 36,607 | Clean fill ratio is 9.58 for as-disposed equipment (soil: debris) | 31,581 | 50% | 2.26 | 8,636 | Clean fill ratio is reduced to the value required for construction debris, 2.26. |
| Heavy steel | Large diameter pipe, tanks, structural steel | 211,415 | 109,936 | 19,561 | 129,693 | Clean fill ratio is 6.63 for as-disposed metals (soil: debris) | 105,707 | 50% | 2.26 | 44,209 | Clean fill ratio is reduced to the value required for construction debris, 2.26. |
| Total Volume ($yd^3$) | | 274,576 | 131,411 | 23,383 | **166,299 (A)** | | 137,288 | | | **52,845 (B)** | Total clean fill required for processed material |
| | | | | | | | | | | **113,455 (A-B)** | Total disposal capacity gained through reduced clean fill requirement (equals volume A minus volume B) |

This page intentionally left blank.

#### 5.4.2.2 Size Reduction of Concrete and General Demolition Debris

The balance of the debris shown in Table B-3, concrete, masonry rubble, and other demolition debris constitutes about 56% of the total or about 644,964 $yd^3$. Concrete and masonry rubble make up about 42% of the total debris volume and 14% is comprised of general demolition debris such as siding, sheet metal, and roofing materials. The density information used to develop the CARAR indicates an as-generated void fraction of 25% for concrete and 50% void fraction for general construction debris. By reducing the void fraction, crushing machines and shredders could have a major impact on landfill space requirements.

Crushed concrete would require a lesser quantity of fill due to the reduction in void space, and a significant fraction of the concrete could be pulverized to a soil-like material that may be used in place of fill. Based on the group of facilities analyzed, the quantity of concrete debris is almost half of the total quantity of debris generated. Consequently, crushed concrete could satisfy the fill requirement for a substantial amount of other debris (equipment, heavy structural materials, etc.). For this evaluation, it was assumed that the concrete rubble volume is reduced by 20% and the fill requirement for concrete rubble is reduced by 50% due to the soil-like, self-filling nature of the pulverized fraction of the concrete. In addition, it is assumed that 50% of the crushed concrete could be used in place of fill material for landfill placement of other debris types. For general construction debris, an industrial shredder would be very effective for reducing the volume and clean fill requirement. A 40–50% size reduction would be expected with a similar percentage reduction in clean fill requirement.

Table B-7 compares the fill requirements for unprocessed concrete and general demolition debris with the anticipated fill requirements for size-reduced materials and provides an estimate of the landfill capacity that could be gained. The capacity gained from reduced clean fill requirement is 225,991 $yd^3$ and the amount of crushed concrete that could be used to replace clean fill is 145,994 $yd^3$. From Appendix A, the anticipated volume of clean fill required for EMDF is 838,993 $yd^3$, so crushed concrete could reduce the total cost of clean fill by about 17 %, equivalent to a purchased clean fill value of nearly $1.2M. About 13% of the capacity gain is from shredding of general debris with the balance from concrete crushing operation. The total capacity gain, 371,985 $yd^3$, approaches the capacity of a full cell. Consequently, additional savings from deducting cell construction costs is possible.

Based on the potential for substantial cost reductions applying VR methods to concrete and general demolition debris, further consideration was warranted. Implementation on a project-by-project basis (VR equipment deployed at the project site, by each D&D contractor) was considered versus a single facility, accessible to all projects. Intuitively, a single facility is more cost effective, therefore a rough order-of-magnitude (ROM) cost estimate for such a facility, was developed.

This page intentionally left blank.

**Table B-7. Disposal Capacity Gained Through Size Reduction of Concrete and General Demolition Debris**

| Debris Type | Description | As-generated Volume for Processing ($yd^3$) | Weight, Tons | As-disposed Volume ($yd^3$) | Clean Fill Requirement for Unprocessed Material ($yd^3$) | Basis | Volume after Size Reducing Material ( $yd^3$) | Volume Reduction | Clean Fill Ratio for Processed Material (Soil: Debris) | Clean Fill Requirement for Processed Material ($yd^3$) | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete and Masonry | Reinforced concrete, concrete block, brick, shield walls | 364,985 | 474,481 | 291,988 | 364,985 | Clean fill ratio is 1.25 for as-disposed dense concrete (soil: concrete) | **291,988 (C)** | 20% | 0.625 | 175,193 | Clean fill ratio is 50% of the CARAR requirement for light concrete, 0.625 |
| Demolition | Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures | 60,605 | 49,090 | 30,303 | 68,484 | Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris) | 36,363 | 40% | 1.36 | 40,847 | Clean fill ratio is 60% of the CARAR requirement for debris, 1.36 |
| Metal (ferrous, light-guage) | Ventilation duct, light framing, small diameter pipe, siding, small tanks | 26,012 | 13,526 | 2,407 | 15,957 | Clean fill ratio is 6.63 for as-disposed compactable metal (soil: debris) | 13,006 | 50% | 3.31 | 7,967 | Clean fill ratio is 50% of the CARAR requirement for debris, 3.31 |
| Roofing Materials (asphalt) | Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt | 30,422 | 23,121 | 15,211 | 0 | No clean fill required, self-filling | 18,253 | 40% | 0 | 0 | Considered self-filling so no clean fill required. |
| Legacy Material and NTS | Containers, furniture, trash, wood | 1,698 | 544 | 849 | 1,715 | Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris) | 1,019 | 40% | 1.36 | 1,145 | Clean fill ratio is 60% of the CARAR requirement for debris, 1.36 |
| Total Volume (yd3) | | 483,723 | 560,761 | 340,758 | **451,142 (A)** | | 360,630 | | | **225,151 (B)** | Total clean fill required for processed material |
| | | | | | | | | | | 225,991 (**A**-**B**) | Disposal capacity gained through reduced clean fill requirement from VR |
| | | | | | | | | | | 145,994 (**C***0.5) | 50% of crushed concrete used to replace clean fill |
| | | | | | | | | | | **371,985** | Total disposal capacity gained (equal to the sum of capacity gained through VR and the quantity of crushed concrete used to replace clean fill.) |

This page intentionally left blank.

#### 5.4.2.3 ROM Cost for Size Reduction Facility

The analysis of crushing and shredding equipment deployment for concrete and general demolition debris indicates the potential for substantial savings in landfill construction costs, and warrants further consideration. Without historical cost data for projects involving this equipment, it was necessary to develop a ROM estimate for a processing facility. It is assumed in this case that the facility would be constructed on the EMDF site in the vicinity of the landfill operation.

The cost of shredding and crushing demolition debris was determined by obtaining budgetary vendor quotes for appropriately-sized equipment and estimating engineering, construction, and operating costs based on manufacturer recommendations and typical DOE project requirements. Demolition projects are typically performed in open air surroundings after selective removal of contaminated building sections and equipment. However, size reduction operations could cause airborne release of contamination that would otherwise remain undisturbed or imbedded in the debris materials. Dust suppression systems could be used, however, the safety of workers and those in areas adjacent to the demolition operations can only be ensured if airborne containment systems are provided. The deployment of size-reduction equipment for radioactively contaminated or potentially radioactively contaminated material requires a containment enclosure with ventilation and a high-efficiency particulate air (HEPA) filtered exhaust system. In addition, the operation will require the support of radiation control personnel for monitoring worker exposures, controlling contamination, and managing radioactive materials. Capital costs associated with size reduction would include the following:

- Size reduction equipment (one crusher and one shredder)
- Material handling equipment for feeding processors and containerizing processed material
- A building enclosure with HEPA filtered exhaust
- Staging areas for incoming debris and outgoing processed materials
- Utility connections (electricity, water, communications)
- Fire protection system
- Lighting
- Air handling units for climate control
- Instrumentation for monitoring ventilation air flow and airborne contamination levels

Processing equipment was selected based on debris quantities and expected rate of debris generation. The expected quantity of concrete and rubble is 478,481 tons to be generated over a 21-year time frame or an average of approximately 22,785 tons per year. A crusher with a maximum processing capacity of 150 tons per hour (tph) is selected for this process. Since much of the concrete will contain rebar, the rate is expected to be about 33% of the maximum or about 50 tph. The machine selected could process the average yearly quantity of concrete debris in about 3 months. The machine is oversized in order to minimize the space needed for staging feed materials for the operation.

The expected quantity of general debris for processing is expected to be about 86,281 tons and consists mainly of light gauge sheet metal, roofing materials, siding, wood framing, ventilation duct, and other materials. The design processing capacity of the shredder selected for this material is 25 tph, with an expected capacity of 10 tph due to expectations of some heavier gauge metals and a fraction of the concrete debris. Like the crusher, the shredder was sized for minimizing the space needed for staging and would be expected to process an average one year quantity of debris in about 3 months. Operating these machines would require the use of two excavators with appropriate tool attachments for handling the debris. The crusher and shredder would be equipped with conveyors for transferring size reduced materials to a transport container.

The enclosed area of the facility would be approximately 3,000 $ft^2$ to accommodate the crusher, shredder, one excavator, and two intermodal containers that would receive the size reduced material. Additional staging areas would encompass about 12,000 $ft^2$.

Planning, engineering design, and construction activities would be significant elements of the capital work scope. Once constructed, commissioning and readiness review activities would be performed prior to process operations. Table B-8 summarizes the capital costs for one facility.

**Table B-8. Capital Costs for EMDF Size Reduction Facility**

| Cost Element | Description | Labor and Materials ($K) |
|---|---|---|
| **Planning and Acquisition** | Includes all planning documents required for DOE capital projects (i.e., Project Execution Plan, alternative analysis, preliminary cost estimate, quality assurance plan, risk management plan, commissioning plan, etc.) | 629 |
| **Engineering Design** | Title I and II design packages including system requirements, specifications, and drawings | 382 |
| **Construction:** | | |
| Mobilization | Contractor plans and mobilization of construction equipment | 47.1 |
| Construction Support | Construction Superintendent, Safety Engineer, Field Supervisor, and equipment rental for project duration | 269.4 |
| Site Preparation | Geotechnical sampling, excavation, and concrete foundation | 204.0 |
| Enclosure | 80 ft × 72 ft × 30 ft height pre-engineered building with structural steel, siding with 4" of insulation, roofing, trim, windows, 3 personnel entry doors, (2) 16 ft rollup doors; Price includes installation. | 199 |
| Plumbing/Fire Protection | Fire hydrant , piping, and controls; potable water piping | 57.8 |
| Electrical and Lighting | Power pole, transformers, disconnect switch, panel boards, receptacles, indoor and outdoor lighting, exit signs, emergency egress signs, cable, conduit, hangers, and racks. | 188 |
| HVAC | Air handling unit, chiller and chilled water piping, intake louvers, control room 2-ton package unit, ductwork, fittings, grilles, and diffusers | 284 |
| HEPA Exhaust System | HEPA filter housings (2), ductwork, dampers, exhaust monitoring, and controls | 482.4 |
| Radiation Control Instrumentation | Rad meters (beta/gamma/alpha), alpha probes, pancake probes, friskers, Model 3030 sample counter, portal monitor | 68.7 |
| Processors (2), excavators (4), and support equipment | Crusher, shredder, delivery, setup and training | 1,952 |
| Demobilization | Turnover documentation, equipment removal, office removal | 32.9 |
| **Commissioning** | Component testing, system tests, procedure development, training, management assessment, and readiness assessment | 220.6 |
| **Subtotal:** | | **$ 5,017** |
| **Overhead at 8.5%** | | **$ 426.4** |
| **Construction contingency at 35%** | | **$ 1,905** |
| **Total Capital Cost** | | **$ 7,348** |

Operating the facility will require utility supply costs, fuel for the processors, maintenance of processors and support equipment, and an operating crew. The operating life of the equipment was investigated to determine if equipment replacement would be necessary at some point in the 22 years of CERCLA waste generation. Based on manufacturer discussions, these systems can be expected to operate for the duration of the 22-year time period of waste generation if maintained properly. The major mechanical components impacting the waste material can be sharpened or replaced, hydraulic pumps can be replaced, and the drive engines can be overhauled if necessary. These maintenance costs are included in the cost estimate. The crew would be composed of the personnel listed in Table B-9.

**Table B-9. Operations Personnel for Size Reduction Facility**

| Resource | Full-time Equivalent (FTE) | Responsibilities |
|---|---|---|
| Operations Supervisor | 1 | The Operations Supervisor would coordinate and supervise all process operations activities and personnel. The Supervisor would ensure that operations are conducted in accordance with procedures and in compliance with applicable permits and regulations. |
| Equipment Operators | 4 | Equipment operators would operate the crusher, shredder, and excavators in accordance with procedures and safety protocols. |
| Truck Driver | 1 | The driver would be responsible for transporting the size reduced debris to the landfill site. |
| Radiation Control Technician | 1 | The RCT would monitor the work area for contamination, prepare radiation work permits for equipment operators, and monitor the performance of the containment and HEPA filter system. |
| Maintenance Technician | 0.25 | The Maintenance Technician would perform preventative maintenance and repair services for the process equipment. |
| Environmental Monitoring Technician | 0.25 | The Environmental Monitoring Technician would monitor and sample for airborne and waterborne contaminants in accordance with environmental permits. |
| Health and Safety Technician | 0.25 | The Health and Safety Technician would monitor work conditions, prepare work/rest schedules for equipment operators based on temperature conditions, and ensure compliance with the worker health and safety plan. |

Project management would also be necessary to administer essential functions that support the safe and effective execution of facility operations. Management personnel would implement and oversee the following activities:

- Health and Safety (H&S)
- Radiation Protection
- QA Program
- Environmental Protection Program
- Site Access Control
- Risk Management
- Employee Training
- Project Controls
- Contract Administration
- Finance
- Accounting and Payroll
- Procurement
- Data Management
- Document Control

For estimating purposes, it was assumed that project management costs would be 20% of total project costs. Overhead costs (taxes, insurance, office space, security, etc.) are expected to be 8.5% of project costs. For a ROM estimate type, a 35% contingency is added to the capital costs to account for unanticipated cost items and resources. Table B-10 provides a summary of estimated life-cycle costs for the size reduction facility. A lump sum estimate of $500 Thousand (K) was included for D&D of the size reduction facility upon completion of operations. It was assumed that the enclosure and equipment would be decontaminated, disassembled, and placed in the EMDF landfill site just prior to landfill capping and closure activities.

**Table B-10. Total Life-cycle Costs for Size Reduction Facility**

| Cost Element | Description | Labor and Materials ($K) |
|---|---|---|
| Capital costs with contingency | Planning, engineering, construction, and commissioning | 7,348 |
| Operating crew | Supervision, equipment operators, truck drivers, RCTs, H&S support, environmental support, sampling costs, personal protective equipment (PPE) | 21,131 |
| Maintenance | Fuel, replacement and reworking of shredder and crusher components, engine overhauls for shredder, crusher, and excavators | 2,113 |
| Utilities and supplies | Electricity, water, replacement HEPA filters | 2,660 |
| Decontamination, demolition, and disposal at completion | Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF. | 500 |
| Project management | 20% of total project costs* | 6,235 |
| Overhead costs | 8.5% | 2,774 |
| **Total Life-cycle Cost** | Capital, operating, and D&D costs (Unescalated) | **42,761** |

*Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

Attachment B provides supporting cost details for the capital and operating cost estimate. The total life-cycle cost from Table B-10 is about $42.8M, or about $88.40 per $yd^3$ of material processed.

#### 5.4.2.4 Cost Effectiveness of Size Reduction

Cost savings as a consequence of size reduction for concrete and general demolition debris include reduced cost of clean fill for the landfill, reduced landfill construction costs, and reduced post-closure costs. For shredding and crushing operations, the total capacity gained is 371,985 $yd^3$ including reduced clean fill requirements and the use of crushed concrete as fill material. This volume is comparable to the volume of a complete disposal cell for the landfill. The cost estimate summary data from Appendix I, Table I-5 was used to estimate the cost savings associated with reducing the size of EMDF by the equivalent of one cell (Cell 6). Table B-11 provides a summary of avoided costs associated with EMDF construction and operations. The reduced costs of construction, construction support, capping, and closure are about $30.1M. The total avoided cost of clean fill in this case is approximately $3M based on a value of $6.50/ton of clean fill. Post-closure maintenance and monitoring is reduced by about $0.79M which is the incremental 100-year savings associated with maintaining the cap of smaller area. Long-term ground water monitoring costs (the bulk of long-term monitoring/maintenance costs) would not change with the removal of one cell from the EMDF. The total avoided costs for Cell 6 would be about $33.9M. The life cycle costs for size reduction are higher than the EMDF avoided costs by about $8.87M, indicating that deployment of a size reduction facility is not cost effective.

**Table B-11. Avoided EMDF Construction Costs Through Size Reduction**

| Cost Element | $M |
|---|---|
| Capital Cost of Cell 6 | 30.1 |
| Avoided cost of clean fill | 3 |
| Long-Term Monitoring and Maintenance (Reduced surveillance and maintenance costs) | 0.79 |
| **Total Cost Avoided if Cell 6 is not constructed** | **33.89** |

#### 5.4.2.5 Evaluation of Alternative Locations for Size Reduction Facility

Since deploying a size reduction facility on the EMDF site is not cost effective, alternative location options were evaluated to determine if cost effectiveness could be improved. Two options were evaluated:

- Installing two facilities adjacent to demolition sites at ORNL and Y-12 using existing buildings for containment enclosures
- Installing a facility adjacent to the EMDF disposal cell area and within the leachate collection zone

Deploying size reduction systems within existing buildings at ORNL or Y-12 near the demolition areas would reduce construction and transportation costs. Construction costs would be reduced by utilizing existing buildings to enclose the size reduction facility and provide ventilation containment. Transportation costs for moving waste materials from the demolition site to the EMDF would be reduced through increasing the bulk density of the debris and allowing more material to be transported per truckload.

The advantages of installing the size reduction facility within the EMDF disposal cell area include utilization of the leachate collection system for water management and containment, and utilization of the heavy equipment used for landfill placement to move the processed materials to the designated landfill placement location, thus eliminating the handling step associated with transporting the processed materials from size reduction facility to the placement location.

#### *5.4.2.5.1 Deployment Using Existing Facilities at ORNL and Y-12 Demolition Sites*

Increasing the bulk density of the debris reduces transportation costs by decreasing the number of transportation events necessary to move the debris from the demolition site to the EMDF. Transporting a 10 $yd^3$ truckload of debris costs an average of $220 per load. As shown in Table B-7, the total volume of the debris prior to size reduction is 645,534 $yd^3$ and 481,264 $yd^3$ after processing for a difference of 164,270 $yd^3$, which is equivalent to the volume that would not require transportation from the demolition site to EMDF. At $220 per 10 $yd^3$ load, the avoided cost of transportation would be $3.6M.

If two suitably sized existing inactive facilities at ORNL and Y-12 could be used to house and contain the two size reduction equipment at both sites, the capital costs associated with containment enclosures and associated support systems would be significantly reduced. However additional processing equipment and labor would be needed to operate at both sites. Table B-12 provides a comparison of size reduction facility costs for the two deployment approaches. Though capital costs, transportation, and D&D costs are reduced, combined operating costs are higher for the two facilities. Total life-cycle costs increase for deployment of size reduction processing at two sites by approximately $2.4M indicating that the cost benefit of using existing facilities to house the equipment is negated by the additional operating costs.

#### *5.4.2.5.2 Deployment within the EMDF Cell Boundary*

The EMDF design layout was reviewed to evaluate the feasibility of installing the size reduction facility within the footprint of the landfill site. The advantages to this approach include utilization of the existing leachate collection system for water management and containment, and the ability to use existing heavy equipment to move the processed materials to the landfill placement location. This differs from deployment outside the cell boundary by allowing processing and placement of waste materials in the same general location. This eliminates the handling step associated with transporting the processed materials from the size reduction facility to the placement location.

To minimize the distance between the size reduction facility and the landfill cells, the facility should be placed in a central location in close proximity to the cells. The first option examined involved placement of the facility within a constructed cell where waste placement activities had not begun. Since utility infrastructure is needed to support the processing, the facility must be constructed at a static location. The last anticipated cell (Cell 5) would be the optimum construction site to allow maximum use of the facility before the cell was needed for waste placement. However, there are several issues associated with this approach including:

- The facility would have to be removed or relocated before all of the waste for EMDF could be processed.
- The facility would need to be placed in the last anticipated cell for maximum utilization. This would negate the phased approach to construction and potentially the sizing of the leachate collection system.
- In the event of heavy rainfall, catchment areas within the cells are expected to accumulate standing water, which could potentially flood the size reduction facility.
- Vibration of the processing equipment could apply additional stress on the components of the liner and leachate collection system.

**Table B-12. Cost Comparison for Size Reduction Facility Deployment at EMDF and at Two Facilities in Existing Buildings at ORNL and Y-12**

| Cost Element | Description | Labor and Materials for Single Facility at EMDF ($K) | Explanation of Change for Deployment at two Demolition Sites | Labor and Materials for two Facilities at ORNL and Y-12 ($K) |
|---|---|---|---|---|
| Capital costs | Planning, construction, and commissioning | 7,348 | Enclosure costs eliminated; processor costs increased for deployment at two sites | 4,537 |
| Operating crew | Supervision, equipment operators, drivers, RCTs, H&S support, environmental support, sampling costs, PPE | 21,131 | Operating crew costs increase for deployment at two sites | 25,640 |
| Transportation | Transportation of debris to EMDF | 14,202 | Transportation costs are reduced by increasing debris bulk density | 10,588 |
| Maintenance | Fuel, replacement and reworking of shredder and crusher components, engine overhauls for shredder, crusher, and excavators | 2,113 | No change (maintenance costs are based on processing quantity) | 2,113 |
| Utilities and supplies | Electricity, water, replacement HEPA filters | 2,660 | Increased utility requirements for two enclosures | 5,273 |
| Decontamination, demolition, and disposal at completion | Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF. | 500 | D&D cost applies to equipment only | 200 |
| Project management | 20% of total project costs* | 6,235 | No change (same percentage) | 7,513 |
| Overhead costs | 8.5% of total project costs | 2,774 | No change in overhead rate | 3,533 |
| **Total Project Cost** | Capital, operating, and D&D costs (not escalated for inflation) | **56,963** | | **59,397** |

*Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

Due to these issues, it was decided to evaluate the placement of the facility at the northern edge of the landfill in an elevated location better suited for moving the processed materials to the active cells and avoiding the potential impact of accumulated storm water (see Figure B-5). The designed topography of the EMDF site indicates a suitable area at the north side of Cell 4 that was deemed optimum for the processing facility. Using this location for the size reduction facility would nevertheless require a significant amount of earthwork to develop the area identified for the facility. Consequently, the phased approach to EMDF construction would have to be modified to allow Phase I to include development of the area north of Cell 4 and construction of the size reduction facility. Also, though the proximity of the size reduction facility would be closer to most areas of the landfill, it would still be necessary to move the processed material from the facility to the placement location. The longest haul distance for transport would be approximately 2,300 ft with an elevation change of 150 ft. Using the heavy equipment required for spreading and compacting the waste to move the processed materials this distance to the placement site may cause a significant loss in productivity and higher fuel costs as compared to using additional dump trucks to move the processed material to the placement site.

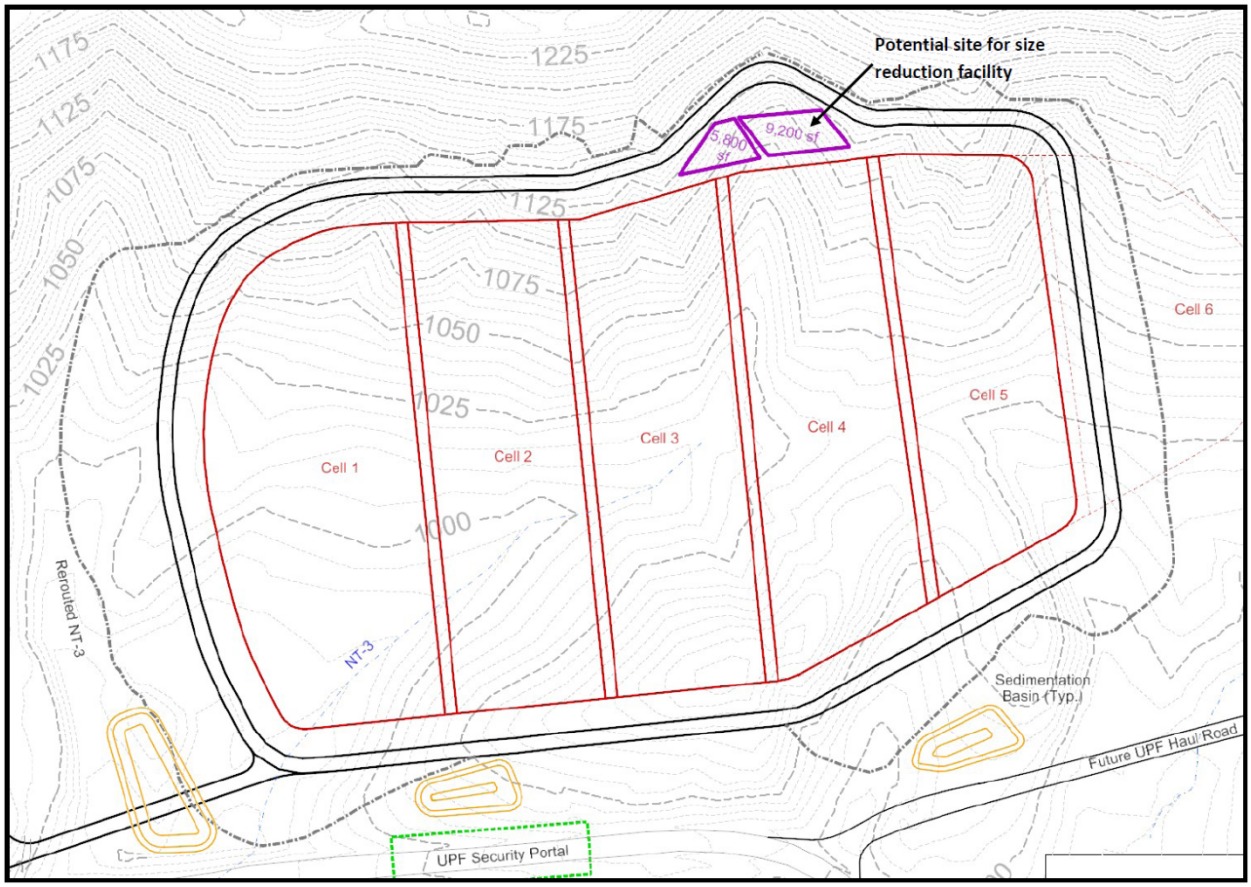



**Figure B-5. EMDF Site Plan with Potential Location for Size Reduction Facility**

The location for the size reduction facility is relatively level and provides an adequate footprint for the processing area, however, this site is on the perimeter of the landfill and could not take advantage of the landfill liner and leachate collection system for containment. To extend the landfill liner under the facility would require approximately 25,000 $ft^2$ of additional liner coverage. Roughly calculating the liner cost per $ft^2$, based on the estimate performed for EMDF, yields \$27.14/$ft^2$ or \$678,500 for the extended area. Constructing a concrete pad with containment for the facility could be performed at a lower cost than extending the liner system and it would accomplish the same purpose of collecting potentially contaminated runoff from the facility. The foundation could be designed to allow runoff from the facility to flow by gravity to the leachate collection system. The facility construction costs include the concrete pad with containment instead of extending the landfill liner and leachate collection system.

For evaluating the potential cost savings associated with constructing the size reduction facility within the landfill footprint, the cost data in Table B-10 for the facility constructed outside the landfill site was used to compare costs with those anticipated for the facility within the landfill footprint. Table B-13 shows the comparative costs for each work element. As shown, the capital costs, maintenance, utilities, and D&D costs would be the same. The difference in operating cost reflects the best possible case where the cost of transporting the processed material from the facility to the placement site is completely avoided by assuming the landfill heavy equipment would be used for that purpose.

As indicated in Table B-13, the cost of size reduction operations is reduced by \$3.8M with elimination of truck transporting the processed material from the size reduction facility to the EMDF cells. However, when compared to the cost benefits in Table B-11, the cost of size reduction remains \$5.05M greater than the cost of EMDF disposal without size reduction processing.

#### 5.4.2.6 Size Reduction Evaluation Conclusions for the On-site Disposal Alternative

Several size reduction technologies and deployment options were explored for size reduction processing of demolition debris of several different types prior to disposal at EMDF. Potential cost benefits were identified and evaluated against the estimated cost of constructing and operating a size reduction facility both at the EMDF site and at the Y-12 and ORNL sites where demolition activities will take place. The results clearly indicate that the cost of implementing size reduction processing is higher than the cost benefits from reduced landfill size, reduced transportation costs, and from reduced quantities of clean fill. Table B-14 provides a summary of the cost/benefit study results.

**Table B-13. Cost Comparison between Size Reduction Facility Installations at EMDF and within the EMDF Landfill Site**

| Cost Element | Description | Labor and Materials for Single Facility at EMDF Outside Landfill Site ($K) | Explanation of Change for Deployment at two Demolition Sites | Labor and Materials for Single Facility at EMDF within Landfill Site ($K) |
|---|---|---|---|---|
| Capital costs | Planning, construction, and commissioning | 7,348 | Increased site preparation costs | 8,395 |
| Operating crew | Supervision, equipment operators, drivers, RCTs, H&S support, environmental support, sampling costs, PPE | 21,131 | Cost decreased by reduced cost for moving waste from facility to waste placement site | 16,808 |
| Maintenance | Fuel, replacement and reworking of shredder and crusher components, engine overhauls for shredder, crusher, and excavators | 2,113 | No change (same processing quantity) | 2,113 |
| Utilities and supplies | Electricity, water, replacement HEPA filters | 2,660 | No change | 2,660 |
| Decontamination, demolition, and disposal at completion | Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF. | 500 | No change | 500 |
| Project management | 20% of total project costs* | 6,235 | No change in percentage | 5,585 |
| Overhead rate | 8.5% of total project costs | 2,774 | No change in rate | 2,877 |
| **Total Project Cost** | Capital, operating, and D&D costs (not escalated for inflation) | **$ 42,761** | | **$ 38,938** |

*Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

**Table B-14. Summary of Size Reduction Cost/Benefit Study Results for the On-site Disposal Alternative**

| Deployment Approach | Avoided Costs | Size Reduction Cost (Capital and Operating) | Net Cost |
|---|---|---|---|
| Size reduction of equipment and heavy structural steel | $5.22M | $13M (K-33 project capital cost only) | (-$7.78M) |
| Size reduction facility for concrete and general debris deployed at the EMDF | $33.89M | $42.76M | (-$8.87M) |
| Size reduction facility for concrete and general debris deployed in existing facilities at the Y-12 and ORNL sites | $37.5M | $48.8M | (-$11.3M) |
| Size reduction facility for concrete and general debris deployed within EMDF landfill site | $33.89M | $38.94 | (-$5.05M) |

### 5.4.2.7 Volume Reduction for Off-Site Disposal

The Off-site Disposal Alternative would provide for the transportation of future CERCLA candidate waste streams to one or more approved off-site disposal facilities and placement of the wastes in those facilities. Volume reduction efforts would have a significant impact on off-site disposal by reducing the number of waste shipments with associated high transportation costs and the disposal fees.

#### *5.4.2.7.1 Size Reduction for Off-site Disposal*

The use of VR equipment to size-reduce and increase the bulk density of demolition debris would, in some cases, increase the quantity of material per shipment and reduce the total number of off-site shipments. The Off-site Disposal Alternative is described in Chapter 6 of the RI/FS and costs are provided in Appendix I, Table I-9. This information was used as a basis for determining the economic benefit of various VR approaches.

In the Off-site Disposal Alternative, all non-classified LLW and LLW/TSCA waste (comprising the majority of the total waste volume evaluated under the Off-site Disposal Alternative as described in Chapter 2) would be shipped to either NNSS in Nye County, Nevada, (Option 1) or Energy*Solutions* in Clive, Utah, (Option 2). All classified waste is trucked to NNSS. The remaining 3% of LLW/RCRA waste would be shipped to Energy*Solutions* in Clive, Utah, or Waste Control Specialists in Andrews, Texas. For purposes of VR comparison, shipment of LLW debris to NNSS (Option 1) is assumed and analyzed, because shipment of LLW debris to Energy*Solutions* is based on weight limits and therefore VR (reduction in volume of waste) could not affect the cost estimate.

Transportation for the off-site disposal estimate assumes that LLW debris would be transported by intermodal containers with 25 $yd^3$ capacity to a truck-to-rail transfer facility at ETTP for rail shipment to Kingman, Arizona, where transloading of intermodals from railcar to trucks would be performed for

transport to NNSS. A single articulated bulk container railcar (ABC railcar) is assumed to carry eight intermodal containers. Transportation cost for one railcar from the ETTP to Kingman, Arizona, would be $25,440 in 2012 dollars (or $3,180 per intermodal container). The cost of unloading the intermodal containers from the railcar and transporting by truck from Kingman to NNSS would be about $1,370 per intermodal container. The intermodal containers would be taken into the appropriate disposal cell and emptied per approved procedures. Empty containers would be surveyed at the disposal facility for release and returned to ORR for reuse. Intermodal containers would be purchased and replaced after 10 years of use.

The cost effectiveness of size reduction would depend upon the type and quantity of material to be shipped off site. Table B-15 summarizes an analysis performed to determine those materials that would benefit from VR processing. The materials and quantities to be processed by VR (Table B-3) were evaluated to estimate the additional quantities that could be loaded per intermodal container. NNSS acceptance criteria limits the maximum volume per intermodal to 18 $yd^3$ and maximum net weight of 36,000 lb. The 18 $yd^3$ maximum is used for intermodals that are to be emptied and returned to the generator to avoid debris jams while dumping the intermodal contents through the hinged door at the end of the container. After determining the total additional weight of material that could be shipped per intermodal, bulk density information was used to determine the equivalent volume in terms of as-generated material, which is the volume that would not require shipment if size reduction processing is performed. As-generated materials that have a relatively high bulk density such as concrete and masonry would not be as cost effective to crush further because the truckload quantity would be limited by weight rather than volume. However, materials with a high void fraction and low density could be size reduced to increase the bulk density and increase the quantity and weight shipped per truckload. These materials include equipment, large diameter ductwork and pipe, structural steel, light framing, siding, small tanks, asphalt shingles and other roofing materials, containers, furniture, trash, and wood. The results show that size reduction processing would be beneficial for all materials except for concrete and masonry.

The materials that benefit from size reduction are generally bulky with high void fraction. Most include metallic debris and would require a shearing machine for processing heavy gauge metal and a shredder for thin gauge metals and light debris. It was assumed that a centrally located size reduction facility at ETTP would be provided to process debris as received by dump truck from the demolitions site. To estimate the facility cost, the data for the EMDF on-site size reduction facility for concrete and general construction debris (see Table B-8), was adjusted by substituting the concrete crusher with a shearing machine. Operating costs were adjusted for the additional labor and energy for operating the shear. In addition, the duration of operations was extended by five years to compensate for the higher costs of off-site shipments and annual budget limitations. Table B-16 provides a summary of the life-cycle costs for the facility.

**Table B-15. Volume Reduction Analysis for the Off-Site Disposal Alternative**

| Description | As-generated Bulk Density (lb/yd$^3$) | As-generated Volume for Processing (yd$^3$) | Total Intermodals without VR | Intermodal net Weight without VR (lb) | Bulk Density after VR (lb/yd$^3$) | Size Reduction Basis | Volume after VR (yd$^3$) | Intermodal Net Weight when Full (lb) | Total Intermodals with VR | Net Intermodal Shipments Avoided | Equivalent As-generated Waste Volume (yd$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes | 680 | 63,162 | 3,509 | 12,240 | 1,360 | 50% size reduction | 31,581 | 24,480 | 1,754 | 1,754 | 31,581 |
| Pipe, tanks, structural steel | 1,040 | 211,415 | 11,745 | 18,720 | 2,080 | 50% size reduction | 105,707 | 36,000 | 5,638 | 5,638 | 101,479 |
| Reinforced concrete, concrete block, brick, shield walls | 2,600 | 364,985 | 26,360 | 36,000 | 3,250 | 20% size reduction ** | 291,988 | 36,000 | 26,360 | 0 | 0 |
| Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures | 1,620 | 60,605 | 3,367 | 29,160 | 2,700 | 40% size reduction | 36,363 | 36,000 | 2,727 | 640 | 11,515 |
| Ventilation duct, light framing, small diameter pipe, siding, small tanks | 1,040 | 26,012 | 1,445 | 18,720 | 1,733 | 40% size reduction | 15,607 | 31,200 | 867 | 578 | 10,405 |
| Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt | 1,520 | 30,422 | 1,690 | 27,360 | 2,533 | 40% size reduction | 18,253 | 36,000 | 1,284 | 406 | 7,301 |
| Containers, furniture, trash, wood | 640 | 1,698 | 94 | 11,520 | 1,067 | 40% size reduction | 1,109 | 19,200 | 57 | 38 | 679 |
| **TOTALS** | | **758,300** | **48,211** | | | | **500,519** | | **39,157** | **9,053** | **162,960** |

** Not included as a waste amenable to VR.

This page intentionally left blank.

**Table B-16. Total Life-cycle Costs for Off-Site Alternative Size Reduction Facility**

| Cost Element | Description | Labor and Materials ($K) |
|---|---|---|
| **Planning and Acquisition** | Includes all planning documents required for DOE capital projects (i.e., Project Execution Plan, alternative analysis, preliminary cost estimate, quality assurance plan, risk management plan, commissioning plan, etc.) | 629 |
| **Engineering Design** | Title I and II design packages including system requirements, specifications, and drawings | 382 |
| **Construction** | | |
| Mobilization | Contractor plans and mobilization of construction equipment | 47 |
| Construction Support | Construction Superintendent, Safety Engineer, Field Supervisor, and equipment rental for project duration | 269 |
| Site Preparation | Geotechnical sampling, excavation, water supply, and concrete foundation; 80 ft × 80 ft × 30 ft height pre-engineered building. | 416 |
| Mechanical Systems | Heating, ventilation, air conditioning, exhaust filtration, plumbing, and fire protection | 810 |
| Electrical and Lighting | Power pole, transformers, disconnect switch, panel boards, receptacles, indoor and outdoor lighting, exit signs, emergency egress signs, cable, conduit, hangers, and racks. | 188 |
| Radiation Control Instrumentation | Rad meters (beta/gamma/alpha), alpha probes, pancake probes, friskers, Model 3030 sample counter, portal monitor | 69 |
| Processing Equipment | Shear machine, shredder, excavators (3), and containers | 9,416 |
| Demobilization | Turnover documentation, equipment removal, office removal | 33 |
| Commissioning | Component testing, system tests, procedure development, training, management assessment, and readiness assessment | 221 |
| **Total Capital Cost** | Planning, design, construction, and commissioning | **12,480** |

**Table B-16. Total Life-cycle Costs for Off-Site Alternative Size Reduction Facility (Continued)**

| Cost Element | Description | Labor and Materials ($K) |
|---|---|---|
| **Operations** | | |
| Operating crew | Supervision, operators, drivers, RCTs, H&S support, environmental support, sampling costs, PPE | 41,564 |
| Maintenance | Rotating or replacing knife blades, greasing, replacing hydraulic fluid, fuel, oil changes, engine overhauls | 2,215 |
| Utilities and supplies | Electricity, water, replacement HEPA filters | 4,318 |
| **Total Operating Cost** | Operating crew, maintenance, and utilities | **48,097** |
| D&D | Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF. | 1,500 |
| Project management | 20% of total project costs* | 12,241 |
| Overhead | 8.5% of total project costs | 6,317 |
| Contingency | 35% of total construction costs | 3,942 |
| **Total Life-cycle Cost** | Capital, operating, and D&D costs (unescalated) | **84,577** |

*Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

The cost of size reduction, $84.6M, must be compared to the avoided cost of off-site disposal to determine cost effectiveness. The avoided cost for off-site disposal was calculated based on a unit rate for off-site disposal of $1,013 per $yd^3$ in 2012 dollars with contingency for disposal Option 1. This value is determined from Appendix I data for the off-site alternative (prior to VR). In Table B-17, the rate was applied to the avoided shipment volume from Table B-15 to determine the avoided cost. When compared to the cost of size reduction, the cost benefit for the Off-site Disposal Alternative Option 1 is a savings of $80.5M.

**Table B-17. Cost Benefit of Size Reduction for Off-site Disposal Alternative (Option 1)**

| Material | Avoided Shipping Volume ( $yd^3$) | Avoided Shipping Cost at $1,013 per $yd^3$ ($K) |
|---|---|---|
| Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes | 31,581 | 31,991 |
| Pipe, tanks, structural steel | 101,479 | 102,798 |
| Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures | 11,515 | 11,665 |
| Ventilation duct, light framing, small diameter piping, siding, small tanks | 10,405 | 10,540 |
| Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt | 7,301 | 7,396 |
| Containers, furniture, trash, wood | 679 | 688 |
| **TOTAL** | 162,960 | 165,078 |
| **Life-cycle Size Reduction Facility Cost, $K** | | **84,577** |
| **Avoided Cost of Off-site Disposal in Option 1, $K** | | **80,501** |

The avoided cost of $80.5M is applied to the Appendix I off-site disposal estimate for Option 1, resulting in a $960 per $yd^3$ (see Appendix I). To determine how this unit rate compares to on-site disposal, it is necessary to determine unit rates for the same materials if disposed at EMDF. The overall unit rate for on-site disposal was determined by dividing the total cost of the EMDF (2012 dollars with 22% contingency) at $777.1 M (from Appendix I, Table I-2 for five cells) by the total as-generated volume of debris and soil 1,948,558 $yd^3$ from Appendix A, Table A-3, resulting in a unit cost of about $399 per $yd^3$. However, this constitutes an average rate and some materials are more costly to dispose of than others. To determine the cost of disposal for a particular waste type, the unit cost of EMDF air space must be determined and applied to the as-disposed waste volume along with the required clean fill volume. The unit cost of air space is given by the total EMDF cost divided by the total as-disposed air space of 2.2M $yd^3$ giving $353.22 per $yd^3$. Table B-18 applies this unit cost to the as-disposed volume of waste types with fill requirements. Unit costs range from $107 to $636 per $yd^3$ and are higher for materials with higher ratios of as-disposed to as-generated volumes and significant fill requirements. All of the unit rates, however, are much lower than the rate for off-site disposal with or without the use of size reduction.

#### *5.4.2.7.2 Recycling, Segregation, and Sequencing for Off-site Disposal*

The benefits of waste recycle and segregation are significant for the Off-site Disposal Alternative. For every $yd^3$ of material recycled or segregated for disposal at the ORR Landfill, the cost avoided is $960 based on the unit rate for off-site disposal, less the cost of recycling or segregation. From Section 5.1.2, the cost of recycling would be about $54 per $yd^3$ and from Section 5.3, the cost of segregation is about $54 per $yd^3$ plus the cost of disposal in the ORR Landfill, which would be far less than the cost of off-site disposal.

Project sequencing would also be beneficial for off-site disposal if waste soil could be made available to mix with low density debris and increase the mass of waste per intermodal for shipments. The challenge for this approach would be the logistics associated with loading intermodal containers with a mixture of soil and debris generated from different CERCLA actions and locations. Additional space for soil stockpiling and costly double-handling of soil would be required for it to be available for mixing with debris. Mixing of waste types would require additional planning and certification effort to obtain approval from the disposal facility for mixing wastes with different profiles.

**Table B-18. Unit Cost Determination for On-site Disposal Cost by Waste Type without Volume Reduction**

| Description | As-generated Volume ($yd^3$) | As-disposed Volume ($yd^3$) | Clean Fill Required ($yd^3$) | Clean Fill Ratio (soil:debris) from CARAR | As-disposed Volume for Waste and Clean Fill ($yd^3$) | Cost of EMDF Airspace at \$353.22/$yd^3$ (\$K) | Cost per $yd^3$ of As-generated Material (\$/$yd^3$) |
|---|---|---|---|---|---|---|---|
| Thick walled steel, large machine tools, large electric motors, process vessels | 210,539 | 12,737 | 122,023 | 9.58 | 134,760 | \$47,600 | \$226.09 |
| Large diameter pipe, structural steel, crane structures | 281,886 | 26,082 | 172,924 | 6.63 | 199,006 | \$70,293 | \$249.37 |
| Reinforced concrete, concrete block, brick, shield walls | 486,647 | 389,317 | 486,647 | 1.25 | 875,964 | \$309,408 | \$635.80 |
| Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures | 80,807 | 40,404 | 91,312 | 2.26 | 131,716 | \$46,525 | \$575.75 |
| Ventilation duct, light framing, small diameter pipe, siding, small tanks | 34,683 | 3,209 | 7,253 | 2.26 | 10,462 | \$3,695 | \$106.54 |
| Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt | 40,562 | 20,281 | 0 | 0 | 20,281 | \$7,164 | \$176.61 |
| Containers, furniture, trash, wood | 2,265 | 1,132 | 2,559 | 2.26 | 3,691 | \$1,304 | \$575.75 |
| **TOTALS** | **1,137,389** | **493,163** | **882,717** | | **1,375,880** | | |

# 6. PREVIOUS VOLUME REDUCTION EVALUATIONS

In August 2001, DOE published the *Waste Management Program Plan for Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act – Generated Waste* (WMPP, DOE 2001a). At the time the WMPP was written, it was believed that current and future expansion capacity of the EMWMF would accommodate forecasted disposal volumes. However, the WMPP indicated that further emphasis to reduce the volume of debris waste may be necessary to achieve an appropriate operating soil-to-debris ratio. Specifically, the WMPP recommended physical size reduction treatment and segregation of clean materials to the ORR Landfill be considered. As a best management practice, it was recommended that clean debris not be disposed at EMWMF because it takes up expensive disposal space and would require additional clean fill to achieve an appropriate soil-to-debris ratio. Also, the contaminated soil disposed at EMWMF should be utilized as fill to reduce the demand for clean soil fill. Both of these recommendations have been implemented as discussed in Sections 5.2 and 5.3.

Subsequent to the first load of waste being disposed at EMWMF during May 2002, DOE published the *Comprehensive Waste Disposition Plan for the DOE Oak Ridge Reservation* in March 2003 (DOE 2003). By this time, it was realized that EMWMF did not have adequate capacity to accommodate the projected CERCLA waste volumes and EMWMF has since been expanded. The goal of the plan was to assist DOE, TDEC, and EPA with ongoing efforts to assure that solid wastes managed by DOE Oak Ridge Environmental Management programs have access to cost-effective and environmentally sound disposal facilities. The plan includes a commitment by DOE to evaluate volume reduction methods as a means of reducing CERCLA waste volumes and conserving the disposal capacity of EMWMF.

In 2004, BJC conducted a VR study focused on the approximately 350,000 $yd^3$ ("as-generated volume" basis) of metal and demolition debris waste streams generated from decontamination and decommissioning of the eight largest buildings at ETTP and from the ETTP Scrap Metal Project (BJC 2004). It also evaluated the current baseline to see if there were additional opportunities for waste segregation. Two size-reduction technologies were evaluated, including shredding and compacting. It was concluded that, at best, 100,000 $yd^3$ of capacity could be gained by applying size-reduction technologies to the targeted waste streams. The cost of size reduction was evaluated against a potential cost savings of \$37 per $yd^3$ for transportation and \$20 per $yd^3$ associated with EMWMF expansion costs. At the time the study was performed, it was believed that 100,000 $yd^3$ would reduce the landfill height and would not affect the landfill footprint; hence, the cost savings were operations related with no benefit from lower construction costs. The cost range for size reduction processing was estimated at \$68 to \$78 per $yd^3$ which is higher than the anticipated cost savings of \$57 per $yd^3$. The study concluded that it was not cost-effective to size reduce the waste or perform additional characterization sampling required to further segregate the waste based on contamination level.

# 7. LESSONS LEARNED

Discussions were held with former employees from the Weldon Spring Site RA Project (WSSRAP) and the Fernald Environmental Management Project (FEMP) sites who were involved with the design and operations of the disposal facilities at each site. Each site constructed on-site disposal facilities for disposal of the vast majority of remediation waste and demolition debris generated by the closure of the sites. While VR was not the primary focus of either site, actions were taken which contributed to tangible reductions in the size of the final disposal facility.

At WSSRAP, a 1.48M $yd^3$ capacity disposal facility was constructed and operated. The facility was used to dispose of demolition rubble from the on-site buildings, contaminated soils, and other wastes originally generated from site operations. Operations of the facility were based on strategic waste placement in the cell. Wastes were transported to the landfill by dump truck and then placed in pre-determined positions.

Prior to loading in the transport vehicles, all debris had to meet size restrictions, so shearing attachments for excavators were used to cut the material to proper size. This was primarily performed to maximize transport efficiency but had the additional benefit of size reduction for the cell, minimizing void spaces that would need to be filled. Flowable grout was used to fill those void spaces that remained. Additionally, some pulverization of the foundation concrete was performed to improve transport efficiency and reduce the volume of waste placed in the cell.

The FEMP constructed an on-site disposal facility with a capacity of over 2.9 M $yd^3$ for disposal of remediation waste, including demolition debris, generated by the closure of the former Feed Materials Production Center. The WAC for the disposal facility included size limitations for the debris being placed in the cell. As at WSSRAP, operations of the facility were based on strategic waste placement. The need for clean fill was minimized by balancing soil and debris placement with sequencing of D&D and soil remediation projects to maintain this balance. Early stages of the remedial action focused almost exclusively on soil remediation which resulted in most of the first cell being filled with waste soil since D&D had not yet begun. Upon realization of this disparity, improved project sequencing was initiated to assure waste soil was available during debris placement. Additionally, Fernald implemented concrete crushing actions, especially on building foundation slabs. Crushed concrete was used in lieu of soil as filler material. A recommendation from FEMP site personnel was to size-reduce debris at the demolition site prior to transport and placement in the disposal cell. This was accomplished with mechanical VR equipment at the demolition site location. The major lesson learned was that balancing soil and debris to minimize clean fill is the best opportunity to conserve landfill capacity.

At ETTP, excavators with crusher and shearing attachments are routinely used to size-reduce materials to meet the EMWMF acceptance criteria and to reduce transportation costs. Excavator attachments for size-reduction are used routinely for D&D projects, however, the primary purpose of the excavators is for building demolition and the low productivity for VR processing alone is not cost effective. As described previously, excavators would be required to support VR operations by minimal size-reducing as necessary for placement in VR equipment feed hoppers.

# 8. SUMMARY

The results of this study indicate that volume reduction methods must be evaluated on a case by case basis and are not always cost effective for disposal of CERCLA waste. Recycling, waste segregation, project sequencing, and size reduction can all be beneficial under certain conditions. However, some methods include technical and administrative challenges that introduce unacceptable costs and risks.

Waste segregation and project sequencing are integral to CERCLA waste management activities. These methods are beneficial to both the On-site and Off-site Disposal Alternatives. Waste segregation requires evaluation to determine if a more rigorous characterization effort would be cost effective under the specific work conditions encountered. Poor waste segregation could result in challenging the EMDF design capacity by disposing of excessive quantities of clean materials in the EMDF. If project sequencing is efficiently executed and the majority of waste soil is used as fill material, EMDF landfill space is conserved. Alternatively, if project sequencing is poor and waste soil is not used to replace clean fill, the additional landfill space occupied by the waste soil would approach the volume of an additional disposal cell. Both segregation and sequencing would benefit off-site disposal by reducing the number of waste shipments and associated costs.

Recycling is potentially beneficial for both On-site and Off-site Disposal Alternatives, but would depend on characterization requirements that are currently uncertain. Once the NRC and DOE have established a sound technical basis for survey and release for solid materials associated with radiological activity, recycling efforts should focus on recovery and recycle of metals. Recycling materials in public

commerce, however, would not be allowed unless the current DOE ban on the recycle of potentially contaminated materials is lifted.

Size reduction processing can be an expensive endeavor that must be evaluated carefully to determine cost effectiveness. The potential for airborne release during processing of potentially contaminated materials is a significant risk, therefore expensive containment systems and operational controls must be provided. These systems increase size reduction facility costs beyond the bounds of cost effectiveness for the On-site Disposal Alternative. However, a size reduction facility for the Off-site Disposal Alternative that transports the bulk of material to NNSS for disposal would be cost effective due to the high cost of transporting the waste off-site.

Volume reduction efforts are essential for preserving the design capacity of the EMDF On-site Disposal Alternative and would substantially reduce the cost of the Off-site Disposal Alternative. Regardless of the disposal method, implementation of waste sequencing, segregation, and recycling efforts to decrease disposal costs are best management practices. Evaluation of further volume reduction approaches will continue to be an integral part of the CERCLA waste disposal strategy at both the program and project level.

# 9. REFERENCES


ANSI-1999. *Surface and Volumetric Radioactivity Standards for Clearance*, ANSI/HPS N13.12, American National Standards Institute and the Health Physics Society, August 31, 1999, New York, New York.

BNFL 2001. Brown, R.J. and Howard, J., U.S. DOE; McAnally, J.L., Miles, R. and D. Nichols, BNFL, Inc.; and Daly, P., Manufacturing Sciences Corporation (USA), *Progress on the East Tennessee Technology Park (ETTP) Three Building Decontamination Project*, Waste Management '01 Conference, February 25-March 1, 2001, Tucson, AZ.

BJC 2004. *Large Building and Scrapyard Volume Reduction Study*, BJC/OR- 1908, Bechtel Jacobs Company LLC under contract with the U.S Department of Energy Office of Environmental Management, August 2004, Oak Ridge, Tennessee.

CU-2009. Fitzgerald, G. C.,*Technical and Economic Analysis of Pre-Shredding Municipal Solid Wastes Prior to Disposal*, Department of Earth and Environmental Engineering, Columbia University, September 2009, New York, NY.

DOE 1988. *Low-Level Radioactive Waste Volume Reduction and Stabilization Technologies Resource Manual*, DOE/LLW-76T, U.S Department of Energy Idaho Operations Office, prepared by Ebasco Services Incorporated, December 1988, Bellevue, Washington.

DOE 1992. *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, DOE-STD-1027-92 Ch 1, U.S. Department of Energy, December 1992, Washington D.C.

DOE 1993. *Radiation Protection of the Public and the Environment*, DOE O 5400.5, Ch 2, U.S. Department of Energy, January 1993, Washington DC.

DOE 1994. *DOE Limited Standard Hazard Baseline Documentation*, DOE-EM-STD-5502-94, U.S. Department of Energy, August 1994, Washington DC.

DOE 2001a. *Waste Management Program Plan for Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act – Generated Waste*, DOE/OR/011-1980&D1, U.S. Department of Energy Office of Environmental Management, August 2001, Oak Ridge, Tennessee.

DOE 2003. *Comprehensive Waste Disposition Plan for the DOE Oak Ridge Reservation*, DOE/OR/01-2045&D2, U.S. Department of Energy Office of Environmental Management, 2003, Oak Ridge, TN.

DOE 2004. *Environmental Management Waste Management Facility Capacity Assurance Remedial Action Report*, DOE/OR/01-2145&D2, U.S. Department of Energy Office of Environmental Management, 2004, Oak Ridge, Tennessee.

DOE 2009a. *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual*, (MARSAME), NUREG-1575, Supp. 1, EPA 402-R-09-001, DOE/HS-0004, U.S. Department of Defense, Department of Energy, Environmental Protection Agency, and Nuclear Regulatory Commission, January 2009, Washington DC.

DOE 2009b. *Modification Record to Federal Facility Agreement for the Oak Ridge Reservation, Major Modification to Appendix J,* FFA Change Control Number FFA-PM/09-010, U.S. EPA Region IV, Atlanta, GA; U.S. DOE, Oak Ridge, TN; and TDEC, Nashville, TN, July 2009.

DOE 2010. *Environmental Management Waste Management Facility 2010 Capacity Assurance Remedial Action Report*, DOE/OR/0l-2463&Dl, U.S. Department of Energy Office of Environmental Management, March 2010, Oak Ridge, Tennessee.

DOE 2011a. *Environmental Management Waste Management Facility 2011 Capacity Assurance Remedial Action Report*, DOE/OR/01-2514&D1, U.S. Department of Energy Office of Environmental Management, 2011,Oak Ridge, Tennessee.

DOE 2011b. *Radiation Protection of the Public and the Environment*, DOE O 458.1, U.S. Department of Energy, February 2011, Washington DC.

DOE 2012a. *Environmental Management Waste Management Facility 2012 Capacity Assurance Remedial Action Report*, DOE/OR/01-2567&D1, U.S. Department of Energy Office of Environmental Management, 2012,Oak Ridge, Tennessee.

DOE 2012b. *Characterization Report for Alpha 5 Building 9201-5 at theY-12 National Security Complex, Volume I*, DOE/OR/01-2540&D2, March 2012,Oak Ridge, Tennessee.

DOE 2012c. *Audit Report, Oak Ridge National Laboratory's Waste Diversion Efforts*, OAS-L-12-06, U.S. Department of Energy Office of Inspector General, July 2012, Washington DC.

IAEA-2004. *Application of the Concepts of Exclusion, Exemption and Clearance*, RS-G-1.7, International Atomic Energy Agency, August 2004, Vienna, Austria.

LANL 2009. DeSousa, F., *LANL Exceeds Early Recovery Act Recycling Goals,* News Center, Los Alamos National Laboratory, March 2009.

LLNL 2008. Yano, G., *Lab earns DOE Pollution Prevention Awards,* LLNL Community News, Lawrence Livermore National Laboratory, September 2008.

NRC 2005a. *Rulemaking Issue Notation Vote SECY-05-0054 for Proposed Rule: Radiological Criteria for Controlling the Disposition of Solid Materials,* RIN 3150-AH18, U.S. Nuclear Regulatory Commission, March 31, 2005, Washington DC.

NRC 2005b. *Commission Voting Record Decision Item: SECY-05-0054; Proposed Rule: Radiological Criteria For Controlling The Disposition Of Solid Materials*, RIN 3150-AH18, U.S. Nuclear Regulatory Commission, June 2005, Washington DC.

Platts 2004. *BNFL nuclear supercompactor being dismantled*, News Release, Platts, Division of McGraw-Hill Companies, September 2004, Washington DC.

USGS 2011. *2010 Minerals Yearbook,* US Department of Interior, US Geological Survey, November 2011.

This page intentionally left blank.

# APPENDIX B - ATTACHMENT A:
# VENDOR INFORMATION

This page intentionally left blank.

| | |
|---|---|
| **Vendor:** | SSI Shredding Systems, Wilsonville, Oregon (www.ssiworld.com) |
| **Equipment Model:** | PRI-MAX 6000 Primary Reducer and the PRI-MAX 770 |
| **Application:** | Demolition debris including wood, siding, thin gauge metal (up to ¼-inch), roofing, shingles, flashing, conduit, sheet metal, ductwork, with a small fraction of concrete materials |

| | |
|---|---|
| Material preparation requirements: | Limited by size of hopper only; 224" L × 94"W × 43" H; 13.1 $yd^{3.}$ |
| Processing capacity: | 60 – 150 tons per hr (10-40 tons per hr for the PRI-MAX 770). |
| Power | 700 HP diesel mobile unit (250 HP for PRI-MAX 770).<br>500 HP electric stationary unit. |
| Maintenance requirements: | Stationary electric units cost about $1 per ton to maintain, including routine maintenance, checkouts, hard-facing of cutters, and periodic shaft and cross member replacements. Hard-facing is usually performed once per month and requires two maintenance operators for two days (32 hrs). |
| Number of operators: | The operator who loads the feed can operate the machine remotely, plus whatever support is needed to move processed materials away from the machine; estimate 1.25 operators. |
| Climate limitations: | None |
| Support equipment: | Excavator dedicated to loading the shredder; conveyor and magnet for separating metals: $150K. |
| Budgetary cost of equipment: | $1.2M for complete system (shredder, drive, conveyor, and magnet) on tracks that move the equipment along with the progress of the demolition. Recommend having a spare shaft/cutter assembly on hand at $80,000 and 10 sets of cross members (cutter table) at $12,000 (for 10). **For a smaller model, the PRI-MAX 770, the cost would be $325,000. The cost of cutters and cross members would be 50% lower than those used for the 6000 model.** |
| Cost of major overhaul: | Replacement or rework of shaft; $80K, plus replacement of cross members $12K; required every 2 years if routine hard-facing is performed. Assume shaft replacement takes two operators two days (same as hard-facing). |
| Typical downtime %: | Stationary electrically driven units are less maintenance intensive and experience about 10% downtime. Mobile diesel powered unit's experiences about 25% downtime. |
| Space required: | Feed hopper 224" L × 94"W × 43" H, plus conveyor and drive engine. |
| Fuel consumption and electrical requirements: | $16/hr electric at 7 cents per kW-hr.<br>18 gal/hr diesel fuel or $72/hr at $4/gal diesel. |
| Other: | Recommends using a concrete crusher instead of (or in addition to) the PRI-MAX if the total fraction of concrete and masonry is over 10% of the total. Recommended ***Eagle*** crusher manufacturer. |

| | |
|---|---|
| **Vendor:** | Shred-Tech Corporation, Cambridge Ontario, Canada (www.shred-tech.com) |
| **Equipment Model:** | Shred Tech ST500 Transportable Shredder |
| **Application:** | Truck tires, magnesium castings, municipal/industrial waste, pallets, wood waste, copper and steel wire and cable, scrap aluminum, etc. |

| | |
|---|---|
| Material preparation requirements: | Limited by size of hopper only; 115” L × 69”W × 40” D. |
| Processing capacity: | 6-20 tons per hr depending on material. |
| Power | 500 HP diesel mobile unit. |
| Maintenance requirements: | Routine cutter maintenance is usually performed once per month and requires two maintenance operators for two days (32 hrs). |
| Number of operators: | Estimate 1.25 operators. |
| Climate limitations: | None |
| Support equipment: | Conveyor included in price. Separate excavator would be used to load feed. |
| Budgetary cost of equipment: | $1,032,640 for shredder, drive, and conveyor. |
| Cost of major overhaul: | Replacement or rework of shaft; assume $40K, |
| Typical downtime %: | Mobile diesel powered unit’s experiences about 25% downtime. |
| Space required: | 60 ft × 8.5 ft for feed hopper plus conveyor and drive engine. |
| Fuel consumption and electrical requirements: | Estimate 12 gal/hr diesel fuel or $48/hr at $4/gal diesel. |

| | |
|---|---|
| **Vendor:** | Eagle Crusher, Galion, Ohio |
| **Equipment Model:** | UltraMax 1000-15CV |
| **Application:** | Demolition concrete and brick with reinforcement steel |

| | |
|---|---|
| Material preparation requirements: | Reduce to 24" cube using excavator. |
| Processing capacity: | Up to 160 tons/hr. |
| Power | 375 HP with power upgrade to allow the addition of conveyor and screens. |
| Maintenance requirements: | Routine oil and filter change-outs for drive engine; rotation of wear plates. |
| Number of operators: | 0.5 FTE operator (same operator who feeds with excavator). |
| Climate limitations: | None |
| Support equipment: | Conveyor, screens (if needed to produce a specific size material). |
| Budgetary cost of equipment: | $456,400 (mobile unit including conveyor, magnetic separator, and 175 HP auxiliary generator). |
| Lease option | $25,000 per month plus conveyor for $2000 per month. |
| Cost of major overhaul: | Blow bars and wear plates require rotation or replacement periodically. Blow bars typically require replacement after every 20,000 tons of processed material. Blow bars cost $3,300 per set. Wear plates may require rotation or replacement every 80,000 tons of material processed. Wear plates cost between $100 and $400 each. There are many wear plates, but only about 6 require replacement. Takes about 4 hrs to replace blow bars, and about 1 hr to replace or rotate wear plates. |
| Typical downtime %: | 80% availability. |
| Space required: | 620 $ft^2$ with conveyor. |
| Fuel consumption and electrical requirements: | About 10 gal/hr diesel fuel. |
| Operating cost: | $1.85 per ton if operated at high production rate (240,000 tons per year); $4 per ton when operated by feeding with an excavator. (Includes fuel, maintenance, periodic replacement of blow bars and wear plates, and cost of capital). |
| Other: | Open-circuit allows for production of material that does not have to meet a particular specification, allows for 90% within a particular size range. Closed-circuit operation produces material within a specified size range using screens.<br>Unique feature by Eagle includes uniformly designed wear plates that can be rotated to provide uniform wearing and extended life. |

| | |
|---|---|
| **Vendor:** | Rubble Master |
| **Equipment Model:** | RM100 (Crusher) |
| **Application:** | Demolition concrete rubble with rebar |

| | |
|---|---|
| Material preparation requirements: | Reduce size of concrete to 12 – 16 inches to reduce bridging and downtime for repositioning. Reduce rebar length to 6 ft of less. |
| Cost of repairs: | Major overhauls start after 1000 hrs; you can add $ 0.15 per ton thereafter.<br>For example : 100 tons per hr × $ 0.15 per ton × 800 hrs per year = $12,000.00. |
| Number of operators: | 1 FTE Operator and a Mechanic one day per week |
| Climate limitations: | None |
| Support equipment: | Includes conveyor. |
| Budgetary cost of equipment: | $500,000 for new machine, used machine at 300 hrs for $460,000. |
| Maintenance requirements: | Lubrication, grease, minor; air filters; periodic oil change; etc. |
| Typical downtime %: | 8% (2 out of 12 hrs); possibly 500 – 1000 hrs operations before major overhaul needed. |
| Space required: | 30 ft × 8 ft. |
| Cost of operating: | Operating cost for an RM60 is $ 0.20, RM70 is $ 0.30, RM80 is $ 0.40 and a RM100 is $ 0.50 per ton, this includes fuel, wear, oil, filters and grease. |
| Fuel consumption and electrical requirements: | 5-6 gal/hr diesel, no electrical requirements. |
| Other: | U.S. distributer: HMI. |

| | |
|---|---|
| **Vendor:** | Harris (equipment company) |
| **Equipment Model:** | BSH-30-2225-B Shear |
| **Application:** | K-33 Project Supercompactor; size reducing heavy gauge metal and equipment |

| | |
|---|---|
| Feed preparation requirements: | Used hand-held plasma cutters and air-arc (arc gouge) cutters to prepare materials for 26' feed box. This was the slow step of the process. The shear operators spent a lot of time in stand-by waiting for material to process. Air-arc cutters were much faster than the plasma cutters, but were much louder due to the use of compressed air, and also emitted a large shower of sparks during operation. This was acceptable for cutting converter vessels because sparks were contained within the vessel. Feed box was 26 ft long and throat width was 5 ft, allowing cut width of 2-5 ft. Longer boxes are available, up to 40 ft. |
| Maintenance requirements: | Rotating and replacing knife blades and greasing the equipment and support systems occupied 6 personnel in two 12-hr shifts, once per month. There are three blades with four cutting edges each. Each blade is about 6 inches thick and weighs 900 lb. Three sets of blades are replaced per year at about $10K per set (total $30K/yr). The largest maintenance cost was in replacing hydraulic fluid pumps due in part to the use of a low flash point fluid (Quinter Lubric 822 by Quaker State). There are seven pumps total and they had to be replaced twice during the operation at about $15K each (total $210K). The fluid cost was $20/gal + $6/gal for disposal of contaminated fluid. The fluid has to be replaced twice (5,000 gal ea. total cost $130K). The type of pump used (piston pump) was used in order to provide a slightly increased cutting power for the unit. For a slightly lower power requirement, vane pumps could have been used and would have been less expensive to operate. The normally used fluid AW46 hydraulic fluid costs about $5/gal. Fluid replacement is usually no more frequent than once every 2 years. It can be filtered and re-used in the unit for up to 10 years. |
| Number of operators: | To operate the shear requires on person at the controls, one person to provide feed, and 3 persons to manage the product which involves moving the intermodals into place, distributing the product in the intermodal, and managing the filled intermodal. Intermodals were frequently punctured during loading due to the size, weight, and shape of the metal pieces. The intermodals were placed on a stand after filling and patched as necessary. Placing flat sheets of metal (waste material) in the bottom of the intermodals prior to loading helped reduce punctures. |
| Installation: | About 6 months required to assemble the shear (with a lot of down time due to DOE work process). Total weight of all components was about 550-600 tons with several components weighing 100 to 125 tons, others from 35 to 95 tons each; about 7 or 8 main components. Unit was assembled by C. Reed Davis. |
| Support equipment: | Track hoes used to rake/distribute material within intermodals. Intermodals did not have full-open lids, making it difficult to distribute material in the container. System included 4 air-cooled oil coolers mounted on roof about 85 ft above the shear. |

| | |
|---|---|
| Budgetary cost of equipment: | $6,800,000 |
| Typical downtime %: | 25% |
| Fuel consumption and electrical requirements: | Electricity costs equivalent to about 1,660 horsepower (7) 200 HP main motors; (1) 100 HP pilot motor, (4) 25 HP cooler pump motors, (4) 15 HP cooler fan motors. |
| Other: | Mobile units are now available, manufactured overseas called Eco Techna. Available in diesel or electric powered. Energy*Solutions* has a machine at their facility in Kingston. Cutting power is about 500 to 700 tons compared to 2225 tons for the K-33 unit. Would not be capable of handling the materials processes in the K-33 project. Mobile units are not powerful enough to handle the materials processed at K-33.<br><br>Mobile units have a 2 ft throat that would limit ability to fold material. Not enough power to fold to get through throat. Much more prep work to feed the cutter. Length limit for feed box is 22 ft. long, some smaller, 15-22 ft range. Probably could not fold machining equipment such as drill presses, lathes, mills, etc. Cast iron for these machines would break and not cut.<br><br>Mobile units typically weigh 80,000 lb or more and are limited to thickness of 1.5 to 2 inches (without folding). Ton per hr rating should be considered a very high end maximum as it is typically limited by the speed required to prepare materials for the feed box. For adequate power, recommend 1,100 lb stationary machines are available that can be moved, but would probably require 60 days to move in the DOE environment. They require a solid concrete foundation, but no piers. Most are diesel powered. Had trouble using these machines for cutting aluminum and copper. Aluminum would gall and foul machine moving parts and cause them to stick. |

# APPENDIX B - ATTACHMENT B:
# VOLUME REDUCTION PROCESSING COST ESTIMATE

This page intentionally left blank.

**Table B-19. Basis for Size Reduction Cost Estimate**

| Basis for Estimate | | |
|---|---|---|
| **Volume ($yd^3$)** | **Weight (tons)** | **Description** |
| 483,723 | 560,761 | Total concrete and demolition debris for processing, $yd^3$ |
| 118,738 | 86,281 | Total for shredding |
| 364,985 | 474,480 | Total for crushing |

**Table B-20. Cost Data for Shredder Operation**

| Shredder Summary Information | | |
|---|---|---|
| **Parameter** | **Data** | **Basis** |
| Manufacturer | SSI Shredders | |
| Model | PRI-MAX 770 | |
| Capacity | 25 Tons/hr max | Based on vendor estimated capacity for C&D waste. |
| Capital Cost | $325,000 | E-mail quote from SSI, June 2011. |
| Transportation and Setup | $10,500 | Assume $5K to transport; SSI tech support for 40 hours at $100/hr plus airfare and per diem of $1,500. |
| Operating hours | 8,628 | 10 tons per hr. |
| Fuel | $224,330 | 6.5 gal/hr diesel fuel or $26/hr at $4/gal diesel (based on direct scaling from 700 HP to 250 HP diesel). |
| Maintenance: Hard-facing of cutters and routine checkout. | $121,872 | Hard-facing is usually performed once per month and requires two maintenance operators for two days (32 hrs); oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout. |
| Major overhaul | $179,600 | At full-time operations (2000 hr/yr), replacement or rework of shaft; $40K, plus replacement of cross members $5K; required every 2 years if routine hard-facing is performed. At 4884 hrs total, assume overhauled three times during the life of the equipment. Assume labor is the same as hard-facing requirement. This also includes $35,000 for a major engine overhaul. |

**Table B-21. Cost Data for Crusher Operation**

| Crusher Summary Information | | |
|---|---|---|
| **Parameter** | **Data** | **Basis** |
| Manufacturer | Eagle Crusher | |
| Model | UltraMax 1000-15CV | |
| Capacity | 150 tons per hr | Product particle size would be 85-90% < 2 inch. Capacity would be 125 tons/hr for product size < 1 inch. |
| Capital Cost (2 units) | $456,400 | Quote from Eagle Crusher. |
| Transportation and Setup | $10,500 | Assume $5K to transport; Eagle Crusher tech support for 40 hours at $100/hr with airfare and per diem ($1,500). |
| Operating hours | 9,490 | 50 tons per hr. |
| Fuel | $379,584 | 10 gal/hr diesel fuel or $40/hr at $4/gal diesel. |
| Maintenance: Changing oil and filters; rotation of wear plates. | $41,145 | Rotation of wear plates every 80,000 tons of material processed, requires two maintenance operators for 4 hrs (8 hrs) + oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout. |
| Major overhaul | $132,862 | Blow bars typically require replacement after every 20,000 tons of processed material. Blow bars cost $3,300 per set. Wear plates may require rotation or replacement every 80,000 tons of material processed. Wear plates cost between $100 and $400 each. There are many wear plates, but only about 6 require replacement. Takes about 4 hrs to replace blow bars, and about 1 hr to replace or rotate wear plates. Also includes $35,000 for a major engine overhaul. |

**Table B-22. Cost Data for Excavator Operation**

| Excavator Summary Information | | |
|---|---|---|
| **Parameter** | **Data** | **Basis** |
| Manufacturer | Volvo | |
| Model | 2010 VOLVO ECR235C | |
| Capacity | 7.5 ton | |
| Capital Cost (4 units) | $814,000 | Source of cost information: McAllister Equipment Company,. Anticipate needing five excavators at $203,500 each over the course of the operation; priced June 2011. |
| Transportation and Setup | $31,200 | Assume $5K to transport; Volvo tech support for one week at $100/hr with airfare and per diem ($1,500) for two units. |
| Operating hours | 36,235 | Combined hrs for shredder and crusher. |
| Fuel | $724,708 | 5 gal/hr diesel fuel or $20/hr at $4/gal diesel for 150 HP diesel engine. |
| Maintenance: Changing oil and filters; inspections | $149,471 | Oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout. |
| Major overhauls | $160,000 | Five major engine overhauls. |

This page intentionally left blank.

# APPENDIX C:
# ON-SITE TREATMENT AND DISPOSAL OPTIONS FOR MERCURY-CONTAMINATED WASTE

This page intentionally left blank.

# CONTENT

1. INTRODUCTION ..... C-4
2. TREATMENT STANDARDS AND TECHNOLOGIES FOR MERCURY-CONTAMINATED WASTE ..... C-4
3. TREATMENT TECHNOLOGIES FOR MERCURY-CONTAMINATED DEBRIS ..... C-5
3.1 THERMAL AND CHEMICAL EXTRACTION ..... C-6
3.2 ENCAPSULATION ..... C-6
3.3 MACROENCAPSULATION TECHNIQUES ..... C-7
4. TREATMENT OPTIONS FOR MERCURY CONTAMINATED Y-12 DEBRIS ..... C-9
4.1 MACROENCAPSULATION AT THE EMDF ..... C-9
4.2 MACROENCAPSULATION AT THE GENERATOR/DEMOLITION SITE ..... C-10
4.3 COMPARISON OF ON-SITE MACROENCAPSULATION OPTIONS ..... C-11
5. REGULATORY APPROACH FOR IN-CELL MACROENCAPSULATION ..... C-14
5.1 WASTE DESCRIPTION ..... C-14
5.2 MERCURY HAZARDOUS WASTE CODE ..... C-15
5.3 ASSESSMENT OF ENVIRONMENTAL IMPACTS ..... C-15
6. REFERENCES ..... C-16
APPENDIX C – ATTACHMENT A: USE OF THE INTERIM MEASURES ARAR WAIVER ..... C-19

# TABLES

Table C-1. Comparison of Debris Macroencapsulation Options for the On-site Disposal Alternative ..... C-12
Table C-2. Estimated Quantities of Mercury-contaminated (D009) Debris ..... C-15

# ACRONYMS

| | |
|---|---|
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| D&D | deactivation and decommissioning |
| DOE | U.S. Department of Energy |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| IMERC | incineration of mercury waste |
| LDR | Land Disposal Restriction |
| ORR | Oak Ridge Reservation |
| PW | process waste |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RI/FS | Remedial Investigation/Feasibility Study |
| RMERC | retort of mercury waste |
| S/S | solidification/stabilization |
| TCLP | Toxicity Characteristic Leaching Procedure |
| U.S. | United States |
| WEMA | West End Mercury Area |
| Y-12 | Y-12 National Security Complex |

# 1. INTRODUCTION

The purpose of this Appendix is to describe and compare options for treatment and disposition of mercury-contaminated mixed waste debris generated by Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) response actions on the Oak Ridge Reservation (ORR). Mercury is a major contaminant of concern for wastes generated in the cleanup of Y-12 National Security Complex (Y-12). These wastes include debris from demolition of four mercury process facility complexes at Y-12 and contaminated soils and sediment generated by the corresponding remediation projects.

Debris and soil/sediment waste having levels of mercury contamination below 40 CFR 268 regulatory limits for land disposal (i.e., upon characterization, result in less than the maximum Toxicity Characteristic Leaching Procedure [TCLP] waste extract concentration for mercury, 0.2 mg/L) are not considered hazardous and do not require treatment for disposal. However, there may be measureable amounts of mercury in this waste. Among wastes that *do* require treatment for the mercury toxicity characteristic prior to disposal, this evaluation considers only demolition debris because disposal of this waste stream is given special consideration in the development and evaluation of the On-site Disposal Alternative for CERCLA waste disposition (see Sections 2.3.3 and 6.2.5, and Appendix H, Section 4.4.2.3 of this Remedial Investigation/Feasibility Study [RI/FS]).

For mercury-contaminated soils requiring treatment, the On-site Disposal Alternative assumes that treatment to remove or immobilize mercury is the responsibility of the project that generates the waste. For purposes of developing Preliminary Waste Acceptance Criteria, the On-site Disposal Alternative considers only mercury contamination in the volume of soils that *will not* be treated to remove or immobilize mercury prior to disposal at an on-site facility (see Appendix H, Section 4.4.2.3). Additional information regarding treatment standards and techniques applicable to mercury-contaminated soils is provided in Section 2 of this appendix.

Based upon available characterization data and waste volume estimates (see RI/FS Chapter 2, and Appendix A), approximately 381,000 $yd^3$ of debris are anticipated to be generated from demolition of mercury-process facilities at Y-12. As much as 150,000 $yd^3$ of this debris (including uncertainty) have been estimated to meet the definition of hazardous or mixed waste based on the mercury toxicity characteristic and would require treatment for land disposal. Current planning for mercury facility demolition includes extensive decontamination efforts to minimize the volume of debris requiring treatment (DOE 2014).

The following sections address the regulatory treatment standards for mercury-contaminated wastes and present a comparative evaluation of on-site debris treatment options with respect to criteria identified in 40 CFR 300.430 for feasibility analyses. This comparative analysis supports the technical approach and assumptions for handling mercury-contaminated debris that are adopted in the On-site Disposal Alternative of this RI/FS (see Section 6.2.5.2).

# 2. TREATMENT STANDARDS AND TECHNOLOGIES FOR MERCURY-CONTAMINATED WASTE

The Resource Conservation and Recovery Act of 1976 (RCRA) identifies hazardous wastes that are restricted from land disposal unless contaminant-specific treatment standards are met. These Land Disposal Restrictions (LDRs) (40 CFR 268) specify the limits (treatment standards) for hazardous constituents in treated wastes or waste extracts, or specify a Technology-Based Standard for treatment.

The LDR treatment standards for non-wastewaters that exhibit or are expected to exhibit the toxicity characteristic for mercury depend on the total mercury concentration in the waste and the types of waste materials present. The threshold for mercury toxicity specified in 40 CFR 261.24 is a TCLP waste extract

concentration of 0.20 mg/L (EPA SW-846, Method 1311). The 40 CFR 268.40 treatment standards for high mercury content wastes (≥ 260 mg/kg total mercury) are technology-based and include incineration (IMERC) for waste including organic constituents, and retorting or roasting (RMERC) in a thermal processing unit for inorganic wastes (including RMERC residues). For low mercury content wastes (<260 mg/kg total mercury, including IMERC residues) the treatment standard is a maximum TCLP waste extract concentration of 0.025 mg/L (or 0.20 mg/L for RMERC residues). These treatment standards apply to both soil and debris waste forms, unless alternative treatment standards for hazardous debris at 40 CFR 268.40 are used as the basis for LDR compliance (EPA 2003). For liquid mercury with radionuclide contamination, the technology-based treatment standard is amalgamation, an immobilization process that creates a more physically stable solid or semi-solid mercury amalgam.

Contaminant immobilization by chemical formation of an insoluble compound (stabilization), coupled with solidification provided by a binding agent (e.g., Portland cement) can be an effective means of meeting treatment standards for hazardous metals. Formation of highly insoluble mercuric sulfide (HgS) is desirable for geochemical stabilization of mercury. However, due to the relatively high solubility of some other mercury compounds, effective stabilization and solidification (S/S) of mercury-contaminated wastes using traditional methods has proven to be challenging (SAIC 1998). Mixed low-level wastes containing mercury can present additional technical challenges related to radioactive constituents.

Since the 1990s, there has been substantial research and technology development for treatment of mercury-mixed wastes, primarily focused on radioactive elemental mercury and mercury-contaminated sludges, soils, and soil-like waste forms (Klasson et al. 1997; Mattus 2001; Morris and Hulet 2003; Perona and Brown 1993, EPA 2007). Several technology demonstration campaigns involving the United States (U.S.) Department of Energy (DOE) National Laboratories (e.g., Adams et al. 2001; Gates et al. 1995; Kalb et al. 2001; Mattus and Mattus 1994; Mattus 2001; Osborne-Lee et al. 1999) and private industry (e.g., ATG 1998, 2000, 2001; DOE 1999a, 1999b, 1999c; 1999d, NFS 2001, UCOR 2012) have identified S/S techniques that can successfully meet mercury TCLP standards for land disposal of treated waste. For Y-12 soils that require mercury treatment for disposal, the RI/FS assumes that individual remedial action projects will utilize one of these proven technologies (e.g., immobilization with sulfur-based polymers) and therefore a particular treatment process for soils is not specified as an element of the On-site Disposal Alternative.

For debris-type waste, effective S/S to immobilize mercury can be more difficult than for soil-type wastes that are easier to mix with the stabilizing and binding agents. In 1992, the U.S. Environmental Protection Agency (EPA) issued technology-based alternative treatment methods and standards for hazardous and mixed waste debris in recognition of the technical challenges of treating debris-like materials (EPA 2003). These treatment alternatives for hazardous debris offer flexibility and potential cost savings as compared to the original LDR treatment processes and standards. The alternative treatment standards for debris, 40 CFR 268.45, include three technology groups: (1) extraction (physical and chemical), (2) destruction (biological and chemical), and (3) immobilization (macroencapsulation, microencapsulation, and sealing). Destruction technologies are not applicable to hazardous metals such as mercury.

# 3. TREATMENT TECHNOLOGIES FOR MERCURY-CONTAMINATED DEBRIS

For mercury-contaminated debris that is considered hazardous (D009) according to the TCLP toxicity threshold of the LDRs, potentially effective treatment technologies include thermal extraction and recovery (including RMERC and thermal desorption), liquid-phase chemical extraction, and immobilization methods. For mixed low-level radioactive debris that requires treatment for mercury, thermal and chemical extraction methods typically generate secondary radioactive waste streams (both liquid and gaseous) and entail operational risks that can make these approaches impractical. These challenges are addressed in more detail in the following paragraphs. Immobilization methods such as

macroencapsulation, which may incorporate mercury S/S as part of the treatment process, are arguably the most practically applicable treatment technology for the large volume of mercury-contaminated demolition debris expected from Y-12.

## 3.1 THERMAL AND CHEMICAL EXTRACTION

Thermal and chemical extraction methods have the advantage of removing mercury from the waste, potentially permitting land disposal or reuse of some materials (e.g., valuable metals). Thermal treatment of mercury-contaminated soils, debris, and other solid wastes has been one of the most commonly applied technologies, in part owing to the potential for removal, recovery and reuse of elemental mercury. Thermal treatments utilize high temperatures and in some cases reduced atmospheric pressure to volatilize mercury from waste, coupled with extraction and condensation of the mercury vapor for reuse or further treatment and disposal.

There are operating commercial facilities that can accept debris-type waste for thermal treatment of mercury contamination, but there are limitations on the size of materials that may be treated, requirements for long distance transport, and very high unit treatment costs (>$100/ton) that make thermal technologies impractical for the majority of Y-12 demolition debris. It is possible that an on-site thermal treatment unit could be designed and built at Y-12 to reduce transportation costs and to accommodate mixed radiological and hazardous constituents in debris, but the costs of siting design, construction, and most especially the operation of such a unit would likely be prohibitive.

Liquid-phase extraction of mercury using lixiviants (chemical washing agents) has been employed as a decontamination technique in cleanup of mercury-use facilities in the natural gas pipeline and chlor-alkali industries. These techniques have included immersion in iodine-iodide solution, surface washing with acids or other chemicals, and high-pressure water-washing (McBeath 1983, Euro Chlor 2009). These methods are suited for application to individual items or small volumes of process equipment, and may not always be effective in meeting RCRA treatment standards for mercury.

A debris-washing approach for the Y-12 demolition waste stream would also generate significant volumes of liquid mixed waste requiring treatment, necessitate additional measures to protect worker health and safety, and increase the risk of unintentional release of contaminants to the environment at the cleanup site. Owing to these added cost and risk considerations, chemical extraction is poorly-suited as a treatment for demolition debris, but similar decontamination techniques may be appropriate and effective for some process equipment and building materials prior to facility demolition.

## 3.2 ENCAPSULATION

Encapsulation is a general technique for physical immobilization of hazardous constituents by enveloping a waste in a low-permeability material to limit exposure to leaching agents and reduce leachability of treated waste. For soil-like wastes, encapsulation by mixing with a binding agent to produce a relatively homogeneous solid in which the waste is well dispersed throughout the encapsulation matrix is termed *microencapsulation*. Microencapsulation is a form of contaminant stabilization that typically employs cementitious binders (Portland cement or pozzolan-lime mixtures) to solidify and stabilize waste. This type of treatment may include various additives to improve compressive strength or enhance set/cure time, or chemical stabilization agents to reduce the leachability of contaminants. Although microencapsulation has been applied to mercury-bearing wastes, the effectiveness of traditional cementitious binders for stabilization of elemental mercury or highly soluble mercury compounds may be limited (SAIC 1998).

Encapsulation of hazardous *debris* with cementitious binders qualifies as microencapsulation under the treatment standards for hazardous debris at 40 CFR 268.45, although some sources refer to all techniques that encase (without mixing) bulk waste materials within a solid, stabilizing matrix as *macroencapsulation* (e.g., SAIC 1998). In general, macroencapsulation refers to the enclosure or

encasement of a bulk mass of waste within an impermeable solid barrier. The treatment standards for hazardous debris define macroencapsulation as "*Application of surface coating materials such as polymeric organics (e.g., resins and plastics) or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media*". The corresponding performance standard for macroencapsulation is "*the encapsulating material must completely encapsulate debris and be resistant to degradation by the debris and its contaminants and materials into which it may come into contact after placement (leachate, other waste, microbes)*" 40 CFR 268.45, Table 1.

## 3.3 MACROENCAPSULATION TECHNIQUES

Treatment by macroencapsulation typically involves enclosing waste in a reinforced bag or rigid container made of inert, low-permeability materials, or encapsulation by pouring an encasing material (e.g., flowable fill) over and around the waste to reduce exposure to leaching media. In practice, containers are often used in combination with encasement to macroencapsulate hazardous debris. Containers may provide the macroencapsulation barrier, or simply serve to hold waste for encasement. Encasement material fills void space within the debris, and usually serves to immobilize contaminants as well. For mercury-contaminated wastes, encasement methods using materials and additives specifically chosen to chemically stabilize mercury (e.g., sulfur polymer cement) have been developed and tested (Mattus and Mattus 1994, SAIC 1998, DOE 1999d, Kalb et al 2001, Chattopadhyay 2004, Randall and Chattopadhyay 2004, EPA 2007).

### Macroencapsulation Containers and Bags

Simply containerizing waste material is not equivalent to macroencapsulation, and the description of technology-based standards at 40 CFR 268.42 states that *"Macroencapsulation specifically does not include any material that would be classified as a tank or container according to 40 CFR 260.10."* However, stainless steel containers with welded closures have been approved for macroencapsulation of mixed waste debris in some cases (Siry 2007), and several commercial vendors offer macroencapsulation products and services that utilize rigid polyethylene containers to meet the performance standard for macroencapsulation (e.g., UltraTech Inc., Chemical Waste Management Inc). These containers are loaded with waste and sealed to prevent contact with leaching media in the disposal environment. Void spaces inside the containers are filled with a suitable material prior to final closure. Reinforced concrete containers, appropriately sealed, have also been used for macroencapsulation.

There are a few vendors that manufacture soft-sided, reinforced bags of various sizes that have been used to meet the definition of macroencapsulation. These reinforced bags, referred to as macro-bags, use inert polymeric material to reduce surface exposure to potential leachate, and are resistant to degradation from waste contaminants. PacTec manufactures a macro-bag that has been approved by Nevada National Security Site as meeting the definition of macroencapsulation for mixed-waste debris and was approved by the Tennessee Department of Environment and Conservation for use at the Environmental Management Waste Management Facility (EMWMF) (DOE 2011). The macro-bag can be placed on the inside of a rigid container and filled with waste, or placed on the outside of a rigid container already filled with waste. Treatment of debris by direct placement in macro-bags (without a container) is not recommended, due to the potential for damaging the bag and compromising the macro-barrier.

### Encasement and In-Cell Macroencapsulation

There are existing companies and facilities that can macroencapsulate waste by pouring an encasing material over and around the waste, sometimes within the land disposal facility itself (in-cell macroencapsulation). The waste is placed in a container and/or other encasement form for encapsulation and then a flowable, cementitious grout is added to fill void spaces and solidify the waste mass. For this type of treatment process, the containers may include intermodal transport containers, standard waste containers of various sizes, or specially constructed reinforced concrete vaults. Depending on the type of

container and method of grouting, the container, the encasing material, or the two in combination may constitute the macroencapsulating barrier per 40 CFR 286.45.

In some cases, standard metal containers are fitted with interior forms ("standoffs") to ensure that the encasing material completely encapsulates the waste, providing a continuous external barrier. With this technique, the encapsulating grout rather than the container provides the encapsulation barrier. This approach decreases the waste capacity of any given size container, and so potentially increases the number of containers required for treatment and disposal. With regulatory approval, this type of macroencapsulation could be completed in-cell, eliminating the need to relocate the heavy waste forms for disposal.

Containerized or uncontainerized hazardous debris may be placed into an in-cell encasement form or reinforced concrete containers and then grouted in place to accomplish in-cell macroencapsulation. Concrete containers may be smaller pre-fabricated units or larger vaults constructed in-cell. The vault or encasement form is loaded with waste and grouted to fill voids and stabilize contamination. Interior seams and exterior surfaces of concrete containers or vaults can be coated with sealants to ensure effective isolation of waste from leaching agents. Complete encapsulation is achieved by sealing containers or vaults with concrete covers, or by ensuring that a sufficient thickness of grout covers the upper surface of the waste. Removable vault covers may be employed to limit exposure of untreated debris, and can facilitate loading and grouting of larger vaults over extended time periods.

In-cell macroencapsulation is also possible with macro-bag and container combinations or with containers made of stainless steel or high density polyethylene where the macro-bag or container itself fulfills the macroencapsulation standard. In either of these cases, flowable fill could be used to stabilize contaminants and fill voids. A similar approach to in-cell grouting of containerized waste for stabilization purposes has been performed at the EMWMF for selected waste streams.

**Chemical Stabilization and Encapsulation Materials**

Materials used for waste encasement or microencapsulation can be formulated to chemically stabilize mercury contamination, reducing the leachability of mercury compounds and providing an added measure of contaminant immobilization to a macroencapsulation treatment process. Various combinations of stabilizing agents (typically sulfur compounds), binding agents (cementitious and polymeric) and encapsulation processes have been developed to improve immobilization of mercury and other contaminants in hazardous and mixed wastes (Morris et al. 2002, EPA 2007). Binding/solidifying materials tested have included polyester and epoxy resins, polyethylene, sulfur polymer cement, chemically bonded phosphate ceramics, asphalt, ceramic silicon foam, rubber, sol-gels, and traditional cementitious binders augmented with activated carbon or other proprietary agents or processes (refer to Randall and Chattopadhyay, 2004 for a review).

For mercury wastes in general, the effectiveness of chemical stabilization will depends on the chemical forms (speciation) of mercury present, the types of waste materials and other contaminants present, and the geochemical nature of the final disposal environment (moisture, pH, redox potential, etc). Developmental testing of encapsulation materials for debris have typically been small scale laboratory exercises, with limited evaluation of mercury leachability in the final waste forms (e.g., Mattus 1998). However, evaluations of encapsulated mercury-contaminated soils and sludge suggest that several different materials can be effective in meeting the RCRA treatment standard (TCLP $\geq$ 0.025 mg/L). Although the long-term performance of these mercury stabilization processes has not been systematically evaluated, it is likely that some formulation of encasement material for chemical stabilization of mercury can provide an additional, cost-effective measure of protection for macroencapsulation of Y-12 demolition debris.

**Debris Macroencapsulation Summary**

The most practical and effective set of macroencapsulation technologies for hazardous debris depends on the waste material characteristics and types of contamination present, in part because those characteristics impact operational and worker safety practices in waste generation, packaging and transport. For example, very large debris/equipment items may be most easily coated with a polyurethane spray as a sealant/macroencapsulant. For process equipment that is highly contaminated with mercury, decontamination prior to treatment may be necessary to permit safe and compliant waste packaging, transport, and treatment. Thus, for mercury-contaminated debris from Y-12, a single technical approach to macroencapsulation may not be applicable to all waste streams, and adopting an appropriate set of techniques is likely to be required.

# 4. TREATMENT OPTIONS FOR MERCURY CONTAMINATED Y-12 DEBRIS

This section evaluates three general options for on-site macroencapsulation in terms of treatment effectiveness, technical and regulatory feasibility, and cost. This approach is similar to the technology screening process described in RI/FS Section 5.1.2, and encompasses the five balancing criteria used to analyze the general waste disposition alternatives in RI/FS Section 7. This evaluation is the basis for selecting the option for on-site treatment of mercury-contaminated mixed waste debris that is assumed under the On-site Disposal Alternative.

For the On-site Disposal Alternative, in which most future CERCLA-generated, low-level radioactive waste from the ORR would be sent to a new on-site facility, mercury-contaminated mixed waste debris that requires treatment for disposal is most likely to be macroencapsulated. Some waste debris having very high mercury content or other special characteristics could require treatment off-site, or by methods other than macroencapsulation, but the volume of these wastes is assumed to be a small fraction of the total. There are two general options for on-site macroencapsulation: (1) macroencapsulation at the disposal site, either in-cell or at an adjacent treatment area, and (2) macroencapsulation at the waste-generator site (demolition site). Treatment at the Environmental Management Disposal Facility (EMDF) would involve transport of untreated hazardous waste to the facility, but also permits a range of more cost-effective technical approaches compared to macroencapsulation of waste at the generator site.

For the Off-Site Alternative, mixed wastes including mercury-contaminated debris would be treated for disposal at off-site treatment and disposal sites, using methods and technologies approved at those sites, including macroencapsulation. The cost estimate for the Off-Site Disposal Alternative (see Section 7.3.7 and Appendix I) assumes treatment and disposal of mixed waste at either Energy*Solutions* in Clive, Utah, or Waste Control Specialists in Andrews, Texas. Both facilities have the necessary permits and have been approved to provide mixed waste treatment and disposal for CERCLA waste.

## 4.1 MACROENCAPSULATION AT THE EMDF

Treatment options for macroencapsulation at the EMDF encompass all of the techniques described in Section 3.2. In the case of in-cell macroencapsulation, containerized or uncontainerized waste would be placed into the final (in-situ) disposal location prior to treatment. Technical options for in-cell macroencapsulation include:

1. In-situ encasement of uncontainerized (bulk) waste within relatively large (100s to 1,000s of cubic yards) concrete vaults constructed inside the disposal cell.
2. In-situ encasement of containerized waste to achieve macroencapsulation.
3. In-situ encasement of waste in sealed metal or polymeric macro-containers, or in-situ encasement of containerized waste coupled with macro-bag encapsulation.

For the macro-container/macro-bag option (#3 above), the encasing material (flowable fill) serves to fill voids and stabilize contaminants and the macro-bag fulfills the performance standard, whereas for technical option #2 encasement also constitutes macroencapsulation according to the performance/design standard identified in 40 CFR 268.45.

Alternatively, untreated waste could be delivered to a separate treatment area or facility at the disposal site, macroencapsulated, and then placed in the landfill cell for final disposal. This approach could employ technical options for macroencapsulation similar to those for the in-cell approach, but requires movement of heavy, treated waste forms for disposal and does not permit large-scale in-situ encasement of waste.

Either approach to performing macroencapsulation at the EMDF will require a temporary exemption from the 40 CFR 268 Subpart C placement prohibitions on land disposal for mercury toxicity characteristic hazardous waste. Details on the proposed regulatory approach are given in Section 5, *Regulatory Approach for In-Cell Macroencapsulation.*

Final determination of the appropriate techniques for on-site macroencapsulation of specific waste streams is beyond the scope of this analysis, and is subject to regulatory approval according to the *Federal Facility Agreement for the Oak Ridge Reservation* (DOE 1992). Selection of appropriate macroencapsulation methods and materials will require consideration of worker health and safety factors, short- and long-term risks to the environment, efficiency in utilizing available disposal capacity (ratio of as disposed waste volume to as-generated volume), and requirements for mercury vapor suppression, secondary waste management (e.g., contact water), and decontamination of equipment.

## 4.2 MACROENCAPSULATION AT THE GENERATOR/DEMOLITION SITE

Treatment options for macroencapsulation of debris at the Y-12 Facility demolition site(s) are constrained by the practical limits on transporting treated waste forms to the on-site disposal facility. Although debris treatment at the generator site would avoid health and safety risks associated with transport of untreated waste, this treatment option precludes large-scale encasement of bulk debris due to the difficulty of transporting massive waste forms within the operational footprint of Y-12. While is it technically possible to transport very large loads with specialized equipment, the operational challenges and costs of implementing such a treatment and transportation scheme at an active industrial site eliminate large-scale bulk encasement as a feasible method. Debris treatment at facility demolition sites using any of the other technologies and methods described in the previous section would be possible, although practical considerations regarding transport load limits and risks of damage to the macroencapsulation barrier (e.g., torn macro-bags) during transport may favor smaller sizes or particular types of macro-enclosures.

One option for macroencapsulation at the demolition site(s) would be to develop a single, centralized debris treatment facility somewhere within the Y-12 West End Mercury Area (WEMA). It is possible that this approach could offer some efficiencies and potential cost savings in the overall scope of planning and executing WEMA facility demolition and waste management activities. A centralized facility could employ multiple technologies for macroencapsulation to accommodate the characteristics of particular waste streams. Given the operational challenges that will arise in demolition of the very large WEMA facilities within the operational footprint of Y-12, the costs and potential benefits of pursuing such a centralized mercury treatment operation are difficult to estimate with certainty. In addition, uncertainty in the specific contracting arrangements that a centralized treatment approach would entail requires an analysis of the implications for the overall cost of procurement and contract management.

If operational and contractor procurement considerations preclude a centralized WEMA treatment facility, macroencapsulation could still be performed at the demolition site for each of the four Y-12 mercury-use facility deactivation and decommissioning (D&D) projects. In this case macroencapsulation techniques would be determined for particular waste streams and particular D&D projects, and treatment would be performed at the project site within an appropriately designed facility or designated treatment area within

the Area of Contamination. Under this scenario is possible that debris treatment operations for each facility D&D project could proceed concurrently under different contractors and project-specific work plans.

## 4.3 COMPARISON OF ON-SITE MACROENCAPSULATION OPTIONS

This section presents a comparison of options for macroencapsulation, either at the disposal facility site or at the waste generation/facility demolition site. The purpose is to provide the basis for technical and operational assumptions regarding debris treatment for mercury toxicity in the On-site Disposal Alternative for CERCLA waste disposition. General factors considered in comparing the waste-generation site verses waste-disposal site treatment options include:

1. **Feasibility and Performance of Macroencapsulation Techniques**: Including the specific products, materials and processes utilized for waste encasement/stabilization and macroencapsulation, as well as the relative risk of macro-barrier failure or damage prior to disposal, consistency of performance (quality control), and anticipated long-term performance of the macro-barrier.

2. **Potential for Release of Mercury or Other Contaminants Prior to Waste Treatment**: Including potential air and surface water pathways during transport and/or prior to treatment, as determined by factors such as waste container specifications, frequency of applying vapor suppression agents and/or soil cover prior to treatment, and the duration of exposure of untreated waste (batch volume and frequency of debris macroencapsulation).

3. **Worker Health and Safety Requirements**: Including personal protective equipment (e.g., respirators) and requirements for medical surveillance of personnel.

4. **Requirements for Size-reduction of Debris by the Waste-generator**

5. **Requirements for Management of Secondary Waste**: Primarily liquids, including elemental mercury recovery, decontamination effluents and contact water resulting from precipitation on exposed, untreated debris.

6. **Environmental Monitoring Requirements**

7. **Efficiency of Disposal Cell Volume Utilization** ("waste loading," or the ratio of waste volume as-disposed to as-generated volume).

Each of these seven general considerations have potential impacts on project risks and costs for the waste generator and/or waste disposal facility risks and costs, and these impacts depend on the particular macroencapsulation techniques used and risk mitigation measures employed (see Table C-1). In selecting a debris treatment option for the On-site Disposal Alternative, a primary consideration of this type is the tradeoff between risk and cost related to the need for and size of waste containers. In-cell macroencapsulation by large-scale, in-situ encasement of bulk debris transported to the disposal facility in trucks eliminates the cost of waste containers, reduces the need for debris size-reduction at the demolition site, and permits more efficient use of disposal cell volume. This cost advantage would be partially offset by the cost of mercury vapor suppression or other measures to mitigate risks of contaminant release during transport or unacceptable worker exposure during waste treatment, prior to completion of macroencapsulation.

**Table C-1. Comparison of Debris Macroencapsulation Options for the On-site Disposal Alternative**

| Factors for Evaluation of Macroencapsulation Options | Macroencapsulation at the Waste Disposal Facility (EMDF) | Macroencapsulation at the Waste Generation (Demolition) Site |
|---|---|---|
| **Feasibility and Performance of Macroencapsulation Techniques** | All available macroencapsulation techniques are technically feasible. (+)<br>Failure of large-scale macroencapsulation vaults could expose larger volumes of treated waste to leaching agents than methods employing smaller units. (-) | Large-scale encasement of bulk waste is not feasible. (-)<br>Vehicle load limits may dictate use of smaller waste containers and increase costs relative to use of fewer, larger container.s (-)<br>Increased risk of macro-barrier damage or failure in transport to disposal facility. (-) |
| **Potential for Release of Contaminants Prior to Waste Treatment** | Transport of untreated debris adds to risk of pre-treatment contaminant release. (-)<br>Mercury vapor suppression or other measures to mitigate risks of contaminant release during transport could increase demolition project costs. (-) | Reduces risk of contaminant release prior to treatment by eliminating need to transport untreated debris. (+)<br>Smaller-scale macroencapsulation volumes will not result in surface (contact) water generation. (+) |
| **Worker Health and Safety Requirements** | Large-scale bulk encasement may require additional protective measures for workers that may increase disposal facility costs. (-) | Impacts on worker safety and health requirements for facility demolition projects with increased size reduction requirements. (-)<br>Impacts on worker safety and health in management of large/heavy forms for transport. (-) |
| **Requirements for Size Reduction of Debris by the Waste Generator** | Bulk encasement of debris would impose least restrictive requirement for debris size reduction by the waste generator. (+) | Waste container specifications (size) would determine debris size-reduction requirements and related impacts to cost of facility demolition projects. (-)<br>More size reduction/handling at the generator site increases possibility of mercury release into the environment. (-) |
| **Secondary Waste Management Requirements** | Recovery and management of elemental mercury prior to waste encasement will be required. (-)<br>Volumes of liquid secondary waste may be greater for large-scale encasement than for other methods, but the overall impact on disposal site wastewater management requirements will be limited. (-) | Impacts on generation of elemental mercury secondary waste due to sizing requirements. (-)<br>No major impacts on scope of liquid secondary waste management requirements. (+) |
| **Environmental Monitoring Requirements** | Will require more environmental monitoring at disposal site. (-) | No major impacts on scope of environmental monitoring requirements for facility demolition projects. (+) |
| **Efficiency of Disposal Cell Volume Utilization** | Large-scale encasement methods maximize efficient use of disposal cell capacity. (+) | Maximum container size and transport vehicle load limits reduce the effective "waste loading" of macroencapsulated debris and the efficiency of disposal cell use. (-) |

For treatment options that would utilize containers for transport, encasement, and/or macroencapsulation of debris, costs will vary with the size, material type, and number of containers required. Debris macroencapsulation at the facility demolition site(s) would likely require the use of a very large number of smaller waste containers because of transport vehicle load limits, and would increase demolition project costs for debris size reduction to accommodate the small containers. Macroencapsulation in relatively small containers, either at the disposal facility or at the demolition project site, could however reduce costs for management of liquid secondary waste streams because of the more limited volumes of debris handled during treatment. Use of smaller containers for debris treatment would also reduce the work efficiency (labor productivity) of the process overall, thereby increasing unit costs. In general, options involving smaller macroencapsulation units, either relatively small in-cell vaults or manufactured waste containers, would make less efficient use of disposal cell space. However, smaller macro-units may also provide better long-term performance (lower risk of contaminant release) because failure of a single macro-unit would expose a smaller volume of waste to leaching agents.

There has been no systematic analysis of the performance of different macroencapsulation materials and techniques under disposal conditions (but see Randall and Chattopadhyay 2004 for a relevant review of encapsulation studies). The RCRA performance standard for this treatment technology includes a structural requirement for complete isolation of the waste from environmental leaching agents by the macro-barrier, and a material stability requirement that the barrier is resistant to chemical degradation by the waste or other materials within the disposal environment. There is no regulatory requirement or criteria for establishing short or long-term attainment of this performance standard within a disposal environment, and no firm basis for a comparative evaluation of techniques approved for macroencapsulation by regulatory agencies. This uncertainty regarding macroencapsulation performance emphasizes the desirability of incorporating an agent to chemically stabilize mercury into the waste encasement material as an added immobilization measure.

To simplify the selection of an assumed technical approach for debris treatment under the On-site Disposal Alternative, it is reasonable to limit consideration to two technical options that capture the essential cost and risk tradeoffs related to the location of treatment (demolition site versus disposal site) and the technical method selected for macroencapsulation.

> **Option 1:** ***Medium-scale in-situ encasement of bulk debris at the disposal facility*** within 30 ft × 30 ft × 10 ft concrete vaults. A sprayable agent to suppress mercury vapor would be applied to debris at the demolition site prior to loading and transport, and additional measures to reduce the risk of mercury release during transport (e.g., closely fitted tarpaulins) applied to vehicles loaded with untreated debris would be required.
>
> **Option 2:** Encasement of debris in relatively small waste containers (<10 $yd^3$) and ***macroencapsulation in reinforced polymeric macro-bags at the demolition site***. Debris would be size reduced appropriately to accommodate waste container dimensions. After the encasing material is completely cured, encapsulated debris would be transported to the on-site disposal facility using measures to limit the risk of damage to the macro-bags during loading and transport.

Assuming Option Number 1 adds the cost of debris treatment to the estimated cost of on-site disposal facility (EMDF) operations, whereas for Option Number 2 the cost of treatment would be included in the facility D&D project budgets and does not increase the estimated cost of the On-site Disposal Alternative. Rough order-of-magnitude cost estimates for these two options suggest that the total cost of macroencapsulation at the demolition site (Option 2) would exceed the cost of in-situ encasement at the on-site disposal facility (Option 1) by a factor of five or more. This cost differential is almost entirely due to the expense of a very large number (>50,000) of waste containers for Option 2.

Under any realistic set of assumptions, the cost of employing added protective measures to permit safe transport of untreated debris in Option 1 would be much less than the added cost of waste containers for

debris treatment via Option 2, even if the use of fewer (approximately 5,000), much larger containers is assumed. Thus, Option 1 is adopted as the technical approach for treatment of mercury-contaminated debris in the On-site Disposal Alternative, and the cost of macroencapsulation by in-situ encasement of bulk debris at the EMDF is included in the cost estimate for the On-site Disposal Alternative (see Appendix I).

# 5. REGULATORY APPROACH FOR IN-CELL MACROENCAPSULATION

LDR regulations at 40 CFR 268 require that hazardous wastes, including those that are hazardous by characteristic, be treated prior to placement in a land disposal unit. Macroencapsulation would be performed within the EMDF cells to enhance operational control, staging, and safety, and to reduce treatment costs. This approach constitutes "placement" prior to LDR treatment standards for the debris having been met. On-site CERCLA remedial response actions must comply with or justify a waiver of the substantive requirements of RCRA when they are determined to be applicable or relevant and appropriate requirements. As stated, RCRA LDRs do not allow placement of a RCRA hazardous waste (e.g., mercury-contaminated debris as is expected to result from the demolition of Y-12 mercury-use facilities) in a disposal facility (on the land) until the applicable treatment standard has been met.

A waiver to the LDR placement restrictions is proposed as a temporary measure until the in-cell macroencapsulation of the hazardous debris can be completed, and the waste rendered non-hazardous by meeting the alternative treatment standards for debris treatment in 40 CFR 268.45. DOE will therefore request a waiver from this provision to allow short-term placement prior to treatment to meet the LDR requirements.

Short-term placement in a macroencapsulation form contained entirely within a disposal cell carries little if any risk. The form itself is a barrier to migration and a means for collecting rainwater and mercury. The form is fully contained within a landfill cell that has a liner, leachate collection system, and a separate leak detection system, which provide multiple additional layers of containment. Macroencapsulation would be carried out in a reasonable amount of time, further reducing the chances of loss of containment. Further, in-cell macroencapsulation will improve operations and safety by co-locating treatment and disposal such that treatment is carried out at a single site, not multiple project sites. Thus handling of mercury-contamination is also minimized, as would be releases to the air and surrounding environment. This has the added benefit of reducing overall costs, as well.

The waiver for temporary placement of untreated wastes within one or more landfill cells is justified on the basis that the placement constitutes an interim action that is a part of a total remedial action, which will achieve all LDR requirements at completion, as allowed under CERCLA Section 121(d)(4)(A) and 40 CFR 300.430(f)(1)(ii)(C)(1). An April 24, 1991 memorandum from the EPA Office of General Counsel (L. Starfield) to S. Golian, Chief, EPA Remedial Guidance Section, and L. Boornazian, Chief, EPA CERCLA Compliance Division, concurred with a very similar approach at the Wasatch Chemical Superfund site (provided as Attachment A to this Appendix). This waiver request is limited to temporary placement for treatment, and does not affect other aspects of LDR compliance.

## 5.1 WASTE DESCRIPTION

Demolition of mercury-contaminated facilities Alpha-2, Alpha-4, Alpha-5, and Beta-4 at the National Nuclear Security Administration's Y-12 Site on the ORR will result in mercury-contaminated (D009) debris that will require treatment to meet LDR treatment standards. These four buildings became contaminated as a result of previous operations associated with the Y-12 mission and require appropriate decontamination, demolition, and disposal actions to allow further use and development of the site. Table C-2 contains the estimated volumes of waste to be generated upon demolition of the facilities noted. A total of 123,231 $yd^3$ as-generated waste is assumed to require treatment based on the Waste

Generation Forecast[1]. This is believed by subject matter experts to be a conservatively high volume estimate of mercury-contaminated debris that might fail TCLP (RCRA D009 waste). However, this is the total volume of debris assumed to be treated and disposed by in-cell macroencapsulation.

## 5.2 MERCURY HAZARDOUS WASTE CODE

Past determinations have shown the mercury-contaminated debris waste, which will be generated upon demolition of the four Y-12 facilities and associated ancillary facilities, as well as the soils and sediments to be generated during remediation, would not carry the U-151 listed waste code (code for discarded elemental mercury product, off-specification metallic mercury product, and container or spill residues thereof). An extensive review of the subject was completed and communicated to regulators (DOE 2005), and the recent and thorough characterization work completed on the Alpha-5 Facility also addressed this topic, confirming that the waste would not be U-151 listed (DOE 2012).

## 5.3 ASSESSMENT OF ENVIRONMENTAL IMPACTS

No environmental impacts due to implementing in-cell macroencapsulation (other than to those identified for the On-site Disposal Alternative described in the RI/FS main document, Section 7.2.2.3) are identified. Mercury-contaminated "contact" water that accumulates in a macroform prior to completion of the macroencapsulation standard will be removed and treated as necessary.

**Table C-2. Estimated Quantities of Mercury-contaminated (D009) Debris**

| Origination of Waste and Waste Type | Facility/Area | Total PW and/or Debris ($yd^3$) | Assumed % of PW and Debris with Mercury Contamination | Assumed Volume of PW/Debris with Mercury Contamination ($yd^3$) |
|---|---|---|---|---|
| **Buildings** (Debris and Process Waste [PW]) | Alpha-2 | 50,952 | 20% | 10,190 |
| | Alpha-4 | 55,085 | 25% | 13,771 |
| | Alpha-5 | 122,623 | 30% | 36,787 |
| | Beta-4 | 71,994 | 30% | 21,598 |
| | | | | |
| **Slabs** (Debris only) | Alpha-2 Complex | 15,160 | 50% | 7,580 |
| | Alpha-4 Complex | 23,833 | 50% | 11,917 |
| | Alpha-5 Complex | 28,151 | 50% | 14,076 |
| | Beta 4-Complex | 13,776 | 50% | 6,888 |
| | 81-10 Area | 280 | 100% | 280 |
| **Other Areas** | | | | 144 |
| **TOTAL** | | **381,854** | | **123,231 *** |

* Consistent with assumptions in this RI/FS, the estimated volume 123,231 $yd^3$ of mercury-contaminated debris requiring treatment to meet LDRs is adjusted by a 25% uncertainty factor to 154,039 $yd^3$. Three percent is assumed to be classified, leaving 149,418 $yd^3$ as reported in Chapter 2 of this RI/FS.

[1] Waste Generation Forecast download September 2014.

# 6. REFERENCES


Adams, J.W., B.S. Bowerman, and P.D. Kalb 2001. *Sulfur Polymer Stabilization/Solidification (SPSS) Treatment of Simulated Mixed-Waste Mercury Contaminated Sludge*. BNL-52648 Formal Report, Brookhaven National Laboratory.

ATG 1998. *Demonstration of the Stabilization Process for Treatment of Radioactively Contaminated Wastes Containing <260 ppm Mercury. MER02 Final Report.* Allied Technology Group, Fremont, California, Report to the Mercury Working Group, Mixed Waste Focus Area.

ATG 2000. *MER03—Demonstration of the Stabilization Process for Treatment of Radioactively Contaminated Wastes Containing >260 ppm Mercury.* Allied Technology Group, Fremont, California.

ATG 2001. *MER04—Demonstration of the Stabilization Process for Treatment of Mercury Sludge Wastes Containing >260 ppm Mercury. MER04 Final Report.* Allied Technology Group, Hayward, California.

Chattopadhyay, S. 2003. *Evaluation of chemically bonded phosphate ceramics for mercury stabilization of a mixed synthetic waste*. EPA/600/R-03/113. United States Environmental Protection Agency, Washington, D.C.

DOE 1992. *Federal Facility Agreement for the Oak Ridge Reservation*, DOE/OR-1014, U.S. Environmental Protection Agency Region IV; U.S. Department of Energy, Oak Ridge Operations; and Tennessee Department of Environment and Conservation, 1992, Nashville TN.

DOE 1998. *Polyethylene Macroencapsulation*, Innovative Technology Summary Report. DOE/EM-0351, Envirocare, Salt Lake City, UT, Brookhaven National Laboratory.

DOE 1999a. *Mixed Waste Focus Area (MWFA), Demonstration of GTS Duratek Process for Stabilizing Mercury Contaminated (<260 ppm) Mixed Wastes*, DOE/EM-0487 (OST #2409), Innovative Technology Summary Report, United States Department of Energy, Washington, D.C.

DOE 1999b. *Mixed Waste Focus Area (MWFA), Demonstration of NFS DeHg Process for Stabilizing Mercury (<260 ppm) Contaminated Mixed Waste*, DOE/EM-0468 (OST #2229), Innovative Technology Summary Report, United States Department of Energy, Washington, D.C.

DOE 1999c. *Mixed Waste Focus Area (MWFA), Demonstration of ATG Process for Stabilizing Mercury (<260 ppm) Contaminated Mixed Waste*, DOE/EM-0479 (OST #2407), Innovative Technology Summary Report, United States Department of Energy, Washington, D.C.

DOE 1999d. *Stabilization Using Phosphate Bonded Ceramics* DOE/EM-0486, DOE Office of Environmental Management and Office of Science and Technology, Washington, DC.

DOE 2005. Letter from DOE Oak Ridge Operations to TDEC, "*Listed/Non-listed Determination Evaluation for Mercury-contaminated Media and Debris at the Y-12 National Security Complex*", DOE-05-0600, June 20, 2005.

DOE 2011. *EPA, TDEC, and DOE Core Team concurrence of High Modulus Polymeric Packaging System (HMPPS) For Macro-encapsulation of Mixed Waste Debris*. R. Young (TDEC), J. Richards (EPA), B. DeMonia (DOE), J. Glenn (DOE).

DOE 2012. *Characterization Report for Alpha 5 Building 9201-5 at the Y-12 National Security Complex, Oak Ridge, Tennessee Volume I*, DOE/OR/01-2540&D2, March 2012, Oak Ridge, TN.

DOE 2014. *Strategic Plan for Mercury Remediation at the Y-12 National Security Complex Oak Ridge, Tennessee*, DOE/OR/01-2605&D2, January 2014.

EPA 2003. *Treatment Standards for Mercury-Containing Debris Memorandum*; To: RCRA Senior Policy Advisors, State Waste Managers; From: Robert Springer, Director Office of Solid Waste, October 23, 2003, U.S. Environmental Protection Agency, Washington, D.C.

EPA 2007. *Treatment Technologies for Mercury in Soil, Waste and Water*. U.S. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation, Washington, D.C.

Euro Chlor 2009. *Guidelines for Decommissioning of Mercury Chlor-Alkali Plants* (Euro Chlor, 2009, Env Prot 3, 5th Edition, Euro Chlor Publication, Brussels)

Gates, D.D., K.K, Chao, and P.A. Cameron 1995. *The Removal of Mercury from Solid Mixed Waste Using Chemical Leaching Processes*. ORNL/TM-12887 Oak Ridge National Laboratory, Oak Ridge Tennessee.

Kalb P.D., J.W. Adams, and L.W. Milian 2001. *Sulfur Polymer Stabilization/Solidification (SPSS) Treatment of Mixed-Waste Mercury Recovered from Environmental Restoration Activities at BNL*. BNL-52614 Formal Report, Brookhaven National Laboratory.

Klasson, KT, L.J. Koran Jr., D.D. Gates, and P.A. Cameron 1997. *Removal of Mercury from Solids Using the Potassium Iodide/Iodine Leaching Process* ORNL/TM-13137 Oak Ridge National Laboratory, Oak Ridge Tennessee.

Mattus, C. H. and A. J. Mattus 1994. *Evaluation of Sulfur Polymer Cement as a Waste Form for the Immobilization of Low-Level Radioactive or Mixed Waste*, ORNL/TM-12657, Oak Ridge National Laboratory, Oak Ridge Tennessee.

Mattus, C.H. 1998. *Demonstration of Macroencapsulation of Mixed Waste Debris Using Sulfur Polymer Cement*. ORNL/TM-13375, Oak Ridge National Laboratory, Oak Ridge Tennessee.

Mattus, C.H. 2001. *Measurements of Mercury Released from Solidified/Stabilized Waste Forms* ORNL/TM-2001/17, Oak Ridge National Laboratory Oak Ridge Tennessee.

McBeath 1983. *Decommissioning of Mercury Cell Chlor-Alkali Plants in Canada, Environmental Protection Service [EPS]*, ES 3-EP-83.5.

Morris, M I and G A Hulet 2003. *Development and Section of Technologies for Mercury Management on U.S. Department Of Energy Sites: The MER01–MER04 and Mercury Speciation Demonstrations*. Waste Management Symposium 2003, Feb 23-27. Tuscon, Arizona.

Morris, M.I., I.W. Osborne-Lee, and G.A. Hulet, 2002. *Demonstration of New Technologies Required for the Treatment of Mixed Waste Contaminated with ≥260 ppm Mercury*, ORNL/TM-2000/147 Oak Ridge National Laboratory, Oak Ridge, Tennessee.

NFS 2001. *Demonstration of the Nuclear Fuel Services, Inc. (NFS), DeHG Stabilization Process for Treatment of Various Mercury Species in Surrogate Waste Containing >260 ppm Mercury*," Draft Report, Nuclear Fuel Services, Erwin, Tennessee.

Osborne-Lee, W., T. B. Conley, M. I. Morris, and G. A. Hulet 1999. *Demonstration Results on the Effect of Mercury Speciation on the Stabilization of Wastes*, ORNL/TM-1999/120, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Perona, J J and C H Brown 1993. *Mixed Waste Integrated Program: A Technology Assessment for Mercury-Containing Mixed Wastes* DOE/MWIP-9.

Randall, P. and S. Chattopadhaya 2004. Advances in encapsulation technologies for the management of mercury-contaminated hazardous wastes. *J. Hazardous Materials*, B114:211-223.

SAIC 1998. Technologies for Immobilizing High Mercury Subcategory Wastes. Science Applications International Corporation, Reston VA

Siry 2007. *Savannah River Site's Macroencapsulation Processing of Less Than 3700 BQ/GM1 TRU Isotopic Mixed Waste for Disposal at The Nevada Test Site*, white paper, Waste Management Conference 2007, Glenn W. Siry, Luke T. Reid.

UCOR 2012. *Treatability Study Report for Y-12 Site Mercury Contaminated Soil, Oak Ridge TN*. UCOR-4323, URS CH2M Oak Ridge LLC.

Wrapp J.K. and E. F. Di Sanza 2010. Macroencapsulation of Mixed Low-Level Radioactive Waste at the Nevada Test Site –Current Capabilities. Waste Management 2010 Conference, March 7-11, 2010, Phoenix, AZ.

This page intentionally left blank.

# APPENDIX C –
# ATTACHMENT A:
# USE OF THE INTERIM MEASURES ARAR WAIVER

This page intentionally left blank.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

April 24, 1991

OFFICE OF
GENERAL COUNSEL

**MEMORANDUM**

SUBJECT: Use of the Interim Measures ARAR Waiver

FROM: Larry Starfield /s/
Attorney
Solid Waste and Emergency
Response Divisions (LE-132S)

TO: Steve Golian, Chief
Remedial Guidance Section
Office of Emergency and Remedial
Response (OS-220W)

Linda Boornazian, Chief
Compliance Section
CERCLA Compliance Division
Office of Waste Programs
Enforcement (OS-510)

I have reviewed your memorandum of March 8, 1991, and concur in the planned use of the interim action waiver at the Wasatch Chemical Superfund site. The statute provides that an applicable or relevant and appropriate requirement (ARAR) of another federal environmental law may be waived for an on-site Superfund response action where, e.g., "the remedial action selected is only part of a total remedial action that will attain such level or standard of control when completed." CERCLA section 121(d)(4)(A), 42 U.S.C. 9621(d)(4)(A) .

As I understand the facts, hazardous wastes to which the RCRA land disposal restrictions apply are located on-site, but not all within the same Area of Contamination (AOC). Under RCRA, restricted hazardous wastes may not be moved into an AOC (i.e., "placed") until they have been treated using Best Demonstrated Available Technology (BDAT). CERCLA section 121(d)(2) requires remedial actions to attain, or justify a waiver of, such a requirement.

In the case you raise, the initial phase of the remedy calls for the placement of the wastes in a concrete vault; the final remedy would then treat those wastes by in-situ vitrification, which will result in the attainment the BDAT treatment

standards.[1] Accordingly, the "total remedial action ... will attain such level or standard of control when completed," and the use of the interim measures waiver is appropriate.

To the extent that similar findings could be made for other in-situ technologies (e.g., biological farming), it may also be possible to invoke the interim action, waiver.

cc: Carrie Wehling, OGC

---

[1]Of course, if the in-situ vitrification approach does not meet the BDAT standard, then the remedy would need to reconsidered.

# APPENDIX D:
# ON-SITE DISPOSAL ALTERNATIVE SITE SCREENING

This page intentionally left blank.

# CONTENTS


ACRONYMS ..... D-5
1. CANDIDATE SITE SCREENING ..... D-6
1.1 METHODOLOGY ..... D-6
1.2 REGULATORY SITING REQUIREMENTS ..... D-6
1.3 IN-SITU SITING OPTIONS ..... D-6
2. PRELIMINARY SCREENING ..... D-8
3. SECONDARY SCREENING ..... D-12
3.1 PROXIMITY TO THE PUBLIC ..... D-12
3.2 SECONDARY SCREENING EVALUATIONS ..... D-13
3.2.1 EBCV Option 2 ..... D-13
3.2.2 EBCV Option 3 ..... D-13
3.2.3 EBCV Option 4 ..... D-13
3.2.4 EBCV Options 6a/6b and 7a/7b – Multiple Small Landfills ..... D-16
3.2.5 Proposed SWSA 7 Site ..... D-16
3.3 REMAINING SITES ..... D-16
4. DETAILED SCREENING ..... D-17
4.1 DESCRIPTION OF WHITE WING SCRAP YARD SITE ..... D-17
4.1.1 Physical Characteristics ..... D-17
4.1.1.1 Geology ..... D-17
4.1.1.2 Surface Water ..... D-18
4.1.1.3 Ground Water ..... D-18
4.1.2 Ecological Characteristics ..... D-19
4.1.2.1 Sensitive Habitats ..... D-19
4.1.2.2 Status Species ..... D-20
4.1.3 Cultural Characteristics ..... D-21
4.1.3.1 Current Land Use ..... D-21
4.1.3.2 Historical Resources ..... D-21
4.1.3.3 Archeological Resources ..... D-21
4.2 DESCRIPTION OF WEST BEAR CREEK VALLEY CANDIDATE SITES ..... D-21
4.2.1 Physical Characteristics ..... D-22
4.2.1.1 Topography ..... D-23
4.2.1.2 Geology ..... D-23
4.2.1.3 Surface Water ..... D-24
4.2.1.4 Ground Water ..... D-25
4.2.2 Ecological Characteristics ..... D-25
4.2.2.1 Sensitive Habitats ..... D-26

4.2.2.2 Status Species ..... D-27
4.2.3 Cultural Characteristics ..... D-27
4.2.3.1 Current Land Use ..... D-28
4.2.3.2 Historical Resources ..... D-28
4.2.3.3 Archeological Resources ..... D-28
4.3 DESCRIPTION OF EAST BEAR CREEK VALLEY CANDIDATE SITE ..... D-28
4.3.1 Physical Characteristics ..... D-28
4.3.1.1 Geology and Soils ..... D-28
4.3.1.2 Surface Water ..... D-29
4.3.1.3 Ground Water ..... D-30
4.3.2 Ecological Characteristics ..... D-30
4.3.2.1 Sensitive Habitats ..... D-30
4.3.2.2 Status Species ..... D-31
4.3.3 Cultural Characteristics ..... D-31
4.3.3.1 Current Land Use ..... D-31
4.3.3.2 Historical Resources ..... D-31
4.3.3.3 Archeological Resources ..... D-31
4.4 DETAILED SCREENING ANALYSIS ..... D-32
4.4.1 WWSY Candidate Site Screening Analysis ..... D-33
4.4.1.1 Effectiveness ..... D-33
4.4.1.2 Implementability ..... D-33
4.4.1.3 Cost ..... D-34
4.4.2 WBCV Candidate Site Screening Analysis ..... D-34
4.4.2.1 Effectiveness ..... D-34
4.4.2.2 Implementability ..... D-35
4.4.2.3 Cost ..... D-35
4.4.3 EBCV Candidate Site Screening Analysis ..... D-36
4.4.3.1 Effectiveness ..... D-36
4.4.3.2 Implementability ..... D-36
4.4.3.3 Cost ..... D-37
4.4.4 Conclusion ..... D-37
5. REFERENCES ..... D-40

# FIGURES

Figure D-1. Current and Future Y-12 Plan ..... D-8
Figure D-2. EMDF Candidate Site Locations ..... D-10
Figure D-3. Possible Footprint for EBCV Option 2 ..... D-15
Figure D-4. Geologic Map of the WWSY Candidate Site ..... D-18
Figure D-5. WWSY Site Natural Features ..... D-20
Figure D-6. Conceptual Footprints of WBCV Sites 8 (Old) and 14 (Revised) ..... D-22
Figure D-7. Geologic Map of the WBCV Candidate Site ..... D-24
Figure D-8. Map of WBCV Ecological, Wetland, and Cultural Features ..... D-27
Figure D-9. Conceptual Footprint of EBCV Site 5 and Surrounding Geology ..... D-29

# TABLES

Table D-1. Candidate Sites Identified for the RI/FS Screening Evaluation ..... D-9
Table D-2. Preliminary Screening of Candidate Sites ..... D-11
Table D-3. Distance to Public Areas ..... D-12
Table D-4. Secondary Screening of Candidate Sites ..... D-14
Table D-5. Comparison and Ratings for Four Final Candidate Sites ..... D-38

# ACRONYMS

| | |
|---|---|
| ANA | Aquatic Natural Area |
| BCBG | Bear Creek Burial Ground |
| BCK | Bear Creek Kilometer |
| BCV | Bear Creek Valley |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| cfs | cubic feet per second |
| DOE | U.S. Department of Energy |
| EBCV | East Bear Creek Valley |
| EFPC | East Fork Poplar Creek |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| ET | Eastern Tributary (to Bear Creek) |
| ETTP | East Tennessee Technology Park |
| HA | Habitat Area |
| LLWDDD | Low-Level Waste Disposal, Development, and Demonstration |
| NA | Natural Area |
| NT | Northern Tributary (to Bear Creek) |
| OREIS | Oak Ridge Environmental Information System |
| ORNL | Oak Ridge National Laboratory |
| ORR | Oak Ridge Reservation |
| ORSSAB | Oak Ridge Site Specific Advisory Board |
| RI/FS | Remedial Investigation/Feasibility Study |
| ROD | Record of Decision |
| SR | State Route |
| SWSA | Solid Waste Storage Area |
| TSCA | Toxic Substance Control Act of 1976 |
| TDEC | Tennessee Department of Environment and Conservation |
| U.S. | United States |
| USGS | U.S. Geological Survey |
| UEFPC | Upper East Fork Poplar Creek |
| WAG | Waste Area Grouping |
| WBCV | West Bear Creek Valley |
| WWSY | White Wing Scrap Yard |
| Y-12 | Y-12 National Security Complex |

# 1. CANDIDATE SITE SCREENING

Review and screening of potential sites for a low-level radioactive waste landfill, the Environmental Management Disposal Facility (EMDF) was conducted as part of the Remedial Investigation/Feasibility Study (RI/FS) alternatives screening process. The United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR) encompasses approximately 33,500 contiguous acres, and thus offers numerous potential sites for consideration. A previous site-screening study identified and evaluated 35 sites on the ORR for a potential on-site disposal facility (DOE 1996).

The Environmental Management Waste Management Facility (EMWMF) RI/FS (DOE 1998) pared the original 35 candidate sites considered in the 1996 study down to three sites that were further evaluated, and the current EMWMF site was selected. This RI/FS re-evaluated 16 candidate sites, including sites identified in the 1996 siting study, the three sites identified in the EMWMF RI/FS, as well as other possible favorable locations. Specifically, those 16 sites include multiple locations in East Bear Creek Valley (EBCV), West Bear Creek Valley (WBCV), and Chestnut Ridge; White Wing Scrap Yard (WWSY); a single Melton Valley location; and two other ORR locations.

## 1.1 METHODOLOGY

The screening process consisted of candidate site identification, data review, and application of a three-stage screening evaluation based on available data and information. The methodology was designed to eliminate sites obviously not meeting project requirements early in the process in order to focus more detailed evaluation on only the more viable sites. Screening was conducted as an iterative process by applying criteria developed on the basis of facility design assumptions, available area, topography, regulatory drivers, and other siting considerations, including land use. Primary and secondary screening focuses on implementability, while the final screening examines implementability, effectiveness, and relative cost per the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) screening method. The 2008 ORR planning document (DOE 2008) helped identify potential conflicts in land-use priorities among various DOE mission goals and objectives, including long term research and protected land areas.

## 1.2 REGULATORY SITING REQUIREMENTS

East Tennessee and the ORR are not ideally suited for land disposal of wastes because of the high annual rainfall (over 50 inches per year, on average), yet the wastes produced here must largely be disposed of here. As a result, certain requirements contained in applicable or relevant and appropriate regulations for siting land disposal units cannot be met except by use of engineered containment systems. Waivers from such siting requirements will be requested in the Proposed Plan, as allowed under CERCLA §121(d)(4)(D) on the basis that the engineered containment systems provide an equivalent or greater standard of performance as opposed to those required by the regulation(s). It is assumed that such waivers can be obtained. These regulations and rationale for waivers are discussed in detail in Appendix G.

## 1.3 IN-SITU SITING OPTIONS

Regulators expressed concerns that disposal of Y-12 National Security Complex (Y-12) mercury-contaminated wastes in Bear Creek Valley (BCV) would lead to a second watershed being impaired by mercury, and requested that the RI/FS consider burial of these wastes within the Upper East Fork Poplar Creek (UEFPC) Watershed as an alternative.

One conceptual approach examined is disposal of contaminated building debris in engineered facilities at, or near, the remediation sites in the Y-12 industrial area. These brownfield disposal sites could be used

post-remediation for such low-impact purposes as parking lots, or vegetated open spaces; however, these areas would generally not be available for other forms of development. This conceptual approach could potentially align with the vision for modernizing the Y-12 industrial area described in *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011). Figure D-1 shows the current and envisioned future plan for Y-12. The long-range vision is for excess Y-12 facilities to be demolished leaving room for several new facilities surrounded by significantly more open space.

The primary benefit of this approach is that mercury-contaminated materials would remain in the watershed that has already been significantly impacted by the contaminant, and thus avoid spreading it to a watershed with relatively little mercury contamination. Further, the disposal sites would remain in an area that will be controlled by DOE or successor agencies for any reasonable foreseeable future. An additional benefit would be gained in a small decrease in transportation costs for moving debris from the demolition site to the disposal site.

Offsetting the benefits are several major disadvantages. First and foremost is increased risk and cost associated with in-place disposal. Risk is increased relative to a single large disposal cell because there would be a need for multiple new disposal cells, each of which has the potential to release contaminants. Second, it would be extremely difficult to sequence the complex operational, demolition, and disposal activities for both soil and debris such that disposal need meets disposal capacity. This also greatly increases overall costs as a result of utilities re-routing and security system changes. Costs would also be increased by the need to design and construct several facilities, instead of one; by the increase in infrastructure needed to serve several facilities; and by the additional monitoring and maintenance required to ensure that each of the several disposal cells performs as designed. Post-remediation operational flexibility would be reduced because the areas devoted to waste disposal would be unusable for any purpose that would require foundations or buried utilities. Additionally, the current Records of Decision (RODs) addressing cleanup in the UEFPC watershed are considered interim RODs (BJC 2002, BJC 2006), and leave open-ended the possibility of needing to address further soil cleanup in the area depending on final ground water and surface water decisions. Disposing of debris and soil in-place would make any further cleanup impractical.

Finally, even under the assumption that the volume of waste to be disposed is the same under the single facility and multiple facility approaches, the effective footprint (waste plus containment system) of multiple facilities after closure would be significantly greater than for a single large facility.

**Figure D-1. Current and Future Y-12 Plan**

Additionally, there are several impediments to implementation of this potential remedy. First, the Y-12 industrial area contains a dense network of burial and overhead utilities that would have to be re-routed to accommodate any burial site(s) large enough to accommodate expected waste volumes. Second, the Perimeter Intrusion Detection and Assessment System would have to be realigned to accommodate disposal sites. Third, the in-place disposal sites would either require early soil clean-up, or if buildings were disposed of in their own footprints, could mask mercury-contaminated soils from further remediation.

The disadvantages of in-place waste burial far out-weigh any benefits realized, and this alternative is therefore not considered further in this document. However, this decision does not preclude future pursuit of alternative disposition of mercury-contaminated debris and/or soil within UEFPC watershed area.

## 2. PRELIMINARY SCREENING

The 16 candidate sites screened for this RI/FS were selected utilizing data and information presented in the 1996 DOE site screening study (DOE 1996), the EMWMF RI/FS (DOE 1998), and a 2008 ORR planning document (DOE 2008a). Table D-1 lists the 16 candidate sites and indicates the basis for their consideration. The site locations are identified by number on Figure D-2. Screening was conducted as an iterative process by applying criteria developed on the basis of facility design assumptions, available area, topography, regulatory drivers, and other siting considerations, including land use.

Table D-2 identifies and briefly describes the preliminary siting criteria the candidate sites were screened against. These include available area, topography, surface water, and karst:

- Area: Use of projected waste volumes in conjunction with design requirements and assumptions resulted in a minimum threshold requirement for a landfill footprint area of 60-70 acres.

- Topography: Topographic constraints on siting were reviewed to determine the suitability of candidate sites for disposal facility development. Considered in this evaluation were degree of slope and geomorphologic indications of site stability, and soil thickness.
- Surface Water: The presence of surface water features, such as streams and wetlands, were a consideration. Consideration was given to whether streams were ephemeral (wet weather conveyances), intermittent, or perennial, whether springs and seeps were present, whether wetlands, if present, are natural or artifacts of construction, and whether the water features represented unique habitats or contained status species.
- Karst: The presence of karst surface features, such as sinkholes, or indications that significant voids may exist beneath the landfill footprint, were considered in relation to structural stability, ground water monitoring, and contaminant migration.

Candidate sites that presented critical construction/engineering obstacles were eliminated from further consideration in the preliminary screening phase. The "discussion" column in Table D-2 identifies those candidate sites retained, identifies the option designs that are derived from an updated or modified design of another listed option, and why six of the candidate sites were eliminated from further consideration. The preliminary screening phase reduced the original 16 candidate sites to ten for further evaluation.

**Table D-1. Candidate Sites Identified for the RI/FS Screening Evaluation**

| Candidate Site* | Basis for Consideration |
|---|---|
| (1) EBCV-Option 1 | Adjacent to EMWMF |
| (2) EBCV-Option 2 | Adjacent to EMWMF, combines Bear Creek Burial Ground (BCBG) remedy component with landfill siting |
| (3) EBCV-Option 3 | Adjacent to EMWMF |
| (4) EBCV-Option 4 | Adjacent to EMWMF |
| (5) EBCV-Option 5 | Adjacent to EMWMF |
| (6) EBCV-Option 6 | Two separate disposal cells (6a & b), adjacent to EMWMF on west and east |
| (7) EBCV-Option 7 | Two separate disposal cells (7a & b) |
| (8) WBCV-Option 8 | Previous waste disposal facility siting study |
| (9) WWSY | Previous waste disposal facility siting study; adjacent to Waste Area Grouping (WAG) 11 |
| (10) Chestnut Ridge | East of Spallation Neutron Source |
| (11) West-Central Chestnut Ridge | Previous waste disposal facility siting study area |
| (12) East Chestnut Ridge | Previous waste disposal facility siting study area |
| (13) Former Breeder Reactor area | Possible favorable location |
| (14) Modified WBCV Option | Revised footprint from Option (8) |
| (15) Solid Waste Storage Area (SWSA) 7 | Former proposed landfill site within Melton Valley, east of legacy waste management areas |
| (16) Advanced Nuclear Site | Former proposed construction site east end of Melton Valley adjacent to Bearden Creek |

*Numbers in parentheses correspond to the areas shown on Figure D-2.

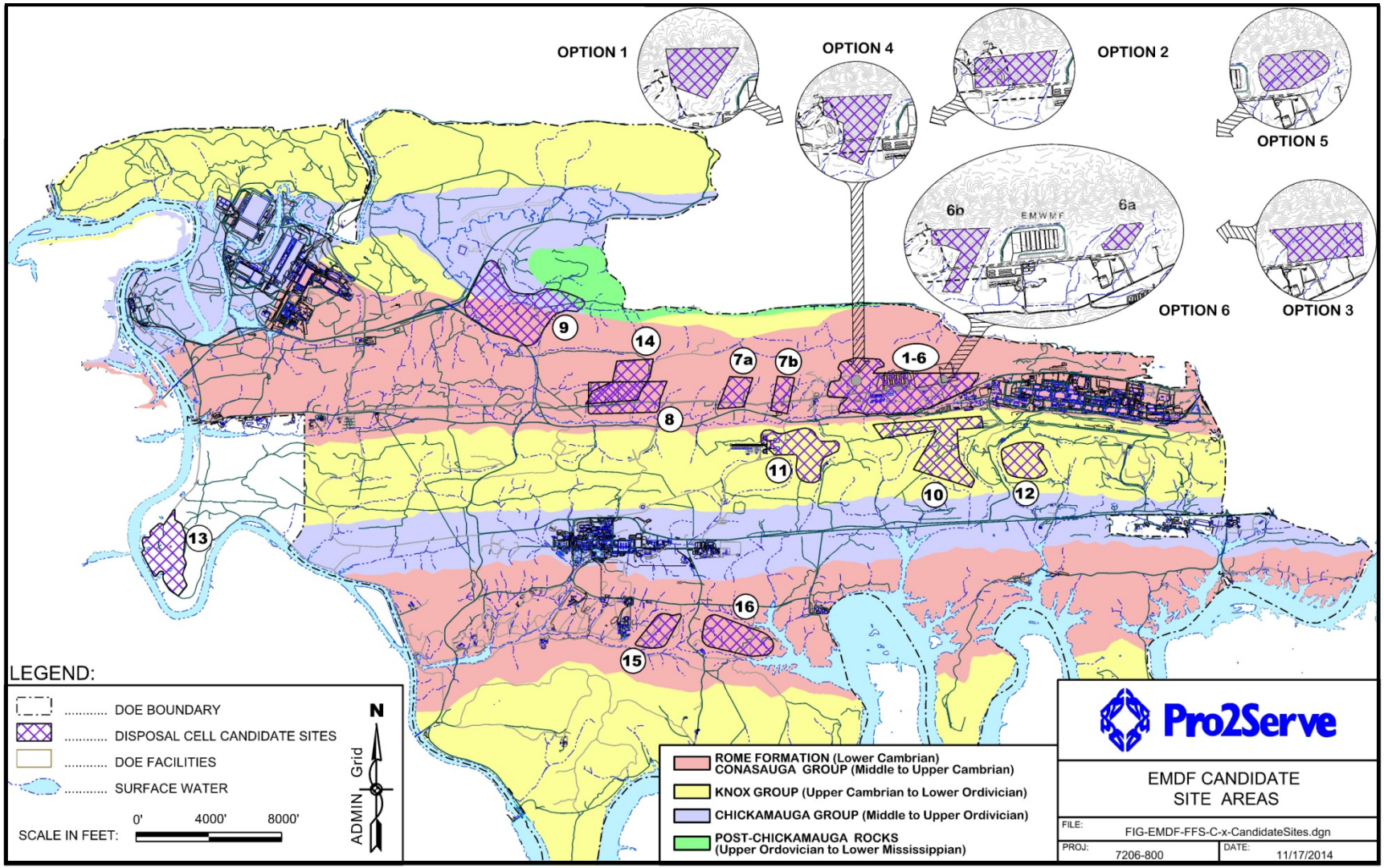



**Figure D-2. EMDF Candidate Site Locations**

**Table D-2. Preliminary Screening of Candidate Sites**

| Candidate Site | Preliminary Screening Criteria | | | | Discussion |
|---|---|---|---|---|---|
| | Insufficient Area | Unfavorable Topography | Surface Water Impacts | Karst Features | |
| (1) EBCV-Option 1 | X | X | | | Site eliminated due to lack of suitable area for development and unfavorable topography. |
| (2) EBCV-Option 2 | | | X | | **Carried forward to secondary screening, see Table D-3.** |
| (3) EBCV-Option 3 | | | X | | **Carried forward to secondary screening, see Table D-3**. |
| (4) EBCV-Option 4 | | | X | | **Carried forward to secondary screening, see Table D-3**. |
| (5) EBCV-Option 5 | | | X | | Modified version of Option 3 design (crosses NT-3 but avoids direct impacts to NT-2). **Carried forward to secondary screening, see Table D-3.** |
| (6) EBCV-Option 6 | | | | | A modified version of Option 4 design with an additional separate cell to the east. **Carried forward to secondary screening, see Table D-3.** |
| (7) EBCV-Option 7 | | | | | **Carried forward to secondary screening, see Table D-3.** |
| (8) WBCV-Option 8 | | | X | | **Carried forward to secondary screening, see Table D-3.** |
| (9) WWSY | | | | ? | **Carried forward to secondary screening, see Table D-3.** |
| (10) Chestnut Ridge | | X | | X | Site eliminated on basis of steep terrain and karst. |
| (11) West-Central Chestnut Ridge | X | | | X | Site eliminated. Lack of suitable area for development due to proximity of Spallation Neutron Source. Karst features are present. |
| (12) East Chestnut Ridge | X | X | X | X | Site eliminated due to lack of suitable area for development, presence of karst, and unfavorable topography. |
| (13) Former Breeder Reactor Area | | | X | X | Site eliminated on basis of proximity to the Clinch River and presence of karst. Site is on TVA-owned land. |
| (14) Modified WBCV Option | | | | | Modified version of Option 8 design; avoids Haul Rd and power line. **Carried forward to secondary screening, see Table D-3.** |
| (15) Proposed SWSA 7 | | | X | | **Carried forward to secondary screening, see Table D-3.** |
| (16) Proposed Advanced Nuclear Site | | | X | | Site eliminated. Site is directly adjacent to the Bearden Creek embayment of Melton Lake. A high power transmission line runs through the site. |

# 3. SECONDARY SCREENING

Ten candidate sites were examined in the second phase of screening of which six were eliminated from further consideration. The modifying criteria used for the secondary screening phase were location and access, proximity to public areas, site contamination, buffer zones, land use, and disposal capacity. Modifying criteria were designed to eliminate sites from further consideration only when either multiple criteria combined to render a site unfavorable for development or there were particularly significant issues associated with a single criterion.

## 3.1 PROXIMITY TO THE PUBLIC

Proximity to the public was a consideration for all sites forwarded to secondary screening. Proximity to the public is defined three ways and summarized in Table D-3:

- Occasional use areas include roads (State Route [SR]-95 [abbreviated 95 in table] or Tuskegee Dr.[T]) and commercial/industrial areas that private citizens may use on a short-term basis.
- Residential areas are those areas occupied by existing single and multi-family structures. Roads in residential areas are not counted as occasional use land.
- Distance to DOE boundary.

All the candidate sites in secondary screening are less than one mile from the DOE boundary, as shown in Table D-3, and a few are less than one mile from existing residential areas (County Club Estates, Rarity Oaks, Groves Park Commons, or lake front homes in Knox County). Two sites are less than 0.5 mile from a public road.

**Table D-3. Distance to Public Areas**

| Candidate Site | Approximate Distance from Candidate Site (Miles) | | |
|---|---|---|---|
| | Occasional Use | Existing Residential | DOE Boundary |
| (2) EBCV-Option 2 | 1.3 (T) | 1.1(CCE) | 0.75 |
| (3) EBCV-Option 3 | 0.8 (T) | 1.1 (GPC) | 0.4 |
| (4) EBCV-Option 4 | 1.4 (T) | 1.1 (CCE) | 0.75 |
| (5) EBCV-Option 5 | 0.8 (T) | 0.8 (GPC) | 0.4 |
| (6) EBCV-Option 6a<br>EBCV-Option 6b | 1.1 (T)<br>0.8 (T) | 1.1 (CCE)<br>0.8 (GPC) | 0.75 |
| (7) EBCV-Option 7a<br>EBCV-Option 7b | 1.9 (95)<br>2.0 (T) | 0.7 (CCE)<br>0.8 (CCE) | 0.75 |
| (8) WBCV-Option 8 | 0.5 (95) | 1.1 (CCE) | 0.75 |
| (9) WWSY | <0.1 (95) | 1.2 (RO) | 0.6 |
| (14) Modified WBCV Option | 0.5 (95) | 1.0 (CCE) | 0.75 |
| (15) Proposed SWSA 7 | 1.3 | 1.65 (KC) | 1.3 |
| Other areas of interest, included for comparison purposes | | | |
| EMWMF | 1.1 (T) | 1.3 (GPC) | 0.75 |
| Y-12 Alpha 5 Complex | 0.8 (T) | 0.5 (GPC) | 0.4 |

CCE Country Club Estates
GPC Groves Park Commons
KC Knox County
RO Rarity Oaks

By way of comparison, the distance from the center of the Y-12 main plant area to the nearest residential area is approximately 0.5 mile.

All ten sites included in secondary screening are within 0.8–1.2 miles of residential areas, and all are within 0.75 mile of the DOE boundary. Distance to public is therefore not a strong discriminator, except for the WWSY site, as discussed below.

## 3.2 SECONDARY SCREENING EVALUATIONS

The rationale for elimination of six of the ten sites is briefly discussed below and summarized in Table D-4.

### 3.2.1 EBCV Option 2

EBCV Option 2 was eliminated because it included a portion of the Bear Creek Burial Grounds (BCBG) and crosses Northern Tributary (NT)-6. EBCV Option 2, shown on Figure D-2, combines a BCBG remedy component with siting of the proposed landfill. Construction of a new landfill under Candidate Site 2 would require excavation of buried waste and residual contaminated soils from several BCBG units including A-North, A-17, and ORP-2 (see Figure D-3) and would impact a portion of NT-6. Note that a Resource Conservation and Recovery Act of 1976 cap has been installed on areas A-North and ORP-2, and would need to be removed prior to excavation. Excavated waste would be placed in the new landfill and/or disposed off-site. As shown in Table D-4, EBCV Option 2 was eliminated from further consideration because the presence of buried waste and site contamination present significant challenges to landfill construction. The challenges include concerns about worker health and safety, remote excavation techniques, remote-handling of wastes, waste treatment and disposal, and transportation of BCBG buried wastes. These factors would result in extremely high implementation costs.

Further, EBCV Option 2 would be inconsistent with the preferred alternative of hydrologic isolation identified in the Proposed Plan for BCBG (DOE 2008b). The preferred alternative includes construction of multilayer engineered caps for all previously uncapped BCBG disposal units plus one previously capped unit (BCBG D-West), construction of upgradient storm-flow trenches to intercept and divert shallow ground water and surface water run-on, and construction of downgradient collection trenches. Remedial alternatives considered in the BCBG Proposed Plan included partial excavation and excavation of the BCBG. Following a CERCLA criteria evaluation, these alternatives were not identified as the preferred alternative. While approval and implementation of a BCBG ROD has been deferred, potential interim actions that could be implemented to reduce migration of contaminants from BCBG are being considered, such as enhanced leachate collection, a component of the preferred alternative presented in the BCBG Proposed Plan.

### 3.2.2 EBCV Option 3

EBCV Option 3 was eliminated because it covers two tributary streams, NT-2 and NT-3. However, see EBCV Option 5, which is a modification of Option 3.

### 3.2.3 EBCV Option 4

EBCV Option 4 consists of an irregular polygon lying between EMWMF and BCBG that was formerly used as a borrow area. In order to provide sufficient volume for the expected wastes, the footprint would need to extend north from near Bear Creek, across the Haul Road and power line right of way and onto the flank of Pine Ridge. Additionally, the south end of the landfill is likely to be within the 100-year floodplain of Bear Creek and the water table would likely be close to the land surface.

**Table D-4. Secondary Screening of Candidate Sites**

| Candidate Site | Secondary Screening Criteria | | | | | Discussion |
|---|---|---|---|---|---|---|
| | Location and Access | Site Contamination | Buffer Zones | Land Use | Disposal Capacity | |
| (2) EBCV-Option 2 | | X | X | | | Site eliminated. Presence of buried waste and site contamination present significant challenges to facility construction. |
| (3) E BCV-Option 3 | | | X | | | Site is eliminated. Covers two tributaries to Bear Creek. |
| (4) EBCV-Option 4 | | ? | X | | X | Site is eliminated. Concern about adequate disposal capacity and shallow ground water table south of the Haul Road. Adjacent to legacy burial ground. |
| (5) EBCV-Option 5 | | | X | | | **Potential Site.** See further discussion in Section 4. |
| (6) EBCV-Option 6a/6b | | | X | X | X | Site eliminated. Adequate disposal capacity could potentially be achieved using two separate cells, but would impact a larger land area. Sites may not be adequate to avoid impinging on stream buffers |
| (7) EBCV-Option 7a/7b | | | X | X | X | Site eliminated. Adequate disposal capacity could potentially be achieved using two separate cells. Site is located in BCV Watershed Zone 2 designated for possible future recreational land use (short-term) and unrestricted land use (long-term). |
| (8) WBCV-Option 8 | | | X | X | | **Potential Site.** See further discussion in Section 4. |
| (9) WWSY | X | ? | X | X | | **Potential Site.** Concern about proximity to public access areas, sensitive habitats, and legacy disposal site. |
| (14) Modified WBCV Option | | | | X | | **Potential Site.** See further discussion in Section 4. |
| (15) Proposed SWSA 7 Site | X | | | X | | Site eliminated. Site is adjacent to the High Flux Isotope Reactor. Access from Y-12 would require more than 2 miles new Haul Road to be constructed. One stream would be eliminated. |

Note: an X in each column indicates that the site has issues with that criterion. A question mark indicates a potential concern.

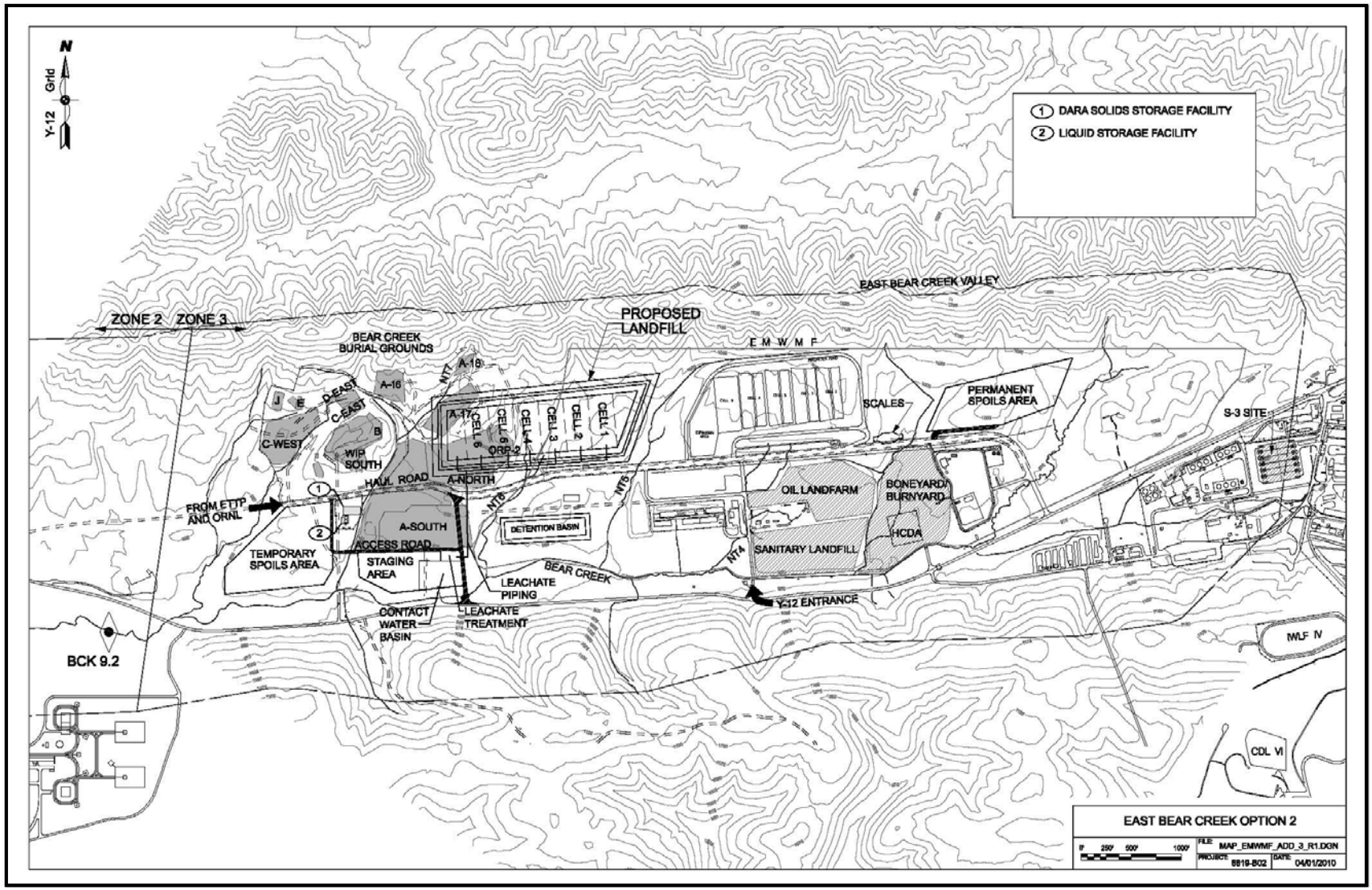



**Figure D-3. Possible Footprint for EBCV Option 2**

### 3.2.4 EBCV Options 6a/6b and 7a/7b – Multiple Small Landfills

One suggestion for avoiding construction over surface water features is use of two or more landfills with relatively small footprints, such as Candidate Sites 6a/6b and 7a/7b.

Each of the smaller landfills has a much smaller total volume (airspace) capacity to total area ratio (e.g., the landfill boundaries/sides take up a much larger portion of the landfill). The height of waste allowable with a smaller landfill is much lower, thus also decreasing the volume available for wastes, which requires a larger aggregate land area. Additionally, requirements such as the 12 ft top layer of waste cannot contain debris (must be soil) are the same for a small landfill, but proportionally represent a larger percentage of the volume available for waste.

The use of multiple landfills may not avoid surface water impacts or maintain adequate buffers between the landfill and streams, because springs and seeps are common and widespread in BCV.

### 3.2.5 Proposed SWSA 7 Site

The SWSA 7 site in Melton Valley, immediately east of the High Flux Isotope Reactor, was extensively evaluated as a potential disposal site in the 1980s. There is adequate area for the expected disposal volume. The SWSA 7 site was earlier investigated as a potential new low-level radioactive waste disposal area (Lomenick, et al. 1983; Rothschild, et al 1984), but was rejected. The site is a hilly area lying between two tributaries to Melton Branch and incorporating a third tributary. Cunningham and Pounds (1991) indicate that wetland vegetation occurs in an artificial pond and possibly at two small sites adjacent to a gravel road. Geologically, the SWSA 7 site is very similar to the WBCV and EBCV sites. The underlying bedrock is composed of Conasauga Group shales, siltstones, and mudstones with lesser amounts of shaley limestone. Groundwater occurs in fractures, and drainage is radial, making monitoring more difficult. There is no karst at this site.

Site topography presents some construction challenges and site preparation would require removal of a larger quantity of soil and rock than at other sites. A short first-order stream (or wet weather conveyance) would be eliminated, as would any wetlands in the area. Approximately two miles of new Haul Road would have to be constructed in order for Y-12 wastes to transit Bethel Valley. This new segment of Haul Road would likely have to cross a portion of the Walker Branch watershed, which is an essentially pristine monitored research area. There are no accessible support facilities at the site, and power, water, leachate containment and treatment systems, and storm water control systems would need to be installed.

The site, as noted above, is adjacent to the High Flux Isotope Reactor, an active facility conducting sensitive work. It is likely that construction and operation of a large landfill would adversely impact High Flux Isotope Reactor operations. Landfill operations may increase risk for workers at the High Flux Isotope Reactor, as well.

Given the proximity to an active reactor facility, need for additional road construction in a research watershed, construction challenges, and the lack of available support facilities, SWSA 7 is eliminated from further consideration.

## 3.3 REMAINING SITES

Four candidate sites passed the secondary screening evaluation: WWSY, WBCV (Site 8), WBCV (Site 14), and EBCV (Site 5). These four sites are evaluated in greater detail below.

# 4. DETAILED SCREENING

Ten sites were carried through to secondary screening, and of these, four merited more detailed consideration, as discussed below.

## 4.1 DESCRIPTION OF WHITE WING SCRAP YARD SITE

WWSY Candidate Site 9 is in the northwestern portion of the ORR, adjacent to SR-95 southeast of the East Tennessee Technology Park (ETTP). The closed WWSY waste disposal area (WAG-11) bounds the site on the east.

### 4.1.1 Physical Characteristics

The WWSY site is an approximately 185-acre area located immediately east of the intersection of SR-58 and SR-95. The proposed landfill footprint would be in the Bear Creek drainage basin between Eastern Tributary (ET)-3 and ET-4. The closed WWSY bounds the area to the north and SR-95 is to the south. Wooded, undisturbed terrain is west, northwest and north east of the site, and on the southeast by Hembree Marsh. Topography at the WWSY site is primarily gently to moderately sloping rounded knolls with small streams.

WAG-11, an approximately 30-acre area northeast of the site being considered for the new CERCLA disposal facility, was used for the burial and aboveground storage of contaminated debris and scrap from ETTP, Y-12 Plant, and Oak Ridge National Laboratory (ORNL) from the early 1950s through the mid-1960s. Non-intrusive studies, conducted subsequent to surface debris removal in 1993, confirm that WAG-11 contains about 115 $yd^3$ of buried material. Several studies conducted at WAG-11 indicate that soils and sediments are contaminated and that ground water may also be contaminated (Rodriguez, et al. 1992; Boegly and Moore 1988).

#### 4.1.1.1 Geology

The geology of WWSY site is complicated due to its position along the imbricate Whiteoak Mountain thrust fault that passes through the site, as shown in Figure D-4. The footwall of the fault (lower plate) is comprised of several formations of the Middle Ordovician-age Nashville Group and Stones River Group and underlies the northwestern portion of the WWSY site north of the Whiteoak Mountain thrust fault.

The Stones River Group in the site area is composed of limestone formations that overlie the Knox Group. In this area the Stones River Group consists of the Pond Springs Formation, the Murfreesboro Limestone, the Ridley Limestone, the Lebanon Limestone and the Carters Limestone. The Nashville Group, made up of the Hermitage Formation, the Cannon Limestone, and the Catheys and Leipers Formation overlie the Stones River Group. These limestone units are conducive to karst formation.

The footprint of the landfill itself is on the hanging wall of the Whiteoak Mountain Thrust sheet, which contains sandstones and shales of the Cambrian-age Rome Formation (Hatcher et al. 1992). The Apison Shale member, forming the lower portion of the Rome Formation, is composed of micaceous shale and siltstone. The upper part of the Rome Formation is composed of well-cemented sandstone with interbedded siltstone and shale.

The structure of the site is defined by complex faulting associated with the White Oak Mountain Thrust Fault. Subsidiary imbricate faults bound the shale and sandstone members of the Rome Formation and separate limestone of the Nashville and Stones River groups from the Rome Formation. North of the Whiteoak Mountain Thrust, the Ordovician limestones dip to the northeast (magnetic north) into the west end of the East Fork Ridge Syncline, and bedding planes curve to wrap around the end of the syncline. On the south side of the thrust fault, the Rome Formation units dip to the south. It is likely that fracture

patterns within the imbricate fault slices are highly complex. There are no recent or seismically-capable faults in the WWSY area.

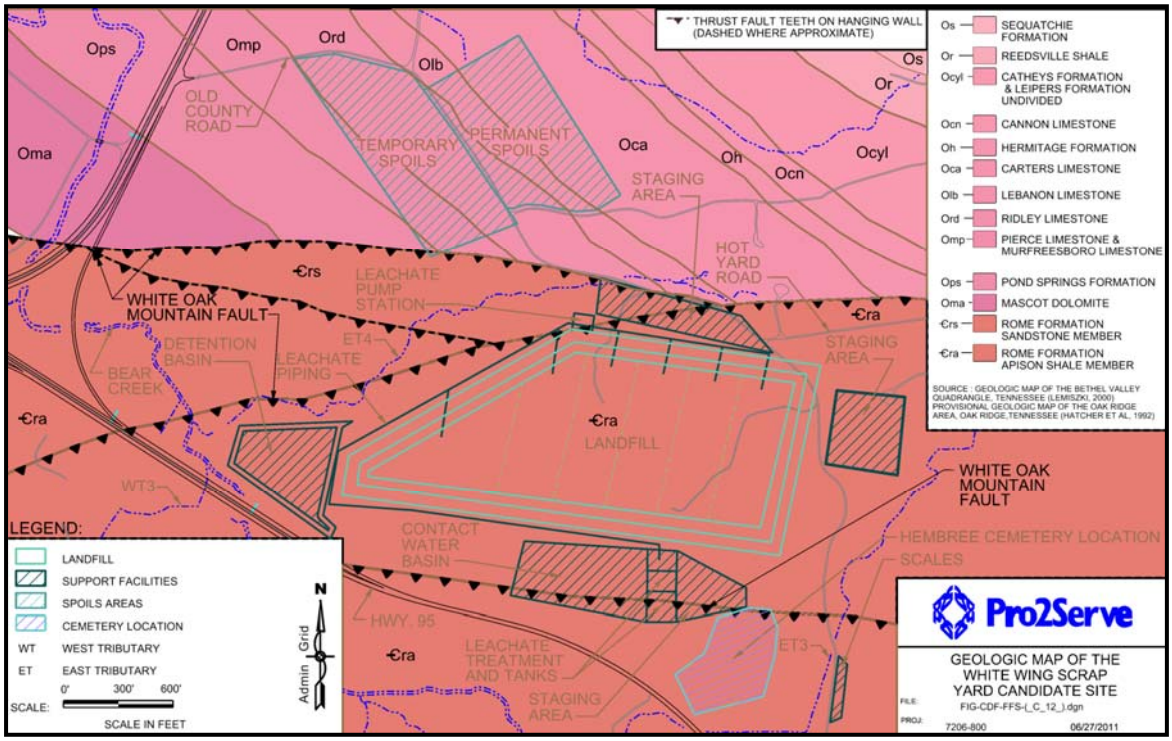



**Figure D-4. Geologic Map of the WWSY Candidate Site**

### 4.1.1.2 Surface Water

The WWSY candidate site lies within the Bear Creek drainage basin roughly 1.25 miles southeast of the junction of Bear Creek and East Fork Poplar Creek (EFPC). Bear Creek in this reach is a third-order stream. Two wetlands are also located in the vicinity of the WWSY candidate site. Hembree Marsh is adjacent to ET-3 near Hembree Cemetery, and the Rein-orchid Marsh is located along Bear Creek on the south side of SR-95 (see Figure D-5).

Surface water hydrology at the site is basically storm-driven with an underlying base flow supported by ground water inflow, as with other basins in the Oak Ridge area. Surface water flow from the WWSY site enters ET-3 and ET-4 which have headwaters on the western terminus of East Fork Ridge. Upper reaches of ET-3 and ET-4 respond primarily to storm flow, but flow in the lower reaches is supported by base flow (ground water inflow).

Four or more springs appear to be present in or near the conceptual CERCLA disposal facility and work area footprint at the WWSY site (Parr and Hughes 2006). These appear to be relatively minor, based on the sparse flow data available in Oak Ridge Environmental Information System (OREIS).

### 4.1.1.3 Ground Water

The ground water hydrology of the WWSY site is governed by the complex underlying geology. Based on data in the OREIS, ground water depth in the Nashville and Stones River Group and Rome Formation and overlying unconsolidated materials varies from less than 2 ft below the ground surface in the

bottomland along ET-3 to 66 ft below the ground surface on the hillside in wells near the former scrap yard. Fractures in all bedrock units and possible solution cavities in carbonate rocks are the primary ground water flow pathways at the WWSY site.

Ground water movement in the Rome Formation occurs mainly along fractures and movement is likely to be very slow. Intergranular matrix permeability is insignificant and contributes little to flow or ground water storage. Ground water flow within the Nashville and Stones River Groups occurs in fractures and karst conduits in limestone that are capable of transmitting large quantities of water through the substrate. There is little interconnected matrix porosity in the limestones, and therefore little storage capacity.

### 4.1.2 Ecological Characteristics

The WWSY candidate site and nearby areas contain upland forest, riparian, and wetland ecotopes. All of the waste unit footprint and most of the potential support areas are on uplands. These habitats are suitable for wildlife and reflect the diversity of environments found throughout the ORR.

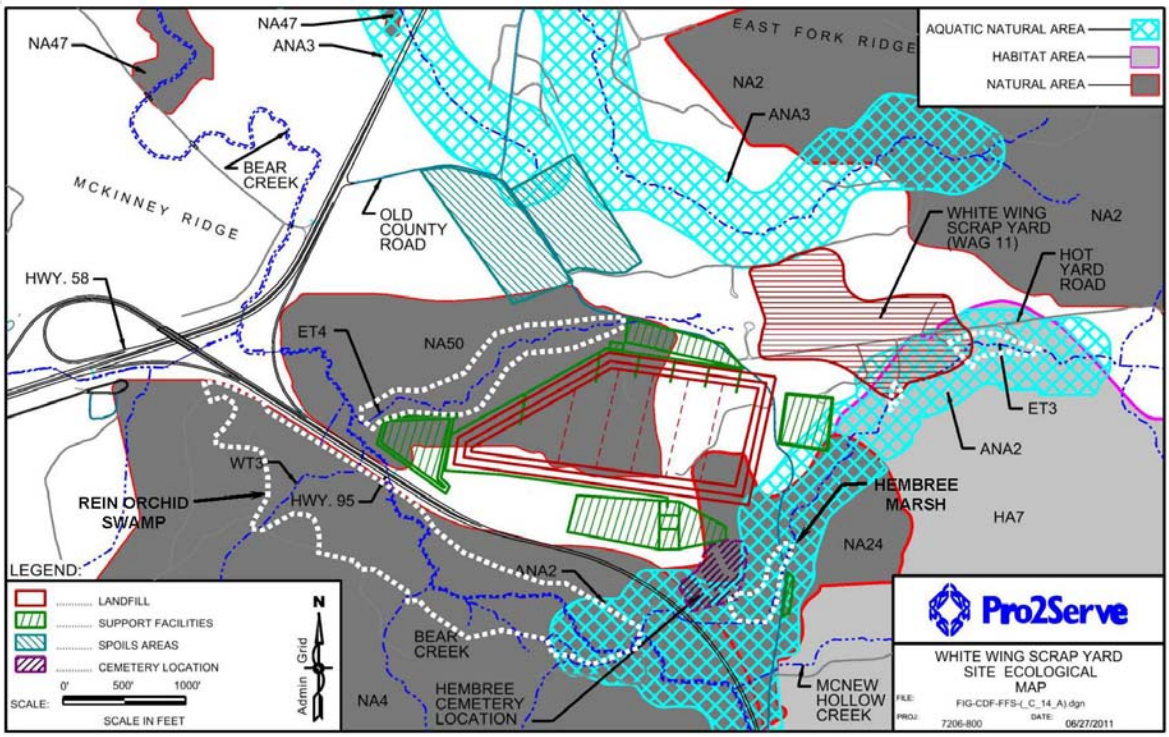
#### 4.1.2.1 Sensitive Habitats

Five Natural Area (NA) areas in the vicinity of the WWSY site have been identified in the ORR Resource Management Plan (Pounds, et al. 1993). These include Aquatic Natural Area (ANA)-2 and -3, and NAs-4, -24, and -50. These are briefly described below and shown on the map in Figure D-5.

- ANA-2 – In the WWSY area, ANA-2 encompasses Bear Creek above the Rein-Orchid Marsh (NA-4) and portions of ET-3.
- ANA-3 – An unnamed second-order stream that flows to EFPC.
- NA-4 – Rein-orchid Marsh is a large wetland that lies along Bear Creek on the south side of SR-95.
- NA-24 – Hembree Marsh is a wetland that lies in a bend of ET-3, just upstream from SR-95.
- NA-50 - Bear Creek ET-4 Area, west of the WWSY site.

Five wetlands may be present in the vicinity of the WWSY site. The two largest are Hembree Marsh and the Rein-orchid Swamp along Bear Creek south of SR-95 in NA-4. Hembree Marsh is a perennially saturated palustrine emergent/scrub-shrub/forested wetland complex covering about 2.75 acres (Rosensteel and Trettin 1993). The Rein-orchid Swamp is an approximately 50 acre perennial wetland that is home to several plant species listed as Threatened or Special Concern in Tennessee (TDEC 2008).

Another wetland is found along ET-4, and two other small wetlands have been identified along ET-3 near WAG-11 (Rosensteel and Trettin 1993). No Threatened, In-need-of-management, or Special Concern plants or animals were noted in these small wetlands.




Approximate Wetland Areas are Outlined in Dashed White Lines.

**Figure D-5. WWSY Site Natural Features**

### 4.1.2.2 Status Species

The following three state-listed animal species (Mitchell, et al. 1996) have been reported in the vicinity of the WWSY candidate site location:

- Four-toed salamander (*Hemidactylium scutatum*), found in Hembree Marsh (NA-24), classified by the state of Tennessee as an In-need-of-management species.
- Southeastern shrew (*Sorex longirostris*) is a Tennessee-listed In-need-of-management species that has been reported near Hembree Marsh (NA-24).
- Northern harrier (*Circus cyaneus*) is a Tennessee-listed In-need-of-management species that probably only passes through ORR during migration.

Based on existing surveys (Cunningham and Pounds 1991, Rosensteel and Trettin 1993), at least the following state-listed plants are found within potentially impacted areas in or adjacent to the conceptual CERCLA disposal facility sites:

- Pink lady slipper (*Cypripedium acaule*) is a Tennessee-listed In-need-of-management species that occurs in HA-7, McNew Hollow, and Hembree Marsh.
- Golden seal (*Hydrastis canadensis*) is a Tennessee-listed In-need-of-management species that is found in NA-2, the East Fork Ridge Mesic Forest.
- Small-head rush (*Juncus brachycephalus*) is a Tennessee species of Special Concern found in NA-24, Hembree Marsh.
- Canada lily (*Lilium canadense*) is a Tennessee Threatened species found in NA-2, East Fork Ridge Mesic Forest and NA-50, Bear Creek ET-4 Area.

- Fen orchid (*Liparis loeselii*) is a Tennessee Threatened orchid inhabiting NA-24, Hembree Marsh.
- Tuberculed rein-orchid (*Platanthera flava* var. *herbiola*) is a Tennessee-listed Threatened species found in NA-4, Rein Orchid Swamp, and NA-50, Bear Creek ET-4 Area.

### 4.1.3 Cultural Characteristics

The land in the immediate vicinity of WWSY is wooded and largely undeveloped, and serves as a buffer for Y-12 and ORNL.

#### 4.1.3.1 Current Land Use

Much of the land within one mile of WWSY, with the exceptions of SR-58, SR-95, and the Horizon Center Industrial Park, is DOE-owned. The straight-line distance to the nearest entrance to Horizon Center is roughly 0.8 mile. Two businesses currently occupy land at the Horizon Center, and it is expected that more businesses will eventually locate there. ETTP is approximately 1.5 miles southwest (straight-line distance) of the proposed WWSY CERCLA disposal facility footprint.

There are currently no residences within two miles of the WWSY candidate site. The closest public access to the candidate site is SR-95, which is roughly 300 ft from the closest edge of the conceptual WWSY waste unit footprint. The waste unit is also within about 300 ft of the Hembree Cemetery. Depending on actual design, facility support areas may be as close as 125 ft to SR-95.

#### 4.1.3.2 Historical Resources

Several archeological surveys were conducted on the ORR in 1977 and 1996. Fielder, et al. (1977) and Duvall and Souza (1996) identified four historic structures (home sites) and a cemetery in the vicinity of the WWSY candidate site. None of these structures remain standing today, and none were found to be eligible for the National Register of Historic Places.

Hembree Cemetery is a family cemetery that contains five marked graves and 12 graves marked only with field stones. The earliest birth date recorded is 1777 and earliest date of burial is 1854 (Parsly 1985).

#### 4.1.3.3 Archeological Resources

There are no known prehistoric sites in the vicinity of the WWSY site (Fielder 1974; DuVall and Souza 1996).

## 4.2 DESCRIPTION OF WEST BEAR CREEK VALLEY CANDIDATE SITES

The following sections provide a description of WBCV Candidate Sites 8 and 14 and surrounding region, emphasizing those environmental attributes that could be affected by construction of a mixed waste landfill. The original WBCV site, shown as Candidate Site 8 in Figure D-2 crossed several stream and wetlands and was bisected by a high voltage power line and the Haul Road. These factors caused a re-evaluation which determined that a smaller area, identified as Candidate Site 14, lying between NT-14 and NT-15 and north of the Haul Road/power line would provide an adequate footprint with up to 2.8 million $yd^3$ of disposal capacity and reduce or avoid impacts to surface water and wetlands. Figure D-6 shows the conceptual footprints of Sites 8 (original footprint) and 14 (revised footprint). Most of the following description is equally applicable to Candidate Sites 8 and 14, but where necessary, is focused more upon Site 14.

### 4.2.1 Physical Characteristics

WBCV Candidate Site 14 conceptual footprint comprises approximately 55 acres located within the Bear Creek Valley watershed. The conceptual landfill footprint is approximately 0.5 mile east of SR-95. The site is bounded to the south by an east-west trending power line right-of-way and the existing Haul Road, to the east by tributary NT-14, to the west by NT-15, and to the north by the steep southern slope of Pine Ridge. The site is mostly forested and slopes moderately to the south. The WBCV site landfill footprint would lie between tributaries NT-14 and NT-15, and support facilities could be sited south, east, and west of the footprint.

A portion of this site was previously evaluated as the preferred site for the Low-level Waste Disposal, Development, and Demonstration (LLWDDD) Program Class L-II Tumulus Facility and underwent extensive characterization as part of that effort (Lietzke, et al., 1988, Walker and Saylor 1988). Soil and ground water sampling, monitoring, and research activities conducted for the LLWDDD Program provide significant data to support site evaluation. Based on these data, no contamination is present at the portion of the site studied under the LLWDDD Program.

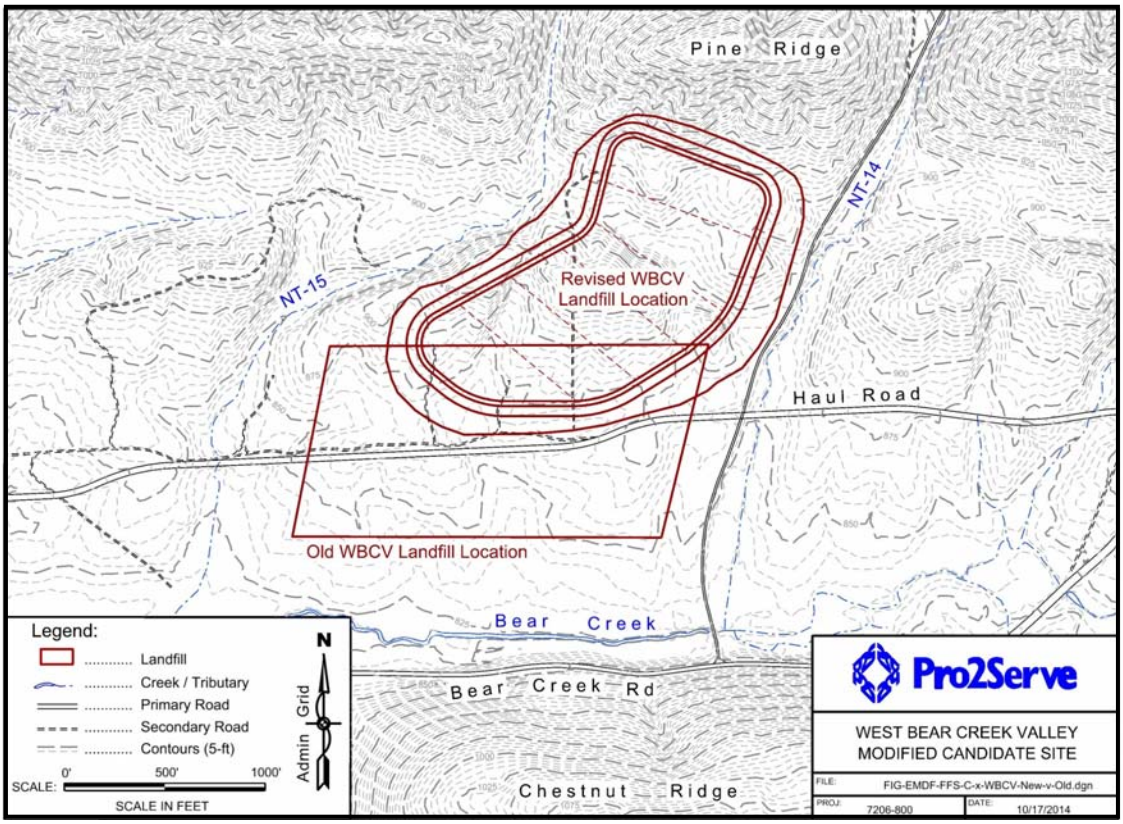



**Figure D-6. Conceptual Footprints of WBCV Sites 8 (Old) and 14 (Revised)**

#### 4.2.1.1 Topography

The WBCV site lies squarely on a spur ridge of extending from Pine Ridge. This ridge is underlain by units of the Maryville Formation and would have to be removed prior to construction of a landfill. The site is situated between NT-14 and NT-15, and NT-15 curves around the north side of the site. A small tributary, possibly a wet weather conveyance, originates in a broad shallow valley near the center of the site and flows southeast to NT-14. Rosensteel and Trettin (1993) identified two wetlands in this drainage basin.

NT-14 is a first order stream that cuts through Pine Ridge. The west side of the site is bounded by steep slopes into the NT-15 valley as well as a small tributary that flows to NT-15 from within the site. The NT-15 valley contains one relatively large and three smaller wetlands, while the small tributary arises from a small wetland. The north side of the site is bounded by the steep south flank of Pine Ridge, but the conceptual landfill footprint does not extend as far upslope as it does at the EBCV site.

#### 4.2.1.2 Geology

The geology and hydrogeology of the WBCV site is very similar to the EBCV site, three miles to the east in BCV. A more comprehensive overview of BCV geology and hydrogeology is provided in Appendix E.

WBCV is located in the upper plate of the Whiteoak Mountain thrust fault within the Valley and Ridge province of the southern Appalachian fold and thrust belt. The site is underlain by rock units of the Lower to Middle Cambrian Conasauga Group, consisting primarily of moderately to steeply dipping, weakly resistant calcareous shales and limestones. The Lower Cambrian Rome Formation underlies the Conasauga Group.

The Conasauga Group in BCV consists of six formations, five of which are sometimes mapped together as the Conasauga Shale (undivided). With the exception of the Maynardville Limestone, the Conasauga Group is a sequence of shale, siltstone, and thin-bedded limestone. Some formations, however, include laterally continuous limestone beds that can be several meters thick, and high permeability zones parallel to bedding planes may exist, especially where solution has enlarged fractures in limestone beds. The six formations in ascending order are the Pumpkin Valley Shale, Rutledge Formation, Rogersville Shale, Maryville Formation, Nolichucky Shale, and Maynardville Limestone (see Figure D-7). The orientation of geologic units is parallel and coincident to the valleys and ridges, varying locally from N47°E to N67°E. These erosionally beveled, conformable rock units dip between 23°–80° to the southeast.

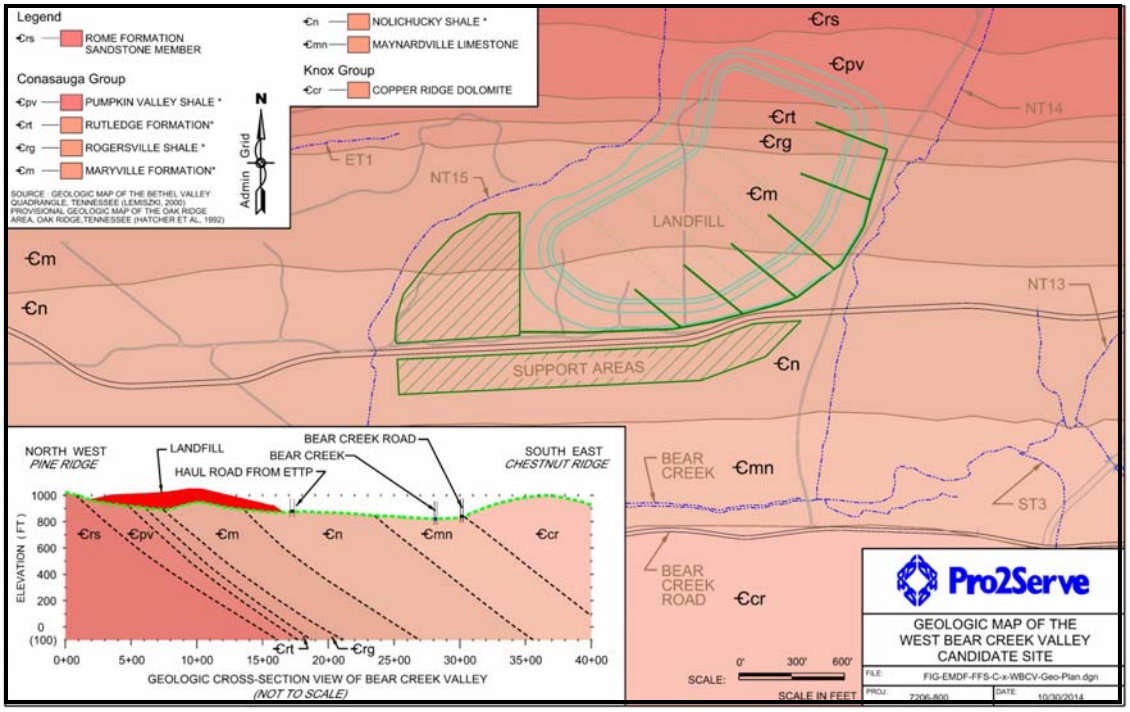



**Figure D-7. Geologic Map of the WBCV Candidate Site**

The WBCV site is on the hanging wall of the White Oak thrust fault, and like other areas of the ORR, site geology is structurally complex. On average, Conasauga strata dip 40°–50° to the southeast and strike northwest. Mesoscale folds are known to occur in the Pumpkin Valley and Maryville formations. There are at least two, and possibly three to four fracture orientations present at the site. The two major sets are perpendicular to bedding and nearly vertical. One set is oriented roughly parallel to strike, and the other is oriented roughly parallel to dip. Fractures are thought to be relatively short but closely spaced, with spacing and length dependent on bed lithology and thickness. Tear faults had been postulated as responsible for controlling the locations and orientations of Bear Creek north tributaries. Lee and Ketelle (1989) examined this theory, and reported that features indicative of faulting were not clearly evident in cores and exploration pits and trenches. They concluded that the presence of a tear fault or faults could not be conclusively demonstrated at the WBCV site.

There is no evidence of active seismically capable faults in the vicinity of the WBCV candidate site.

### 4.2.1.3 Surface Water

Bear Creek is the predominant surface water feature in WBCV. Bear Creek is a second- or perhaps third-order stream in this area. It originates at the west end of the Y-12 Plant and flows west before turning north through a water gap in Pine Ridge to join EFPC near the ETTP. The re-oriented WBCV site lies between Bear Creek tributaries NT-14 and NT-15. Bear Creek in the vicinity of the WBCV candidate site and the lower reaches of nearby tributaries exhibits base flow supported by ground water inflow, while high stage flow and flow in the upper reaches of tributaries appear to be largely storm-driven.

Southworth, et al. (1992) reports hydrologic data for seven stations near the WBCV site: Bear Creek Kilometer (BCK) 4.55, BCK 4.70, BCK 5.15, BCK 6.24, and BCK 7.87, as well as NT-14 and NT-15. Discharge volume increases from a mean of about 60–120 gallons per minute (gpm) at BCK 6.24, upstream from the WBCV site, to 732–1,320 gpm at BCK 4.70, immediately downstream, for the measurement period 1985–1987. Discharge increases to 1,640 to 1,760 gpm at BCK 4.55 for the same

measurement period, largely due to contributions from springs SS7 and SS8. Portions of Bear Creek above BCK 4.55 are losing reaches, with water being lost to the bedrock flow system. One result is that BCK 4.70 experiences occasional periods of zero flow, while some reaches upstream of this point do not.

Average annual flow rates for NT-14, based on three years (1985–1987) of weekly measurements, ranged from 0.14 cfs (63.4 gpm) to 0.27 cfs (120.5 gpm). NT-14 maximum flow volumes ranged from 0.64 cfs (287 gpm) in 1985 to 4.4 cfs (1,975 gpm) in 1987. NT-15 flow data are available only for 1987, which had an average discharge of 0.1 cfs (42.8 gpm) and a maximum of 5.0 cfs (2,244 gpm). The fact that NT-5 had a higher maximum discharge than NT-14 is interesting, since the drainage area of NT-15 (0.12 $mi^2$) is less than half that of NT-14 (0.3 $mi^2$). Both experience periods of zero flow during late summer and fall (Southworth, et al. 1992). Robinson and Johnson (1996) and Southworth, et al (1992) both reported that NT-14 and NT-15 were dry during periods of low base flow.

Paar and Hughes (2006) and Robinson and Johnson (1996) identified numerous springs and seeps in the vicinity of the WBCV site, some of which occur within the conceptual CERCLA disposal facility and work area footprint. Many of the springs flowed only during periods of high base flow, while others flowed during both high and low base flow periods (Robinson and Johnson 1996). Most seeps that are upslope from Bear Creek were not observed to exhibit flow at any time (Robinson and Johnson 1996).

#### 4.2.1.4 Ground Water

The saturated zone hosts a complex set of flow regimes. The water table, which defines the top of the saturated zone, may occur above, at, or below the soil-bedrock boundary, depending on season, weather conditions, and topographic position. Most of the ground water flow occurs in fracture systems in the upper few 10s of feet of bedrock and the lower part of the weathered soil zone. No dissolution features, such as epikarst or open conduits, were reported by Lee and Ketelle (1989). Fracture aperture decreases with greater depth and flow is restricted accordingly until it essentially ceases. A brackish to saline aquaclude occurs at a depth of greater than 300 ft in BCV (Solomon, et al. 1992; Moore 1988). The aquaclude is thought to represent the boundary at which flow ceases, but data are not sufficient to confirm this conclusion.

With the exception of the Maynardville Limestone and the Knox Group, rocks at the WBCV site are relatively low in calcium carbonate and are classified as aquitards, with ground water flow and discharge being relatively less than in the open conduits of the adjacent Maynardville and Copper Ridge aquifers. The orientations of well-connected fractures are predominantly parallel to bedding planes (i.e., geological strike). This results in flow anisotropy such that flow along strike is less impeded than flow along or across bedding (dip) planes.

Ground water at the candidate site ranges from less than 5 ft deep to greater than 40 ft deep. Ground water movement is relatively slow with discharge in the southern portion of the site to Bear Creek. Flow in the Rutledge and Rogersville Formations probably moves laterally to the tributaries as topography and the dominance of bedding-plane and strike-parallel fractures would suggest.

### 4.2.2 Ecological Characteristics

The WBCV candidate site, including potential support areas, encompasses upland mixed deciduous forests, riparian habitat along Bear Creek and its tributaries, and potentially some wetlands. The waste unit footprint and support areas are mostly on uplands, but may include small potential wetland and riparian areas. These habitats, suitable for wildlife, reflect the diversity of environments found throughout ORR.

#### 4.2.2.1 Sensitive Habitats

Three natural areas have been identified in the vicinity of the WBCV (Pounds, et al. 1993). These include ANA-2, NA-13, and Habitat Area (HA)-7.

- ANA-2 – In the WBCV area, ANA-2 encompasses Bear Creek and most of NT-14. Bear Creek in this area is bordered by a mature deciduous forest, with numerous small wetland areas.
- NA-l3 – Pine Ridge Wetlands is at or immediately upstream of the WBCV area and includes Bear Creek tributary bottoms and surrounding upland areas.
- HA-7 – An area that contains plant species that may be commercially exploited.

Figure D-8 is a map of the natural areas that occur near the WBCV site.

The Bear Creek stream bottom near WBCV is moderately rocky with areas of sand and silt deposition. Relatively little aquatic vegetation is present, but localized algal mats were observed at station BCK 7.87 (Southworth, et al. 1992). Six species of fish were documented at BCK 7.87, and none of these are intolerant of poor water quality (Southworth, et al. 1992), indicating that species diversity is limited as a result of contaminants from upstream. The Tennessee dace (*Phoxinus tennesseensis*), listed in Tennessee as a species In-need-of-management, was present at the BCK 7.87 sampling site (Southworth, et al. 1992). The invertebrate species count and density was similar to reference sites outside of the ORR (Southworth, et al. 1992).

Wetlands on ORR were surveyed in 1990 and identified using National Wetlands Inventory maps and field surveys (Cunningham and Pounds 1991, Rosensteel and Trettin 1992). One major wetland, Pine Ridge Wetland (NA-13) was identified along Bear Creek upstream from the WBCV candidate site, and broadly includes the headwater areas of NT-9, NT-10, NT-11, NT12, and NT-13). NA-13 is described as palustrine (non-tidal wetlands dominated by trees, shrubs, or persistent emergent vegetation), forested, and temporarily flooded (Parr 2011b, Baranski, 2009). Rosensteel and Trettin (1992) identified eight smaller wetlands in the general vicinity of the WBCV site, several of which would or could be impacted by landfill construction and operations. Figure D-8 shows the locations of these wetlands. In the event the WBCV site is selected for further development, a formal wetlands delineation survey and other detailed design considerations would be used to determine the extent of impacts.

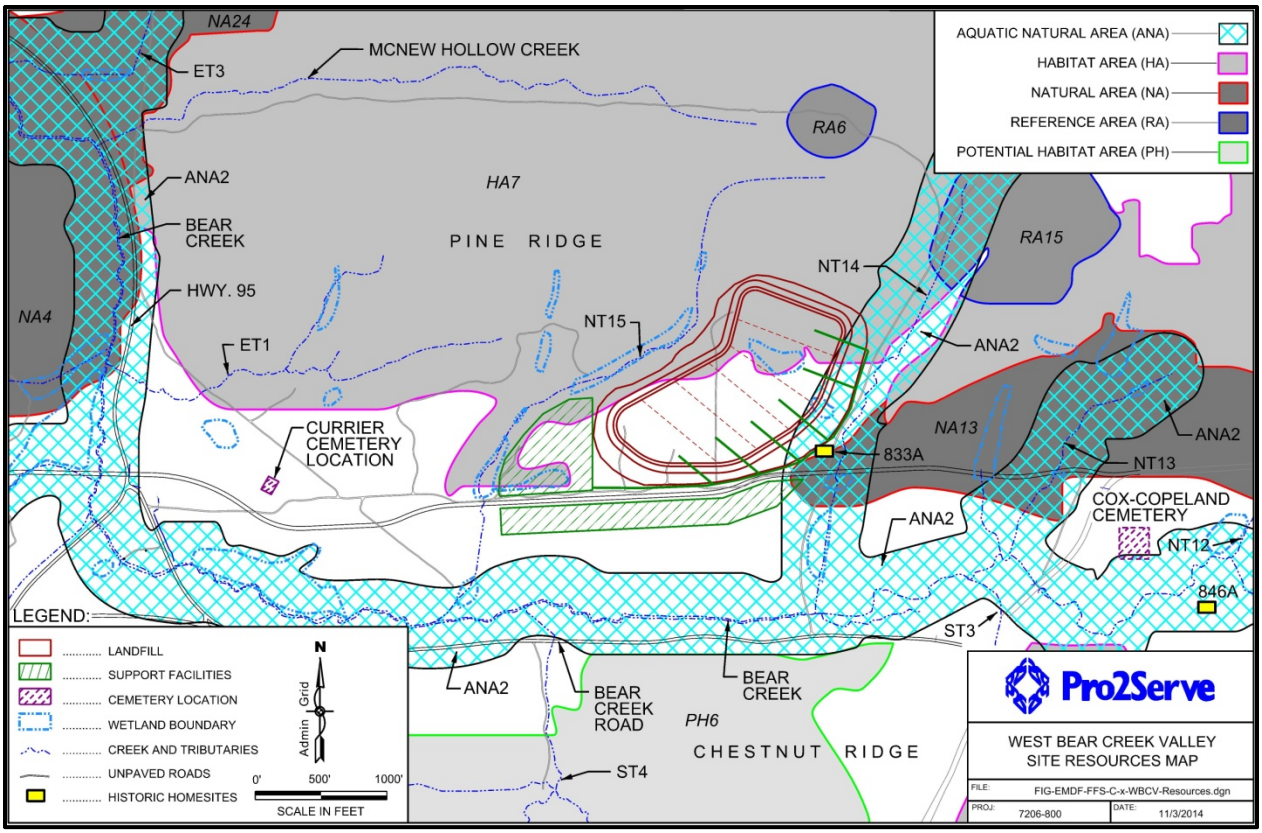



**Figure D-8. Map of WBCV Ecological, Wetland, and Cultural Features**

### 4.2.2.2 Status Species

The following two listed species have been reported from the WBCV candidate site location:

- The Tennessee dace, found in Bear Creek (ANA-2) and other waters on the ORR, is a Tennessee-listed In-need-of-management species.
- The northern harrier (*Circus cyaneus*) is a Tennessee-listed In-need-of-management species that probably only occurs on the ORR during annual migrations. It is not known to nest on ORR.

Based on existing surveys, at least the following listed plants are found within potentially impacted areas near the WBCV site:

- Canada lily (*Lilium canadense*), found in many areas on ORR, including NA-13, is listed as a threatened species in Tennessee.
- Tuberculed rein-orchid (*Platanthera flava* var. *herbiola*) is a Tennessee threatened species found in NA-13.

### 4.2.3 Cultural Characteristics

There are currently no residential, commercial, or industrial areas within 1 mile of the WBCV candidate site. One cemetery and six to eight probable home/farm sites were present in BCV between SR-95 and NT-14 prior to World War II. The current DOE patrol road paralleling NT-14 is shown on U.S. Geological Survey (USGS) topographic maps as a county road prior to World War II.

#### 4.2.3.1 Current Land Use

The WBCV candidate site is roughly 1.7 mile southwest of the closed BCBG and 3,000 ft from SR-95. The WBCV site is occupied and surrounded by undeveloped wooded land owned by DOE. The current land use classification for the site is *Unrestricted Use,* though DOE has no plans to release this land for public or private use.

#### 4.2.3.2 Historical Resources

Two sites of historic significance occur in the vicinity of WBCV candidate sites 8 and 14. These include one foundation and one cemetery (see Figure D-8). Two other pre-World War II sites, the Cox Cemetery and home site 846A, are located east of NT-13, outside of the probable operational footprint for the revised WBCV site. A second structure is shown on the 1941 USGS topographic map closer to the confluence of NT-14 with Bear Creek; this structure is not mentioned in DuVall and Souza (1996).

The remnant foundation of one structure (site 833A) is located adjacent to NT-14 just north of the Haul Road (Fielder, et al. 1977, DuVall and Souza 1996). Duvall and Souza (1996) described this site as containing scattered stones and bricks, possibly the remnants of a chimney or foundation piers, and a depression that may have been a cellar. Fielder et al. (1977) noted that the site had a foundation of undetermined function. This site is not eligible for listing on the National Register of Historic Places. Two family cemeteries are in the vicinity of the WBCV site. Currier Cemetery is located west of the WBCV site and cemetery contains six inscribed grave markers and about 40 graves marked with fieldstones. Cox-Copeland Cemetery is east of the WBCV site and contains five inscribed grave markers and 28 graves marked only with field stones (Parsly 1985).

#### 4.2.3.3 Archeological Resources

There are no known prehistoric sites in the vicinity of the WBCV site (Fielder 1974, DuVall and Souza 1996).

### 4.3 DESCRIPTION OF EAST BEAR CREEK VALLEY CANDIDATE SITE

The following sections provide a description of the EBCV Candidate Site 5 and its surrounding region, emphasizing those environmental attributes that could be affected by construction of an on-site landfill. A much more detailed appraisal of EBCV Candidate Site 5 conditions is provided in Appendix E.

#### 4.3.1 Physical Characteristics

EBCV Candidate Site 5 is immediately east of the EMWMF, and is bounded on the north by Pine Ridge, the east by the valley of NT-2, and the south by the Haul Road.

#### 4.3.1.1 Geology and Soils

The geology and hydrogeology of the EBCV site is very similar to the WBCV site, three miles to the west in BCV. A more comprehensive overview of BCV geology and hydrogeology, and the EBCV site in specific, is provided in Appendix E.

Like the WBCV site, the EBCV candidate site is located in the upper plate of the Whiteoak Mountain thrust fault within the Valley and Ridge province of the southern Appalachian fold and thrust belt. The site is underlain by rock units of the Lower to Middle Cambrian Conasauga Group, consisting primarily of moderately to steeply dipping, weakly resistant calcareous shales and limestones. The Lower Cambrian Rome Formation underlies the Conasauga Group.

The Conasauga Group in the BCV consists of six formations, five of which are sometimes mapped together as the Conasauga Shale (undivided). With the exception of the Maynardville Limestone, the

Conasauga Group is a sequence of shale, siltstone, and thin-bedded limestone. Some formations, however, include laterally continuous limestone beds that can be several meters thick, and high permeability zones parallel to bedding planes may exist. The six formations in ascending order are the Pumpkin Valley Shale, Rutledge Formation, Rogersville Shale, Maryville Formation, Nolichucky Shale, and Maynardville Limestone (see Figure D-9).

The EBCV site is on the hanging wall of the White Oak thrust fault, and like other areas of the ORR, site geology is structurally complex. On average, Conasauga strata dip 40° to 50° to the southeast and strike northwest. Mesoscale folds are known to occur in the Pumpkin Valley and Maryville formations. There are at least two, and possibly three to four fracture orientations present at the site.

There is no evidence of active seismically capable faults in the vicinity of the EBCV candidate site.

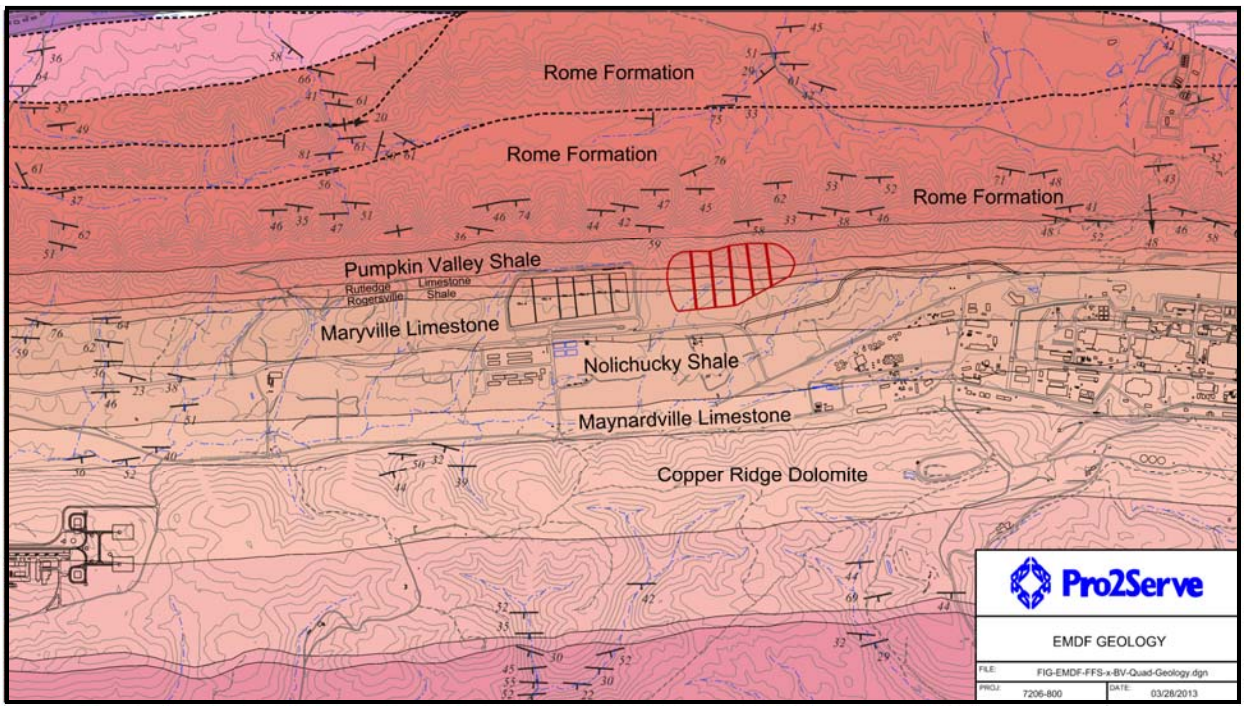



**Figure D-9. Conceptual Footprint of EBCV Site 5 and Surrounding Geology**

### 4.3.1.2 Surface Water

NT-3 and NT-2 are the predominant surface water features at the EBCV site. Both streams are first-order headwater streams that originate on the flank of Pine Ridge and flow to Bear Creek. These tributaries exhibit base flow supported by ground water inflow, while high stage flow and flow in the upper reaches of tributaries appear to be largely storm-driven. Both streams experience periods of little or no flow, and both have gaining and losing reaches within the EBCV area (Robinson and Mitchell 1996).

There are at least four springs and seeps in the NT-3 watershed, and two or three seepage areas in the NT-2 watershed above the Haul Road. These are low-flow features that are often dry in the late summer months.

Flow rate data are limited. Robinson and Johnson (1996) report NT-3 flow rates on the order of 0.01–0.04 cfs for a one week wet season measurement period, and dry conditions for a one week dry

season measurement period in 1994. For NT-2, the wet season flow rate varied from 0.01 to 0.15 cfs, and the dry season flow was zero, for the same measurement periods as for NT-3 (Robinson and Johnson 1996).

Data available in the OREIS for an NT-3 measurement station just below the Haul Row indicate an average flow rate of 0.2 cfs and a maximum of 1.6 cfs for an 18-month period in 2010 and 2011.

#### 4.3.1.3 Ground Water

The stratigraphic units underlying the EBCV site are dominantly clastic (siltstones and shales) with relatively low in calcium carbonate content. Ground water storage and flow occurs primarily in fractures, and as a result, these units are classified as aquitards. This fracture system exhibits pronounced flow anisotropy in which flow paths along strike are more well developed than flow paths along or across bedding (dip) planes.

The water table at the EBCV was found to occur above, at, or below the soil-bedrock boundary, depending on season, weather conditions, and topographic position. Most of the ground water flow occurs in fracture systems in the upper few 10s of feet of bedrock and the lower part of the weathered soil zone. No dissolution features, such as epikarst or open conduits, were observed in cores or drilling for the Phase I Limited Site Characterization (see Appendix E). Fracture aperture, and hence, hydraulic conductivity, decreases with greater depth and flow is restricted accordingly until it essentially ceases.

The Phase I Limited Site Characterization (see report in Appendix E) found that depth to ground water at the EBCV candidate site ranges from less than 5 ft to greater than 40 ft, depending on topographic position. Ground water movement is relatively slow with discharge in the southern portion of the site to Bear Creek. Shallow ground water responds rapidly to rainfall.

### 4.3.2 Ecological Characteristics

The EBCV candidate site, including potential support areas, encompasses upland mixed deciduous forests, riparian habitat along Bear Creek and its tributaries, and several wetlands. Prior to a down-burst event in May 2013, the EBCV site was covered with a mature upland deciduous hardwood forest, and crossed by two intermittent streams. Several springs, and seeps, and small upland wetlands also exist within the site.

#### 4.3.2.1 Sensitive Habitats

Area ANA-2, Bear Creek, extends from SR-95 to the confluence of NT-3. No portion of the EBCV site is expected to directly impact ANA-2.

Aquatic resource data are available for two stations along Bear Creek near the EBCV site. The Bear Creek stream bottom near EBCV is moderately rocky with areas of sand and silt deposition. Four species of fish were documented at BCK 11.83 (at the confluence of NT-3) and three species were observed at BCK 12.36, (near the confluence of NT-2). None of the observed species are intolerant of poor water quality (Southworth, et al. 1992), indicating that species diversity is limited as a result of contaminants from upstream. The Tennessee Dace (*Phoxinus tennesseensis*), listed in Tennessee as a species In-need-of-management, was present at both sampling sites (Southworth, et al. 1992). The invertebrate species count and density was found to be lower than at the WBCV site, an indication of the impact of contaminants entering the Bear Creek headwaters (Southworth, et al. 1992).

A formal wetlands delineation survey was completed for the EBCV site and results are summarized in Appendix E. Reference Area 5 (RA-5) encompasses an approximately one-acre (0.5 ha) wetland known as the Quillwort Temporary Pond. This wetland was created by the presence of a restrictor plate on the NT-3 culvert under the Haul Road that backs up NT-3 to form a ponded area. A second small (0.04-acre)

wetland was also noted near the head of NT-3. Both of these wetlands would be destroyed by landfill construction.

Portions of two wetlands on tributaries of NT-2 would likely be affected if the EBCV site is selected and built. Both wetlands have been extensively modified and enlarged as part of recent construction of the Uranium Processing Facility Haul Road. Neither of these appears to have contained listed species (Rosensteel and Trettin 1993; Giffen, et al. 2009).

#### 4.3.2.2 Status Species

The Tennessee Dace, found in Bear Creek (ANA-2) and other waters on the ORR, is a Tennessee-listed In-need-of-management species. The weir on Bear Creek has created a large population of Tennessee Dace in Bear Creek by blocking upstream movement of predators and competing species. This species requires clean gravel substrate for successful breeding.

Available data do not indicate that any federal- or state-listed plants species are present in or near the EBCV candidate site. The Haul Road culvert is an effective barrier to upstream migration of small fish, such as the Tennessee Dace, and because NT-3 upstream from the Haul Road is periodically dry, no fish population would be expected.

### 4.3.3 Cultural Characteristics

The EBCV candidate site is in and adjacent to industrial use areas, including Y-12 industrial facilities and several former (legacy) and active (EMWMF) waste management facilities.

#### 4.3.3.1 Current Land Use

The EBCV candidate site is roughly 0.9 mile east of the closed BCBG and 4.15 miles (6.7 km) from SR-95. The EBCV site is occupied and surrounded by undeveloped wooded land owned by DOE. The current land use classification for the site is *Industrial Use*. DOE has no plans to release this land for public or private use.

Two isolated current rural residences on East Fork Ridge are within 2 km (1.25 miles) of the EBCV candidate site. A recently developed subdivision, Groves Park Commons, fronting Tuskegee Drive, is also within 2 km of the center of the EMDF site and approximately 0.9 km (0.57 mile) from the main Y-12 industrial area.

#### 4.3.3.2 Historical Resources

Six probable home/farm structures are shown in BCV between NT-4 and Bear Creek-East Fork Poplar Creek drainage divide on the 1941 USGS Bethel Valley 7.5-minute topographic quadrangle map (130-E). The majority of these structures were on the valley floor relatively close to Bear Creek. DuVall (1998) conducted a survey of the EBCV area and found no indication of historic structures. There is no indication of significant agricultural activity in the footprint area prior to World War II, and the site has not been used for any industrial purpose since Y-12 was originally constructed.

#### 4.3.3.3 Archeological Resources

Shovel tests conducted by DuVall (1998) showed no evidence of prehistoric artifacts in the vicinity of the EBCV site (DuVall 1998).

## 4.4 DETAILED SCREENING ANALYSIS

The remaining four candidate sites were evaluated against three CERCLA screening criteria: Effectiveness, Implementability, and Cost. Each of the three CERCLA criteria were sub-divided into sub-criteria for ease of evaluation. Sub-criteria were designed to eliminate sites from further consideration only when either multiple sub-criteria combined to render a site unfavorable for development, or there were particularly significant issues associated with a single sub-criterion. These sub-criteria generally represent concerns that would need to be addressed for areas carried forward as final candidate sites, rather than a basis for elimination. An explanation of the sub-criteria is provided below:

- **Effectiveness and Implementability**
  - **Location and Access:** Location is a significant consideration for protection of human health and environment. It is closely related to current and future land use. Public access and viewscape is an allied consideration. In addition, transportation of waste to the site, and ability to access the site (e.g. the use of public roads, required modifications for access) must be examined in a relative fashion and may affect relative cost. Security of the site is an issue, since classified wastes will be disposed. The ability of the site to be secured long term is also a consideration under this criteria.
  - **Land Use:** Current and future land use qualifications for a site are a significant consideration, especially in terms of protection of human health. This is closely linked with buffer zone considerations. For example, a brownfield area is much more desirable for use as a landfill than as a greenfield area. Areas that are planned for possible future recreational use would be much less desirable than areas under future industrial use zoning, a position that has been stated by the Oak Ridge Site Specific Advisory Board (ORSSAB).
  - **Buffer Zones:** Buffer zones include those associated with geographic areas and geologic conditions. Requirements for geologic buffers underlying landfills were not used as a basis to defer candidate sites from further evaluation because these buffers can be engineered to provide "equivalent or superior protection." Strict application of these requirements in the screening phase of the process would result in premature elimination of otherwise viable locations.
    - Tennessee Department of Environment and Conservation (TDEC) Division of Solid Waste Management buffer zone standards for proximity to constructed appurtenances, property lines, residences, and wells (TDEC 0400-11-01-.04[3]) are met by all sites considered here.
    - The geographic buffer of 200 ft (TDEC 0400-11-01-.04[3][a][4]) from the normal boundaries of springs, streams, lakes, and other bodies of water (does not apply to wet weather conveyances) may, for some sites, be reasonably engineered to provide equivalent protectiveness and was therefore not considered a preliminary screening requirement. However, a waiver of this requirement would be needed, and is considered to be achievable based on a design achieving equivalent protection.
    - TDEC land disposal requirement for radiological waste (0400-20-11-.17[1][h] that states a hydrogeologic unit used for disposal shall not discharge ground water to the surface within the disposal site will be met through engineered features, but will require a waiver based on equivalent protectiveness.
    - The Toxic Substance Control Act geologic buffer requirement (CFR 761.75[b][3]) that the waste be at least 50 ft above mean high water table was not considered a detriment because, although a buffer of such thickness may not reasonably be constructed, a waiver of this requirement is considered to be achievable on the basis of the design achieving

equivalent protection. U.S. Environmental Protection Agency Region IV has granted this waiver elsewhere because it typically cannot be achieved in the southeastern states.

- **Disposal Capacity:** The ability of a site to provide sufficient disposal capacity for all waste is a major consideration under Implementability. This sub-criterion is different from the initial screening criterion of sufficient area in that it considers volume, as opposed to footprint area. DOE M 435.1 requires that disposal facilities be located and sized to accommodate the projected volume of wastes to be received.
- **Site Contamination:** Existing site contamination could lead to issues regarding the ability to properly monitor a site during operations and post-closure and/or excessive costs involved in site preparations (e.g., to remediate the site prior to use). On the other hand, use of a previously contaminated brownfield area may be considered beneficial if the added contaminant burden is small or negligible, and if risk reduction is achieved in other locations.

- **Relative Cost:**
  - **Cost:** This is an important consideration that can, if the differential is significant, ultimately determine the feasibility of one site over another. At this stage, the costs are relative, one site to another, based on the activities believed to be necessary to implement the option.

An explanation of the screening analysis for each site follows. At the end of the discussion, Table D-5 provides a brief summary of the findings, along with a semi-quantitative rating to aide in differentiating between the sites.

### 4.4.1 WWSY Candidate Site Screening Analysis

The WWSY candidate site is eliminated from further consideration on the bases of effectiveness, implementability, and cost relative to other ORR sites of interest.

#### 4.4.1.1 Effectiveness

The WWYS candidate site is positioned on a low knoll, which should prevent lateral ground water in-migration and, once the final cap is in place, allow more effective reduction of infiltration.

The WWSY candidate site would be less effective in protecting human health and the environment than other sites being considered. From the human health perspective, the site is close to the publicly accessible SR-95. This not only brings the public in close proximity to the site, but reduces the land buffer to the extent that security becomes a major concern. Further, the narrow buffer offers little room for managing a release, should one occur.

Given that the WWSY site is on a low knoll, ground water under the site is likely to flow in a quasi-radial pattern, such that contaminants could surface in ET-3, ET-4, or Bear Creek, or all three. These features are only a short distance from the candidate site. This increases the risk that contaminants rapidly affect surface waters and enter public areas. It also greatly complicates remedial actions.

Finally, the complex geology of the site greatly increases the complexity of ground water monitoring and modeling. Potential karstic terrain is found immediately northwest of the candidate site. Accurate prediction of flow paths may not be possible.

#### 4.4.1.2 Implementability

There are no insurmountable engineering obstacles to be overcome at the WWYS site, although karst may be a potential issue for support areas located north of the Whiteoak Mountain Thrust Fault. There are no known karstic lithostratigraphic units at either the WBCV or EBCV sites. Direct impacts to streams and

wetlands at the WWSY site should be mitigated by proper planning and implementation of storm water control systems.

There are few infrastructure resources currently available at or near the WWSY candidate site. The approximately two miles of existing gravel patrol roads that connect the site to the existing Haul Road via Gum Branch and McNew Hollow are light-duty forest tracks that would require substantial upgrades to be capable of handling heavy truck traffic. A second routing option involves constructing a connector between the Haul Road and the candidate site adjacent to S-95. This route would require excavation and removal of a large slice at the south end of Pine Ridge to provide a level alignment in the Bear Creek water gap. This route would place waste haulers adjacent to private traffic on SR-95, with the attendant risk of accident and exposure.

No power or water utilities currently serve the site and these would have to be constructed. Water management structures (tanks, impoundments, piping) would need to be built to handle and treat, as necessary, leachate, sewage, and storm water. Other infrastructure, such as scales, office space, parking, and maintenance would need to be constructed. A fence surrounding the landfill and its support facilities would have to be added and patrolled to prevent intrusion.

The WWSY candidate site is also adjacent to two wetlands that contain federal or state species of concern. Even assuming a well implemented storm water and sedimentation control plan, landfill construction, operation, and closure pose significant risks for damage to these plant and animal resources and water quality through siltation, dust, reduction of forest cover, and re-routing of surface water. Construction may disrupt ground water flow patterns such that springs and seeps are adversely affected, which would in turn impact wetlands. Landfill construction and operation at neither the WBCV nor the EBCV sites would impact species of concern, although some wetlands would be impacted. All three remaining sites would more or less permanently remove existing forest habitats, depending on the final cover selected for the landfill cap.

The expected future use of the WWSY area is *Recreational*. The area would need to be reclassified for *Controlled Industrial Use* if a landfill were sited at this location.

#### 4.4.1.3 Cost

Costs for constructing and operating a landfill at the WWSY candidate site would be significantly higher than for other sites being considered, primarily due to the lack of infrastructure, but also due to increased costs for security and waste transportation. Environmental monitoring costs would be higher because of the proximity of sensitive habitats and because ground water flow from the site may be radial.

### 4.4.2 WBCV Candidate Site Screening Analysis

WBCV Candidate Sites 8 and 14 are eliminated from further consideration on the bases of effectiveness, implementability, and cost relative to other ORR sites of interest.

#### 4.4.2.1 Effectiveness

The WBCV candidate sites would be slightly less effective in protecting human health and the environment during operations than the EBCV site being considered, but more effective than the WWSY site. From the human health perspective, the site is within 3,000 ft of the publically accessible SR-95, and therefore presents greater risk in the event of a loss of containment. The site may be visible from the road, but is sufficiently distant that routine operations would not pose a direct risk to traffic on SR-95.

WBCV Candidate Site 8 is close to Bear Creek and there would be a concomitantly increased risk that a contaminant release would impact the stream and the Maynardville karst system. Candidate Site 14 is farther from Bear Creek and ground water flow paths are correspondingly longer. This may, to some

extent be offset by the presence of NT-14 (Gum Branch), which, because of ground water flow anisotropy, may be the surface water receptor for releases from a landfill.

The southern edge of the Candidate Site 8 footprint may be within the 500-year floodplain (this would be determined during design), but Candidate Site 14 is well outside the 500-year floodplain.

There are no known karstic lithostratigraphic units beneath the WBCV footprint, but the karstic Maynardville Limestone underlies Bear Creek south of the site. The Option 8 footprint lies primarily on Maryville and Nolichucky formation rocks, both of which contain limestones (Lee and Ketelle 1989). Drilling in EBCV has shown that the contact between the Nolichucky and Maynardville formations is highly prone to conduit development, and that cavities have been encountered in wells drilled in the Nolichucky Shale. The Option 14 footprint lies on Rutledge, Rogersville, Maryville, and Nolichucky formations, and is thus preferred over Option 8.

#### 4.4.2.2 Implementability

Infrastructure resources, including the Haul Road and power line, are currently available at the WBCV candidate site, but it lacks the office space, water handling, and other resources available at the EBCV site. Both the Haul Road and power line right of way would require realignment to accommodate landfill construction for the Option 8 conceptual footprint, but not for the Option 14 footprint. The spur ridge near the center of the revised WBCV site (Option 14) would have to be excavated and suitable overburden material stockpiled for reuse.

The WBCV Option 8 candidate site is north of one wetland, NA-13, and Bear Creek which contain federal or state species of concern, and the revised site, Option 14, encompasses or bounds seven other wetlands that have not been fully delineated. While landfill construction and operation should not significantly impact the NA-13 wetland, construction, operation, and closure may pose significant risks for damage to Bear Creek water quality through siltation and re-routing of surface water. Wetlands along the NT-14 tributary and along NT-15 and it east tributary would be destroyed or adversely impacted by landfill construction and operation at the Option 14 site. Landfill construction and operation at the WBCV site would have lower potential to impact sensitive ecological resources than at the WWSY site, and would have similar or greater impacts to sensitive biological resources than the EBCV site. Impacts to the NA-13 wetlands could be avoided through appropriate support area design and implementation of storm water management practices during construction and operation. Impacts to other wetlands could not be avoided. Use of the WBCV site would remove existing forest habitats, depending on the final cover selected for the landfill cap; this impact is essentially the same for all three sites.

Direct impacts to streams and wetlands at WBCV Option 8 site during construction and operation should be mitigated by proper planning and implementation of storm water control systems. Construction of conceptual site Option 14 would eliminate two tributaries and two adjacent streams would have to be re-channeled or re-routed. The overall site topography is less steep than at the EBCV site. The NA-13 wetland is almost entirely upstream from the site, so should experience little direct impact.

The WBCV candidate sites are within the future *Unrestricted Use* land zoning, and placement of a permanent waste management unit at this location would effectively change the land use for the area between SR-95 and the Y-12 Plant to *Controlled Industrial Use*, to remain under permanent DOE control.

#### 4.4.2.3 Cost

Costs for constructing and operating a landfill at the WBCV candidate site would be higher than for the EBCV Candidate Option 5 site, due to the lack of infrastructure, the need to remove large volumes of soil and rock, as well as due to increased costs for security and waste transportation from Y-12. Environmental monitoring costs should be similar to the EBCV site.

### 4.4.3 EBCV Candidate Site Screening Analysis

The EBCV candidate site is retained as a potential candidate site on the bases of effectiveness, implementability, and cost relative to other ORR sites of interest.

#### 4.4.3.1 Effectiveness

The EBCV candidate site appears to be slightly more effective in protecting human health and the environment than the WBCV candidate sites during operations, but considerably more effective than the WWSY site. The EBCV site is approximately six miles from SR-95 and 0.6 mile from the DOE boundary with the City of Oak Ridge. It is in a *Controlled Industrial Use* area that will be retained and managed by DOE for the foreseeable future due to the presence of historic and active waste management sites. The EBCV area is also within the Y-12 security envelope, reducing the chances for inadvertent intrusion as compared to the other sites considered.

The EBCV candidate site would destroy or adversely impact two to four wetlands. It would not impact any listed/threatened plant or animal species. Landfill construction and operation at the EBCV site would have greater potential to impact sensitive ecological resources than the WBCV site, but less than at the WWSY site. Because much of the existing forest at the EBCV site was destroyed by natural forces, there are correspondingly fewer impacts than at either the WBCV or WWSY sites.

The EBCV candidate site is situated on fine-grained clastic bedrock units, including the Pumpkin Valley, Rutledge, Rogersville, and lower Maryville formations. These units are less prone to cavity/conduit development than the carbonates of the Maynardville Limestone and Copper Ridge Dolomite to the south.

#### 4.4.3.2 Implementability

The EBCV site presents several challenges. First, the site will require an extensive underdrain to manage and divert near-surface ground water (springs, seeps, and NT-2 and NT-3) and maintain low water table elevations. Second, in the conceptual design, a small portion of the NT-3 watershed on the upper slopes of Pine Ridge will remain, and a French drain and ditch will be needed to convey surface water around the landfill. Finally, portions of the landfill and cap will abut the steep sides of Pine Ridge, and care must be exercised to prevent mass wasting during construction and operation; this will not be an issue after landfill closure. All of these issues are well within current engineering capabilities and practice.

There are no known karstic lithostratigraphic units beneath the WBCV footprint, but the karstic Maynardville Limestone underlies Bear Creek 1,500 ft south of the site.

NT-3 and NT-2 will be directly impacted by landfill construction. The main (east) branch of NT-3 would be entirely covered by the landfill, as would some smaller branches of NT-2 and NT-3. Four to six springs and seeps would also be covered. Direct impacts to streams and wetlands outside the landfill area should be mitigated by proper planning and implementation of storm water control systems.

Utilities, office space, water handling, and other infrastructure are currently available at the EMWMF and limited modifications would be required to make these available to the EBCV site. The EBCV site is within the *Controlled Industrial Use* zone, and would thus be under the permanent control and stewardship of DOE. There would be no change of land use designation.

The EBCV site is adjacent to brownfield areas that encompass legacy burial sites and the active EMWMF. In general, public opinion as represented through the ORSSAB, has indicated that placement of a new landfill in a brownfield area is much preferred to placement in a greenfield area (see ORSSAB recommendations 180, 200, and 223, as well as discussions noted in meeting minutes for December 15, 2010, January 18, 2012, October 17, 2012, and February 19, 2014).

#### 4.4.3.3 Cost

Costs for constructing and operating a landfill at the EBCV candidate site would be lower than for WBCV Candidate Site 14, primarily due to the availability of infrastructure, but also due to decreased costs for security and waste transportation from Y-12. WBCV Candidate Site 8 costs would be higher than both WBCV Candidate Site 14 and EBCV Candidate Site 5 primarily due to the need to realign the Haul Road and power line. The cost differential between the EBCV site and the WWSY site is far greater than for either of the other sites.

### 4.4.4 Conclusion

A numeric evaluation of the WWSY, WBCV, and EBCV candidate sites presented in Table D-5 identified EBCV Option 5 as the preferred site to be used in the formal RI/FS alternatives analysis.

The WWSY site was found to be inferior to the other three sites, primarily because of its very close proximity to public areas, potential to impact sensitive species, and high development cost.

The two WBCV sites had similar rankings, with WBCV Option 8 and Option 14 differentiated primarily on implementation issues. WBCV Option 8 was not selected because of the high costs for rerouting the power line and Haul Road and its location on Maryville and Nolichucky formation bedrock. WBCV Option 14 was not selected because of the impacts to streams and wetlands and the requirements to remove large volumes of in-place soil and bedrock (i.e., the spur ridge). Both WBCV Options would require extensive infrastructure development. Other concerns relative to the WBCV site is that it is situated within a green field area intended for future *Unrestricted Use;* construction and operation of a landfill would require that the WBCV area future land use be re-designated as *Controlled Industrial Use* area (Zone 1). Further, the WBCV site would be the only site of its kind in the area. Finally, the proximity of the WBCV site to SR-95 increases the need and costs for security coverage.

The primary discriminators for preferring EBCV Option 5 are:

- Land use is Controlled Industrial and will remain so for the foreseeable future.
- The conceptual footprint is situated in a natural bowl (the NT-3 valley) and is buttressed by a spur ridge to the south.
- The conceptual landfill footprint is underlain by the Pumpkin Valley, Rogersville, Rutledge, and lower Maryville formations.
- Infrastructure is already present and can be re-used with minimal modifications.
- The site is within the Y-12 security envelope and is well isolated from public access.

Based on the above considerations, EBCV Option 5 is the preferred site for use in the formal CERCLA alternatives analysis.

**Table D-5. Comparison and Ratings for Four Final Candidate Sites**

| Screening Criteria | Sub-criteria | WWSY | WBCV Option 8 | WBCV Option 14 | EBCV Option 5 |
|---|---|---|---|---|---|
| **EFFECTIVENESS and IMPLEMENTABILITY** | **Location / Access** | • Visible to the public and within close proximity to SR-95.<br>• Very extensive infrastructure development required to provide access.<br>• The ability to provide security long term is inferior to the EBCV option due to the distance from other patrolled areas. | • Not visible to the public.<br>• Requires infrastructure construction/modification, but not as much as WWSY.<br>• The ability to provide security long term is inferior to the EBCV option due to the distance from other patrolled areas. | • Not visible to the public.<br>• Requires extensive soil/rock excavation, infrastructure construction, but not as much as WWSY or WBCV Option 8.<br>• The ability to provide security long term is inferior to the EBCV option due to the distance from other patrolled areas. | • Not visible to the public.<br>• Does not require additional non-public road(s) to be constructed to access the site. Existing infrastructure available.<br>• The ability to provide security long term is superior to other two sites due to the proximity to other patrolled areas. |
| | *Rating* | *1* | *3* | *3* | *5* |
| | **Land Use** | • Current and future land use is Unrestricted, although area will remain under DOE control within DOE ORR boundaries for the foreseeable future.<br>• Greenfield area; presence of a facility would definitely influence adjacent future developments.<br>• Approximate footprint 70 acres. | • Current and future land use is Unrestricted, although area will remain under DOE control within DOE ORR boundaries for the foreseeable future.<br>• Greenfield area; however, presence of a facility may not influence adjacent future developments.<br>• Approximate footprint 60 acres. | • Current and future land use is Unrestricted, although area will remain under DOE control within DOE ORR boundaries for the foreseeable future.<br>• Greenfield area; however, presence of a facility may not influence adjacent future developments.<br>• Approximate footprint 55 acres. | • Current and future land use is DOE - Controlled Industrial use.<br>• Oak Ridge Site-Specific Advisory Board recommends placement in brown field area.<br>• Brownfield area; presence of facility would very likely not influence adjacent future land development/use.<br>• Approximate footprint 50 acres. |
| | *Rating* | *2* | *3* | *4* | *5* |

**Table D-5. Comparison and Ratings for Four Final Candidate Sites (Continued)**

| Screening Criteria | Sub-criteria | WWSY | WBCV Option 8 | WBCV Option 14 | EBCV Option 5 |
|---|---|---|---|---|---|
| EFFECTIVENESS and IMPLEMENTABILITY | **Site Hydrology Features and Buffers** | • Contains seeps/springs in footprint..<br>• Site is adjacent to critical habitats.<br>• Requires Toxic Substance Control Act of 1976 (TSCA) 50 ft buffer waiver.<br>• Proximity to public via SR-95. | • Contains seeps/springs in footprint..<br>• Overlies Nolichucky & Maynardville formations.<br>• Requires TSCA 50 ft buffer waiver.<br>• Isolated from public. | • Contains seeps/springs in footprint..<br>• Impacts 7 wetlands and 4 small streams.<br>• Might require waiver to solid waste landfill requirement to maintain 200 ft buffer from stream.<br>• Requires TSCA 50 ft buffer waiver.<br>• Isolated from public. | • Crosses a tributary, contains seeps/springs in footprint..<br>• Impacts 5 wetlands and 3 small streams.<br>• Requires TSCA 50 ft buffer waiver.<br>• Isolated from public. |
| | *Rating* | *2* | *1* | *2* | *3* |
| | **Disposal Capacity** | • Meets disposal capacity needs. | • Exceeds disposal capacity needs. | • Exceeds disposal capacity needs. | • Meets disposal capacity needs. |
| | *Rating* | *4* | *5* | *5* | *4* |
| | **Site Contamination** | • Site is not thought to be contaminated by previous waste disposal practices; but a previous disposal site is adjacent and could affect ability to monitor the site. | • Site is not thought to be contaminated by previous waste disposal practices. | • Site is not thought to be contaminated by previous waste disposal practices. | • Site is not thought to be contaminated by previous waste disposal practices.<br>• Site is adjacent and upgradient of former and active waste management sites. |
| | *Rating* | *4* | *5* | *5* | *4* |
| **RELATIVE COST** | | • Relative cost is highest, due to extensive infrastructure (access roads and utilities installation) required. | • Relative cost is lower than WWSY, but higher than EBCV, due to relative differences for infrastructure installation (access roads and utilities) required. | • Relative cost is lower than WWSY, but may be lower than WBCV Option 8. Cost expected to be higher than EBCV. | • Relative cost of implementation is least, because existing infrastructure can be used. |
| *Rating* | | *2* | *4* | *4* | *5* |
| ***Ratings Total*** | | ***15*** | ***21*** | ***23*** | ***26*** |

Rating key: *0. Not applicable / 1. Worst/Least / 2. Worse/Less / 3. Average/Neutral / 4. Better/More / 5. Best/Most*

# 5. REFERENCES


Boegly, W.J., Jr. and Moore, G.K. 1988. *Environmental Data Package for the White Wing Scrap Yard (WAG 11)*. ORNL/RAP-45.

Cunningham, M., and L. Pounds. 1991. *Resource Management Plan for the Oak Ridge Reservation*. *Volume 28: Wetlands on the Oak Ridge Reservation*. ORNL/NERP-5, Oak Ridge, TN.

DOE 1996. *Identification and Screening of Candidate Sites for the Environmental Management Waste Management Facility, Oak Ridge, Tennessee*. DOE/OR/02-1508&D1.

DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2.

DOE 2000. *Record of Decision for the Phase I Activities in Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.* DOE/OR/01-1750&D4.

DOE 2008. *Oak Ridge Reservation Planning: Integrating Multiple Land Use Needs*. DOE/ORO/01-2264.

DOE 2011. *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex.* DOE/EIS-0387.

DuVall, G.D. and Souza, P.A. 1996. *An Evaluation of the Previously Recorded and Inventoried Sites on the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-4964.

Fielder, G.F. Jr., 1974. *Archeological Survey with Emphasis on Prehistoric Sites of the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-4694.

Fielder, G.F. Jr., Ahler, S.R., and Barrington, B. 1977. *Historic Sites Reconnaissance of the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-5811.

Giffen, N., Peterson, M., Reasor, S., Pounds, L., and Byrd, G., 2009. *Wetland and Sensitive Species Survey Report for Y-12: Proposed Uranium Processing Facility (UPF)*. RP-SH-801768-A006, Rev. 2 (November 2009).

Hatcher, Jr., R. D., P. J. Lemiszki, R. B. Dreier, R. H. Ketelle, R. R. Lee, D. A. Leitzke,W. M. McMaster, J. L. Foreman, and S. Y. Lee. 1992. *Status Report on the Geology of the Oak Ridge Reservation.* ORNL TM-12074.

Lee, R.R. and Ketelle, R.H. 1989. *Geology of the West Bear Creek Site*. ORNL/TM-10887.

Lietzke, D.A. et al., 1988. *Soils, Surficial Geology, and Geomorphology of the Bear Creek Valley Low-Level Waste Disposal Development and Demonstration Program Site.* ORNL/TM-10573.

Lomenick, T.F., Byerly, D.W., and Gonzales, S. 1983. *Evaluation of the ORNL Area for Future Waste Burial Facilities*. ORNL/TM-8695.

Mitchell, J.M., E.R. Vail, J.W. Webb, J.E. Evans, A.L. King, P.A. Hamlett. 1996. *Survey of Protected Terrestrial Vertebrates on the Oak Ridge Reservation*. ES/ER/TM-188/R1.

ORNL 2002. *Oak Ridge Laboratory Land and Facility Plan*. ORNL/TM-2002/1.

Parr, P.D., and J.F. Hughes. 2006. *Oak Ridge Reservation Physical Characteristics and Natural Resources.* ORNL/TM-2006/110.

Parr, P. D. 2011a. Personal communication (e-mail) regarding natural area, August 22, 2011.

Parr, P. D. 2011b. Personal communication (e-mail) regarding HA-7, September 9, 2011.

Parsly, M. P. 1985. Inscriptions from Old Cemeteries on the Oak Ridge (Manhattan Project) Area: Anderson and Roane Counties, Tennessee. Oak Ridge, TN.

Robinson, J.A. and Johnson, G.C. 1996. *Results of a Seepage Investigation at Bear Creek Valley, Oak Ridge, Tennessee January – September 1994*. U.S. Geological Survey Open-File Report 95-459.

Rosensteel, B. A., and C. C. Trettin. 1993. *Identification and Characterization of Wetlands in the Bear Creek Watershed.* Y/TS-1016.

Rodriguez, R.E., P.F. Tiner, and J.K. Williams. 1992. *Surface Debris Inventory at White Wing Scrap Yard, Oak Ridge Reservation, Oak Ridge, Tennessee.* ORNL/ER-135.

Rothschild, E.R., Huff, D.D., Haase, C.S., Clapp, R.B., Spalding, B.P., Farmer, C.D., and Farrow, N.D. 1984. *Geohydrologic Characterization of Proposed Solid Waste Storage Area (SWSA 7).* ORNL/TM-9314.

Solomon, D.K., G.K. Moore, L.E. Toran, R.B. Dreier, and W.M. McMaster. 1992. *Status Report: A Hydrologic Framework for the Oak Ridge Reservation,* ORNL/TM-12026.

Southworth, G.R., Loar, J.M., Ryon, M.G., Smith, J.G., Stewart, A.J., and Burris, J.A. 1992. *Ecological Effects of Contaminants and Remedial Actions in Bear Creek*. ORNL/TM-11977.

# APPENDIX E:
# PREFERRED SITE DESCRIPTION AND CHARACTERIZATION

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... E-6
1. SITE DESCRIPTION ..... E-8
1.1 REGIONAL GEOGRAPHY AND PHYSIOGRAPHY ..... E-8
1.2 REGIONAL LAND USE AND DEMOGRAPHICS ..... E-10
1.2.1 Land Use ..... E-10
1.2.2 Demographics ..... E-10
1.3 TRANSPORTATION ..... E-13
1.4 CLIMATE AND AIR QUALITY ..... E-13
1.4.1 Climate ..... E-13
1.4.2 Air Quality ..... E-14
2. PROPOSED ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY SITE DESCRIPTION ..... E-15
2.1 LOCATION AND SETTING ..... E-15
2.1.1 Local Demographics ..... E-16
2.1.2 Limited Site Characterization ..... E-17
2.2 SITE GEOLOGY ..... E-18
2.2.1 Topography and Geomorphology ..... E-18
2.2.2 Lithostratigraphy ..... E-19
2.2.2.1 Rome Formation ..... E-19
2.2.2.2 Conasauga Group ..... E-22
2.2.2.3 Knox Group ..... E-24
2.2.3 Geologic Structure ..... E-25
2.2.4 Seismicity ..... E-28
2.2.5 Geotechnical Characteristics ..... E-30
2.3 GROUND WATER ..... E-31
2.3.1 Aquifer Characteristics ..... E-31
2.3.1.1 Matrix pores ..... E-31
2.3.1.2 Fractures ..... E-31
2.3.1.3 Cavities ..... E-33
2.3.2 Hydraulic Conductivity and Results of Tracer Tests ..... E-34
2.3.2.1 Range of Hydraulic Conductivity ..... E-34
2.3.2.2 Results of tracer tests ..... E-39
2.3.3 Ground Water Flow ..... E-41
2.3.3.1 Unsaturated Zone ..... E-41
2.3.3.2 Saturated Zone ..... E-42
2.3.3.3 Aquiclude ..... E-50

2.3.4 Ground Water Indicator Parameters ..... E-50
2.3.5 Ground Water Contaminants ..... E-51
2.4 SURFACE WATER HYDROLOGY ..... E-52
2.4.1 Water Budget ..... E-52
2.4.2 Northern Tributaries of Bear Creek ..... E-54
2.4.2.1 Stream Flow Characteristics ..... E-56
2.4.2.2 Gaining and Losing Reaches ..... E-57
2.4.2.3 Tributary Chemistry Indicators ..... E-57
2.4.2.4 Tributary Contaminants ..... E-57
2.4.3 Bear Creek ..... E-59
2.4.3.1 Stream Flow Characteristics ..... E-59
2.4.3.2 Gaining and Losing Reaches ..... E-59
2.4.3.3 Bear Creek Water Chemistry ..... E-60
2.4.3.4 Bear Creek Contaminants ..... E-60
2.5 CONCEPTUAL MODEL ..... E-61
2.6 ECOLOGICAL SETTING ..... E-64
2.6.1 Recent Changes in Site Conditions ..... E-64
2.6.2 Aquatic Habitats and Sensitive Species ..... E-66
2.6.2.1 Wetlands ..... E-66
2.6.2.2 Aquatic Resource Monitoring in Bear Creek ..... E-66
2.6.2.3 NT-3 Stream Ecology ..... E-68
2.6.3 Terrestrial Habitats and Sensitive Species ..... E-70
2.6.3.1 Terrestrial Flora ..... E-70
2.6.3.2 Terrestrial Fauna ..... E-70
2.6.3.3 Avifauna ..... E-71
2.6.4 Results of Recent Surveys at the EMDF Site ..... E-71
2.6.5 Terrestrial Status Species ..... E-72
2.6.6 Other Natural Resources ..... E-74
2.7 CULTURAL RESOURCES ..... E-74
3. REFERENCES ..... E-77
APPENDIX E - ATTACHMENT A: PHASE I CHARACTERIZATION REPORT OF THE ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY SITE IN EAST BEAR CREEK VALLEY ..... E-86

# FIGURES

Figure E-1. Bear Creek Valley and Land Use Zones Established in the Phase I ROD ..... E-9
Figure E-2. Oak Ridge Reservation and Nearby Census Tracts in Vicinity of the Proposed EMDF .... E-12
Figure E-3. Tennessee Counties in which Ten or More ORO Employees Lived during 2012..... E-13
Figure E-4. Representative Wind Rose Diagram for theY-12West Meteorology Tower in 2010..... E-14
Figure E-5. Historical Map Progression for the Candidate Site..... E-16
Figure E-6. Distance to Nearest Residents from the Proposed EMDF ..... E-17
Figure E-7. Phase I Site Characterization Monitoring Well and Flume Locations..... E-18
Figure E-8. Geologic Map of the EMDF Area ..... E-20
Figure E-9. Generalized Structural-Stratigraphic Cross-Section for the Proposed EMDF Site ..... E-21
Figure E-10. Increasing Complexity Added by Multiple Fracture Sets..... E-26
Figure E-11. Schmidt Stereonets for Wells GW-968 and GW-970..... E-28
Figure E-12. Conceptual Model of Ground Water Zones in BCV ..... E-43
Figure E-13. Hydraulic Head Distribution across EBCV ..... E-45
Figure E-14. Cross-Sectional Representation from a Computer Model of Ground Water Hydraulic Head and Flow Patterns for EBCV..... E-45
Figure E-15. Ground Water Table Elevations for the Proposed EMDF Site on December 25, 2014..... E-46
Figure E-16. Water Table Fluctuations Measured during Phase I Site Characterization..... E-48
Figure E-17. Streams and Wetlands in the NT-3 Drainage Basin ..... E-55
Figure E-18. Conceptualization of Development of Self-Organized Permeability in Carbonate Aquifer ..... E-62
Figure E-19. Block Diagram Illustrating Conceptual Ground Water Flow Model for the Proposed EMDF Site ..... E-63
Figure E-20. Area of Severe Wind Impacts due to the May 19, 2013 Downburst ..... E-64
Figure E-22. Before and After Photos of the NT-2 Wetland ..... E-65
Figure E-23. Locations of Acoustic Stations used in the 2013 Bat Survey ..... E-73
Figure E-24. Streams, Wetlands, and Resource Areas in the EMDF Area..... E-75
Figure E-25. Area Covered by Archaeological Reconnaissance Report in DuVall (1998)..... E-76

# TABLES

Table E-1. Total 2010 Population in Five nearest Counties ..... E-10
Table E-2. Population Data for Adjacent Census Tracts in the 2010 Census ..... E-11
Table E-3. DOE-ORO Employees and Payroll for the Top Five Counties in 2012 ..... E-13
Table E-4. Earthquake Magnitude and Intensity Scales ..... E-29
Table E-5. Mean Hydraulic Conductivity by Formation Compared to Preliminary WAC Model Input ..... E-35
Table E-6. Summary Hydraulic Conductivity Data by Depth in Conasauga Formation Rocks at the WBCV Site Compared to Preliminary WAC Model Input ..... E-36
Table E-7. Hydraulic Anisotropy in the Conasauga Formations ..... E-38
Table E-8. Geochemical Zones in the Conasauga Group Formations ..... E-49
Table E-9. Water Budget Estimates for Areas of the Oak Ridge Reservation ..... E-53
Table E-10. Summarized Water Chemistry Parameters for NT-2 and NT-3 ..... E-58
Table E-11. Summary of Bear Creek Water Chemistry Indicators ..... E-60
Table E-12. Results of Acoustic Bat Survey ..... E-74

# ACRONYMS

| | |
|---|---|
| ANA | Aquatic Natural Area |
| AWQC | ambient water quality criteria |
| BCBG | Bear Creek Burial Ground |
| BCK | Bear Creek Kilometer |
| BCV | Bear Creek Valley |
| BNI | Bechtel National, Inc. |
| BY/BY | Boneyard/Burnyard |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| DOE | U.S. Department of Energy |
| EBCV | East Bear Creek Valley |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| ETSZ | East Tennessee Seismic Zone |
| ETTP | East Tennessee Technology Park |
| FS | Feasibility Study |
| MSL | mean sea level |
| NAAQS | National Ambient Air Quality Standards |
| ORERP | Oak Ridge Environmental Research Park |
| NT | Northern Tributary (to Bear Creek) |
| ORNL | Oak Ridge National Laboratory |
| ORO | Oak Ridge Office |
| ORP | oxidation-reduction potential |
| ORR | Oak Ridge Reservation |
| PCB | polychlorinated biphenyl |
| PreWAC | Preliminary Waste Acceptance Criteria |
| RA | Reference Area |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| SU | standard unit |
| SR | State Route |
| TCE | trichloroethene |
| TDEC | Tennessee Department of Environment and Conservation |
| U.S. | United States |

| | |
|---|---|
| UPF | Uranium Processing Facility |
| USCS | Unified Soil Classification System |
| USGS | U.S. Geographic Services |
| UEFPC | Upper East Fork Poplar Creek |
| VOC | volatile organic compound |
| WAC | waste acceptance criteria |
| WAG | Waste Area Grouping |
| WBCV | West Bear Creek Valley |
| Y-12 | Y-12 National Security Complex |

# 1. SITE DESCRIPTION

This Appendix to the Remedial Investigation (RI)/Feasibility Study (FS) describes the regional and detailed environmental setting of the proposed site for a new disposal facility for waste generated by Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) actions on the United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR). The RI/FS evaluates alternatives for disposing of most future CERCLA waste expected to be generated during environmental restoration of the ORR after the existing Environmental Management Waste Management Facility (EMWMF) reaches capacity.

The site description includes regional and site-specific information about geography and physiography, land use and demographics, transportation, climate and air quality, geology, soils, hydrogeology, surface water, ecologic resources, and historical and cultural resources. The purpose of this Appendix is to provide information regarding the site screening and selection process and to document conditions at the proposed Environmental Management Disposal Facility (EMDF) site (see Figure E-1).

## 1.1 REGIONAL GEOGRAPHY AND PHYSIOGRAPHY

East Tennessee is located in the central portion of the Southern Appalachian physiographic region. The region's distinctive terrain is naturally divided into three internally complex physiographic subregions based on differences in geology, ecology and biodiversity, and a wide range of local climates and soils. The ORR is located in the western portion of the Valley and Ridge Physiographic Province, which is characterized by a series of parallel narrow, elongated ridges and valleys that follow a northeast-to-southwest trend (Hatcher et al. 1992). The Valley and Ridge Physiographic Province developed on thick, folded and thrust-faulted beds of sedimentary rock deposited during the Paleozoic era. Thrust faults and the long axes of the tilted beds associated with thrust faults control the shapes and orientations of a series of long, narrow parallel ridges and intervening valleys. Ten major imbricate thrust faults, in which thrust sheets overlap somewhat like roof shingles, have been mapped in East Tennessee. Two of these thrust sheets, defined by the Copper Ridge and Whiteoak Mountain thrust faults, traverse the ORR (Lemizski 2000; Hatcher, et al. 1992). The axes of the ridge-and-valley terrain within the ORR lie approximately along an east-northeast–west-southwest axis (60°–240°). Bedrock at the ORR consists of interbedded fractured weathered shale and limestone, resulting in significant vertical and horizontal heterogeneity. The differing degrees of resistance to erosion of the shales, sandstones, and carbonate rocks that comprise the regional bedrock help to determine local relief. Limestone units are extensively weathered to massive clay lenses with dispersed residual nodules of limestone bedrock. The more resistant shale has weathered to an extensively fractured residuum (saprolite) containing highly interconnected fracture networks.

There are six continuous ridges and one short ridge on the ORR. From north to south the ridges are Blackoak, East Fork, a short unnamed ridge, Pine, Chestnut, Haw, and Copper ridges. These ridges are separated by (in the same order) East Fork Valley, two unnamed valleys, Bear Creek Valley (BCV), Bethel Valley, and Melton Valley. The ground elevations within the ORR ranges from a low of 750 ft above mean sea level (MSL) along the Clinch River to a high of over 1,300 ft MSL on Copper Ridge. The topographic relief between valley floors and ridge crests is generally on the order of 300 to 350 ft.

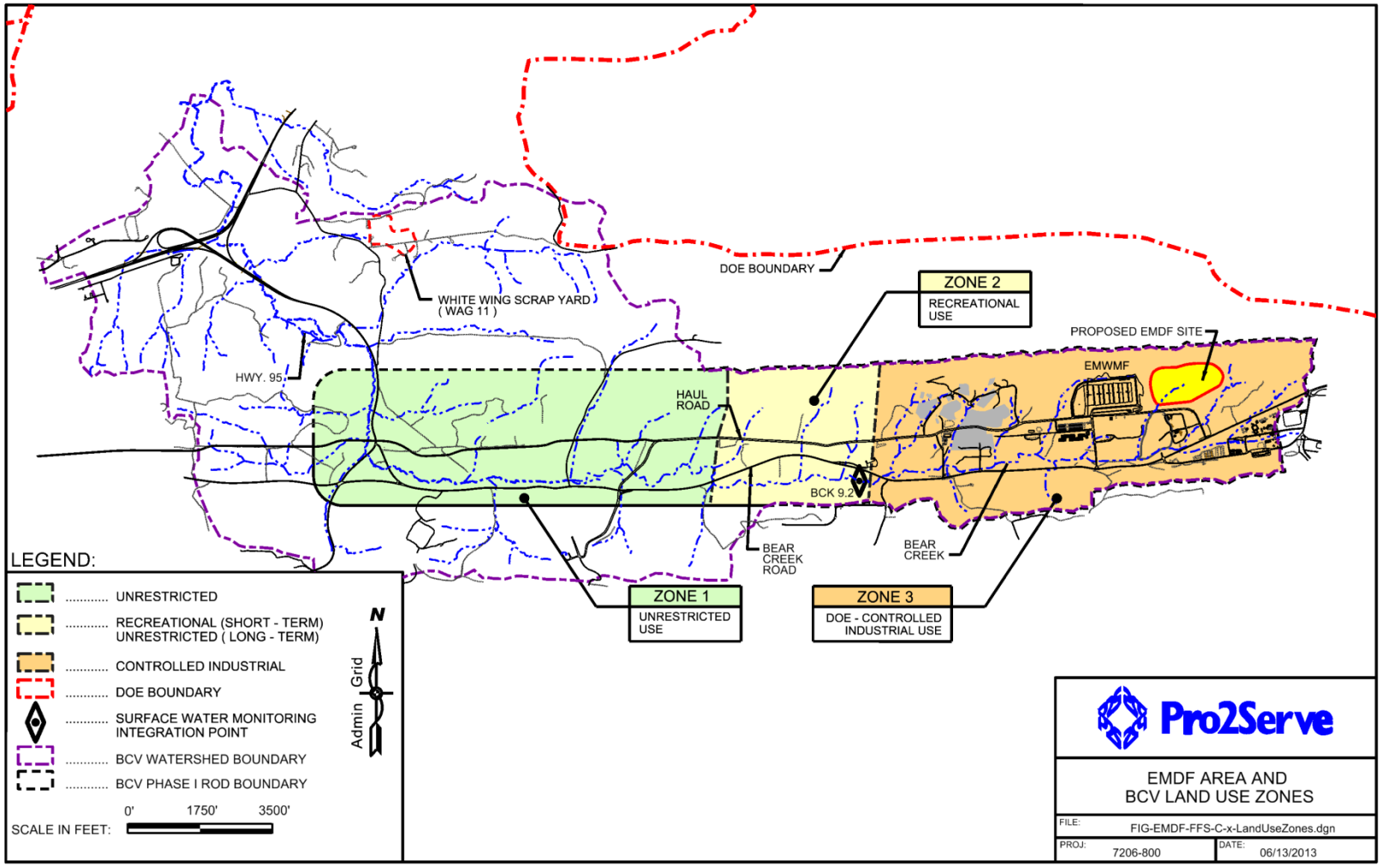



**Figure E-1. Bear Creek Valley and Land Use Zones Established in the Phase I ROD**

## 1.2 REGIONAL LAND USE AND DEMOGRAPHICS

The ORR currently occupies 33,542 acres in Anderson and Roane Counties. The land on the ORR is used for multiple purposes to meet DOE's mission goals and objectives, and approximately one-third of the land (11,300 acres) is intensively developed (ORNL 2002) as the East Tennessee Technology Park (ETTP), Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12). Land uses near, but outside, the ORR, are predominantly rural, with agricultural and forest land dominating, and urban, mainly represented by the City of Oak Ridge. The residential areas of the city of Oak Ridge that abut the ORR are primarily along the northern and eastern boundaries of the reservation. Some Roane County residents have homes adjacent to the western boundary of the ORR. The Clinch River forms a boundary between Knox County, Loudon County, and portions of Roane County.

### 1.2.1 Land Use

Uses of the land area surrounding the developed DOE facilities include safety, security, and emergency planning; research and education; cleanup and remediation; environmental regulatory monitoring; wildlife management; biosolids land application; protection of cultural and historic resources; wildland fire prevention; land-stewardship activities; use and maintenance of reservation infrastructure; and activities in public areas (DOE 2008a). The largest mixed use is biological and ecological research in the Oak Ridge Environmental Research Park (ORERP), which encompasses 20,000 acres, the majority of the ORR (DOE 2011a). The ORERP, established in 1980, is used by the nation's scientific community as an outdoor laboratory for environmental science research on the impact of human activities on the eastern deciduous forest ecosystem.

### 1.2.2 Demographics

The five counties nearest to the proposed EMDF candidate site, Anderson, Knox, Loudon, Morgan, and Roane, have a total 2010 census population of 632,079 and over 286,000 housing units. Table E-1 summarizes basic demographic data for the five-county area.

**Table E-1. Total 2010 Population in Five nearest Counties**

| County | Population | Housing Units |
|---|---|---|
| Anderson | 75,129 | 34,717 |
| Knox | 432,226 | 194,949 |
| Loudon | 48,556 | 21,725 |
| Morgan | 21,987 | 8,920 |
| Roane | 54,181 | 25,716 |
| TOTALS | 632,079 | 286,027 |

Source: U.S. Census Bureau, 2010 Census

Oak Ridge, the nearest city, has a population of 29,330 (2010 census); of these, 3,059 reside in Roane County with the remaining 26,271 residing in Anderson County. The estimated population of Oak Ridge for 2014 was 29,419(± 33)[1]. The proposed EMDF site lies in Anderson County census tract 9801, which has no residential population. Populations of adjoining census tracts are provided in Table E-2. Counties and nearby census tracts in vicinity of the proposed EMDF are shown in Figure E-2.

**Table E-2. Population Data for Adjacent Census Tracts in the 2010 Census**

| County | Tract | 2010 Population | % of Population Under Age 17 | 2010 Total Housing Units | 2010 Occupied Housing Units |
|---|---|---|---|---|---|
| Anderson | 201 | 3,111 | 22.7 | 1,794 | 1,546 |
| | 202.01 | 3,670 | 21.2 | 1,691 | 1,535 |
| | 202.02 | 4,507 | 18.9 | 2,215 | 2,025 |
| | 9801 | 0 | 0 | 0 | 0 |
| Roane | 9801 | 0 | 0 | 0 | 0 |
| Knox | 59.06 | 1,671 | 23.8 | 644 | 617 |
| | 59.07 | 2,970 | 25.7 | 1,267 | 1,153 |

Source: U.S. Census Bureau, 2010 Census

The age distribution for Oak Ridge is skewed towards an older population than for the state of Tennessee as a whole, with slightly lower percentages in the age groups from birth to age 44, and slightly greater population in the age groups from age 45 to over age 85. The sex distribution for Oak Ridge is similar to that of Tennessee. The estimated 2014 racial composition of Oak Ridge is 84.3% white, 9.5% black, 2.7% Asian, and 0.5% other races. About 2.9% of the population identifies as mixed-race, and 4.9% identifies as Hispanic or Latino.

The number of employees involved in DOE-Oak Ridge Office (ORO) work during 2009 was 13,621. This total includes both Federal and contractor employees. The 2009 payroll was $1,067,919,527.

Employees reside in over 20 counties, as shown in Figure E-3. Knox, Anderson, and Roane counties together hold about 82% of these employees. The top five counties account for 89% of employees and 92% of the 2009 DOE payroll. Data for the top five counties are provided in Table E-3.

Environmental justice concerns have been raised regarding the Scarboro community immediately north of the main Y-12 industrial area. This area is more than 1.5 miles from the proposed EMDF location. Pine Ridge separates the Scarboro community from the proposed landfill site. A former golf course and recently developed subdivision lie between the EMDF site and the edge of the Scarboro community. Ground water flow and prevailing wind patterns would move any EMDF releases away from the Scarboro community. Therefore, it is concluded that no environmental justice issues arise from this action.

[1] http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk accessed January 5, 2015. Estimates are not provided at the level of census tracts.

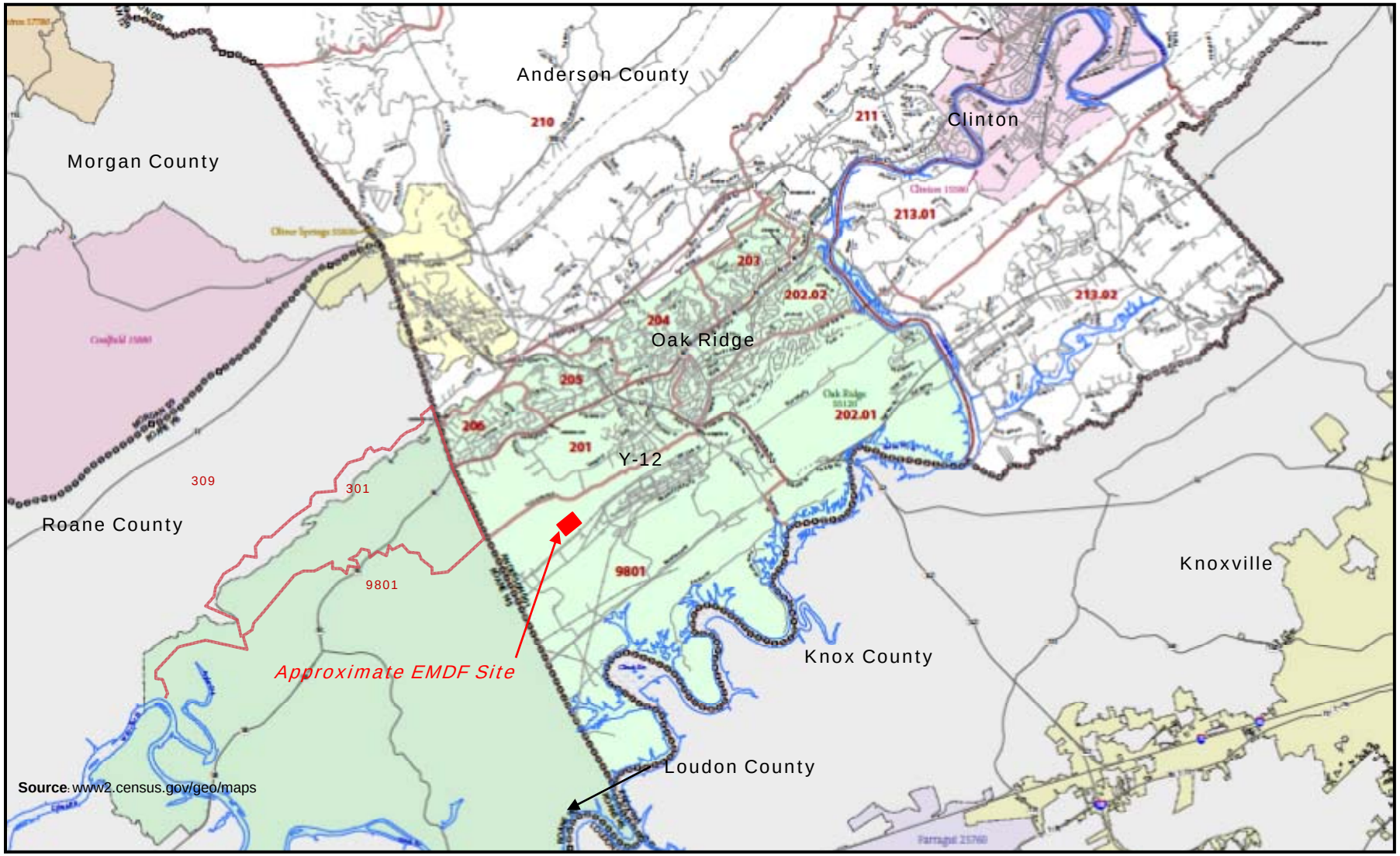



**Figure E-2. Oak Ridge Reservation and Nearby Census Tracts in Vicinity of the Proposed EMDF**

**Table E-3. DOE-ORO Employees and Payroll for the Top Five Counties in 2012**

| County | 2012 Employees | 2012 Payroll |
|---|---|---|
| Knox | 5,721 | $511,329,075 |
| Anderson | 3,065 | $246,469,051 |
| Roane | 1,978 | $157,088,580 |
| Loudon | 669 | $56,489,413 |
| Blount | 405 | $31,332,173 |

Source: http://www.oakridge.doe.gov/external/portals/0/hr/12-31-12%20payroll%20&%20residence.pdf

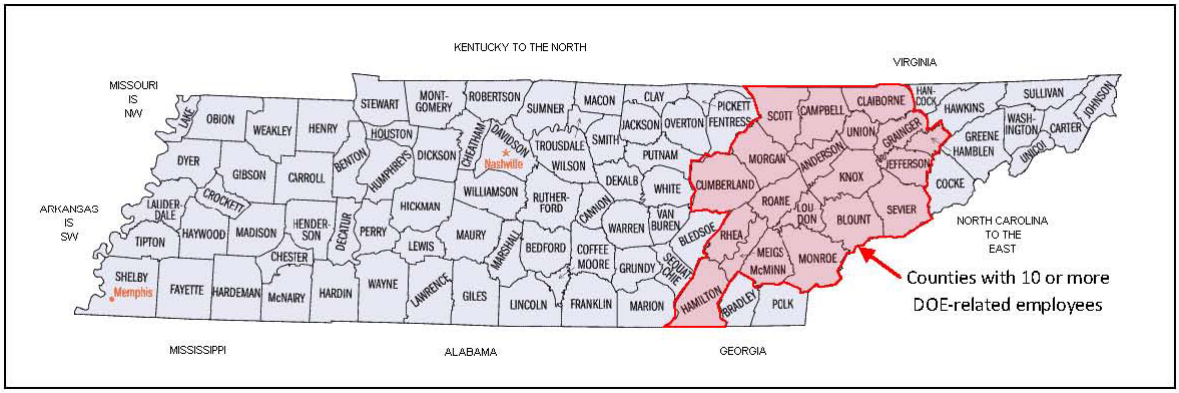



**Figure E-3. Tennessee Counties in which Ten or More ORO Employees Lived during 2012**

## 1.3 TRANSPORTATION

The proposed EMDF site has access via Bear Creek Road to State Route (SR) -58 and SR-95, which connect to I-40 within 4.5 miles. Note, however, that all waste movement on the ORR for the On-site Disposal Alternative would be on non-public controlled-access haul roads constructed specifically for transporting wastes to the disposal site.

## 1.4 CLIMATE AND AIR QUALITY

Abundant climate data are available from the National Oceanic and Atmospheric Administration station in Oak Ridge, as well as from ORNL, which operates seven meteorological towers scattered over the ORR.

### 1.4.1 Climate

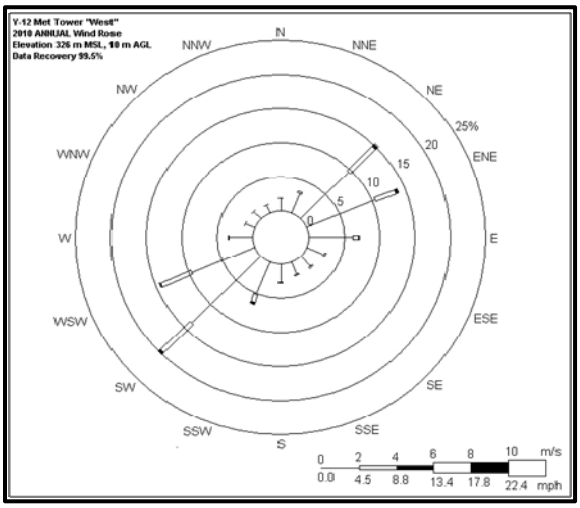
The Oak Ridge area climate may be broadly classified as humid subtropical (Parr and Hughes 2006). The region receives a surplus of precipitation relative to the calculated amount of evapotranspiration that is

normally experienced throughout the year. The region experiences warm to hot summers and cool winters.

Annual precipitation averages 52.6 in. water-equivalent, with an average of 10.4 in. snow per year.[2] The wet season occurs from November to May, and there is a short dry season from August through October.

The ORNL Meteorological Program compiles 30-year average and 63-year record temperature and precipitation data. The 30-year average maximum daily temperatures range from a low of 46.9° F in January to 88.5° F in July, and the mean annual maximum temperature is 69.6° F. The 30-year average minimum temperatures vary from 28° F in January to 67.5° F in July. The mean annual temperature is 58.5° F.

Wind direction is slightly bimodal. The dominant wind direction is from the southwest and winds from the northeast form the secondary wind direction. Figure E-4 provides an annual wind rose for the Y-12 West Tower for 10 m above ground level; the wind roses from 15 m and 60 m are very similar. The Y-12 West Tower is approximately 0.8 miles northwest of the proposed EMDF site. In essence, the primary wind directions parallel the ridges.




Source: http://www.ornl.gov/~das/web/page7.cfm

**Figure E-4. Representative Wind Rose Diagram for theY-12West Meteorology Tower in 2010**

### 1.4.2 Air Quality

The U.S. Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants: carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), ozone ($O_3$), particulate matter with aerodynamic diameter less than or equal to 2.5 μm ($PM_{2.5}$), particulate matter with an aerodynamic diameter less than or equal to 10 μm in diameter ($PM_{10}$), and lead (Pb). Areas that meet NAAQS limits are classified as attainment areas, while areas that exceed NAAQS for a particular pollutant are classified as nonattainment areas for that pollutant. On March 12, 2008, the EPA promulgated the new ozone standard of 0.075 parts per million.

[2] Climate statistics are from http://www.ornl.gov/~das/web/ Normals/30YRNorm.pdf

The ORR located in Anderson and Roane Counties is part of the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region (40 CFR 81.57). The EPA has designated Anderson County an 8-hour ozone and $PM_{2.5}$ non-attainment area. Air quality in the greater Knoxville and Oak Ridge area is in attainment for all other criteria pollutants, as defined by NAAQS.

# 2. PROPOSED ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY SITE DESCRIPTION

The proposed EMDF site location and setting, site geology, ground water, surface water hydrology, conceptual flow model, ecological setting, and cultural resources are described below.

## 2.1 LOCATION AND SETTING

The proposed EMDF site is located in East Bear Creek Valley (EBCV) adjacent to and east of the existing EMWMF. East BCV is a historical waste management area that contains several closed land disposal facilities, in addition to the currently operating EMWMF. The proposed EMDF site is on the lower south-facing slopes of Pine Ridge and north of Bear Creek and will permanently occupy 60 to 70 acres.

The site is situated on undeveloped land between Northern Tributary (NT)-3 and NT-2, with the Haul Road marking the approximate south boundary, and the north boundary being on the flank of Pine Ridge. The site is approximately 1,100 ft north of Bear Creek at the nearest point. The current position of the Y-12 security boundary "blue line" is roughly coincident with the west edge of the conceptual EMDF footprint (see Figure 6-2 in Chapter 6 of this RI/FS).

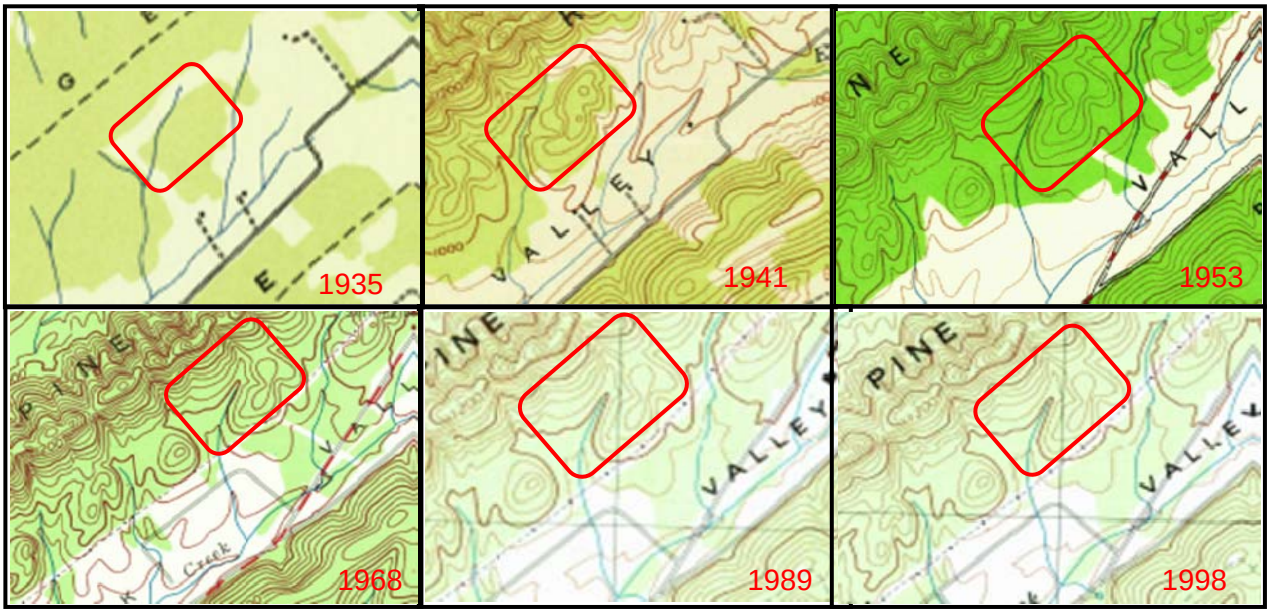
BCV is approximately 10 miles long and extends west from the eastern end of the Y-12 industrial area to the Clinch River. The BCV Watershed extends from the divide between BCV and Upper East Fork Poplar Creek (UEFPC) west to the Bear Creek water gap through Pine Ridge. The water gap begins approximately where Bear Creek turns northward at SR-58/95.

The BCV Phase I Record of Decision (ROD) (DOE 2000) divides the BCV watershed into three zones for the purposes of establishing and evaluating performance standards for each zone in terms of land and resource uses and residential risks following remediation, as shown in Figure E-1. The proposed EMDF site is located in Zone 3, which is an historical waste management area and has the designated future land use classification of "Controlled Industrial Use" in the BCV Phase I ROD.

The candidate site is adjacent to existing waste disposal facilities and the operational area of Y-12, and will remain under DOE control and within DOE ORR boundaries for the foreseeable future. No change in the anticipated land use classification is expected to be required if the EMDF is constructed at this site. The proposed EMDF site is heavily wooded and shows little indication of anthropogenic alterations. There are no current operations at the site. Review of the U.S. Geological Survey (USGS) 7.5-minute quadrangle maps for the Bethel Valley Quadrangle for 1935, 1941, 1953, 1968, 1989, and 1998 (progression is shown in Figure E-5) indicate that much of the site has been wooded throughout the period. The 1935 map shows a rectilinear clearing that extended up the flank of Pine Ridge near NT-3, then turning northwest parallel to the ridge crest until it joined with a large cleared area east of NT-2. Two presumably residential or farm structures are south of the site near Bear Creek. Other than drives from Bear Creek Road to the structures, no roads or trails are shown for the area. By 1941, much of the rectilinear cleared area had become forested, although the large cleared area east of NT-2 had expanded across NT-2. The core wooded area remained wooded throughout the entire period.

By 1953, the rectilinear clearing was entirely wooded, as was much of the open area east of NT-2. The flatter areas nearer to Bear Creek remained open, and the structures were no longer evident. (DuVall and Souza [1996] indicate that there was little remaining indication of a structure at one of these sites when they surveyed it in the 1990s). Reforestation of the area continued, so that by 1968, the entire candidate

area was again covered, except for two power line rights of way. The forested area has remained essentially constant since 1968, except that the north trending power line track disappeared. Based on this review, it appears that much of the candidate site remained forested from 1968 to 1998, except for some apparent agricultural clearing. It does not appear from map reviews that any industrial activities beyond installation and maintenance of a power line occurred in the area of the proposed EMDF site.




Red rectangle shows approximate location of the proposed EMDF site.

**Figure E-5. Historical Map Progression for the Candidate Site**

### 2.1.1 Local Demographics

The nearest resident is approximately 0.84 mile north of the proposed EMDF site, and a larger residential subdivision is about 1.1 miles to the northeast. Figure E-6 shows these residential locations. Anderson County census tract 201 is closest to the proposed EMDF site, had a population of 2,463 in 2000 and 3,111 in 2010, a 26.3% gain. Tract 201 had 1,794 housing units in 2010. The 2010 population density for tract 201, which includes much of the center of Oak Ridge, is 585 persons per square mile. Most of the Tract 201 population lives in the eastern half of the tract.

Roane County census tract 301 is immediately west of Anderson County census tract 201, and had a 2010 population of 3,224. This tract includes the entire west end of Oak Ridge east of the Clinch River. Tract 301 had a population density of 459 persons per square mile in 2010. Most of the population of Tract 301 is along or north of Oak Ridge Turnpike.

The U.S. Census Bureau projected that Anderson County population would grow by 19% from 2010 (75,129) to 2064 (89,814), and that Roane County population (54,181) would decline by about 10% over the same period (53,373).

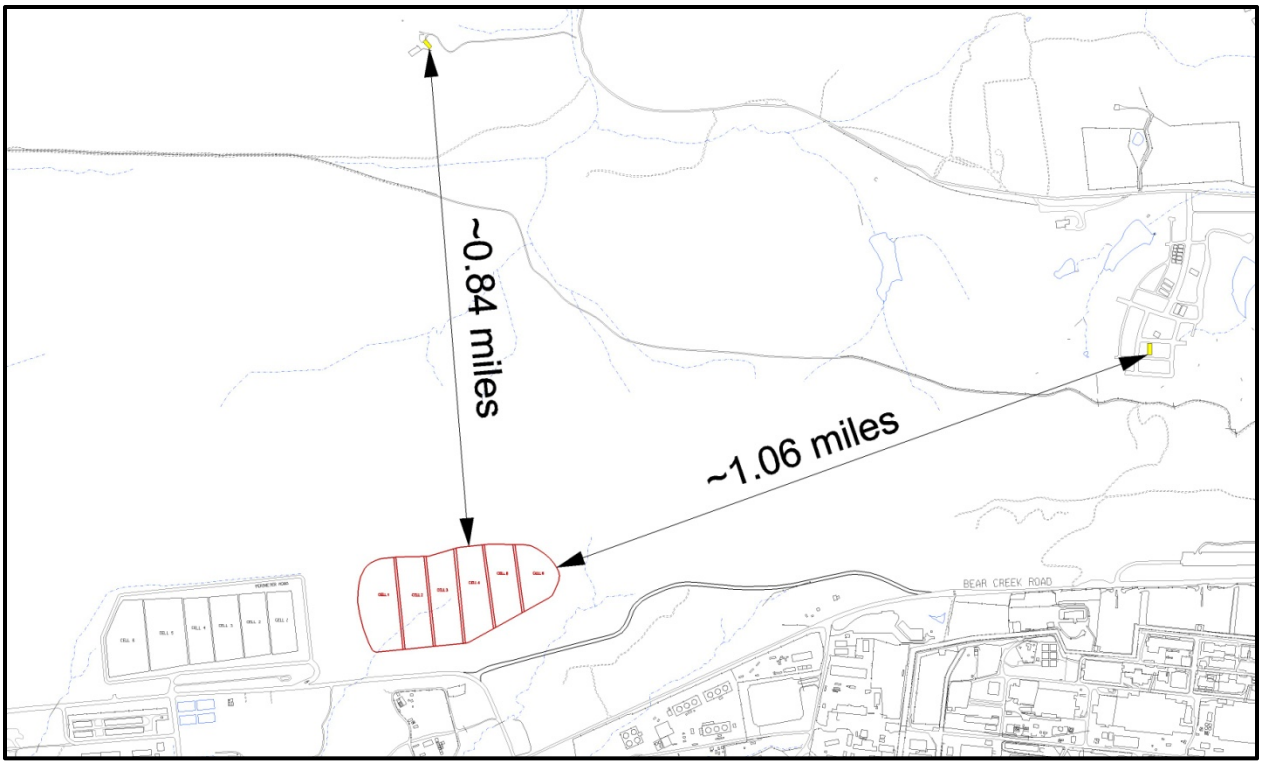



**Figure E-6. Distance to Nearest Residents from the Proposed EMDF**

### 2.1.2 Limited Site Characterization

A limited Phase I Site Characterization was conducted of the proposed EMDF to provide site-specific geological and hydrogeological data. The Phase I site characterization activities were conducted to allay concerns voiced by Tennessee Department of Environment and Conservation (TDEC) regarding the suitability of this site for a low-level waste landfill. The Phase I Site Characterization included installation of five shallow-deep well pairs at strategic locations and three flumes to monitor surface water, as shown in Figure E-7. One well, GW-977, was a dry hole. Two wells were cored throughout the bedrock interval, and geophysical logging was conducted in all deep wells. Packer tests were carried out in all deep wells, and slug tests were conducted in the four shallow wells that encountered the water table. The nine wells that encountered ground water and all three flumes were instrumented to continuously monitor and record water level and water quality data. Results are summarized in Appendix E, where appropriate, and Attachment A contains the full Phase I report, including logs, test results, and monitoring results; these results have been summarized in this Appendix.

The results of the Phase I site characterization were in general alignment with the findings of studies conducted elsewhere on Pine Ridge (c.f., Lee and Ketelle 1989; King and Haase 1987; BNI 1984) and the ORR (Hatcher, et al. 1992; Haase, et al. 1985), and summarize below.

A second phase of site characterization would be planned using the Data Quality Objectives process and in full accordance with Federal Facility Agreement planning requirements if this site is approved for a landfill.

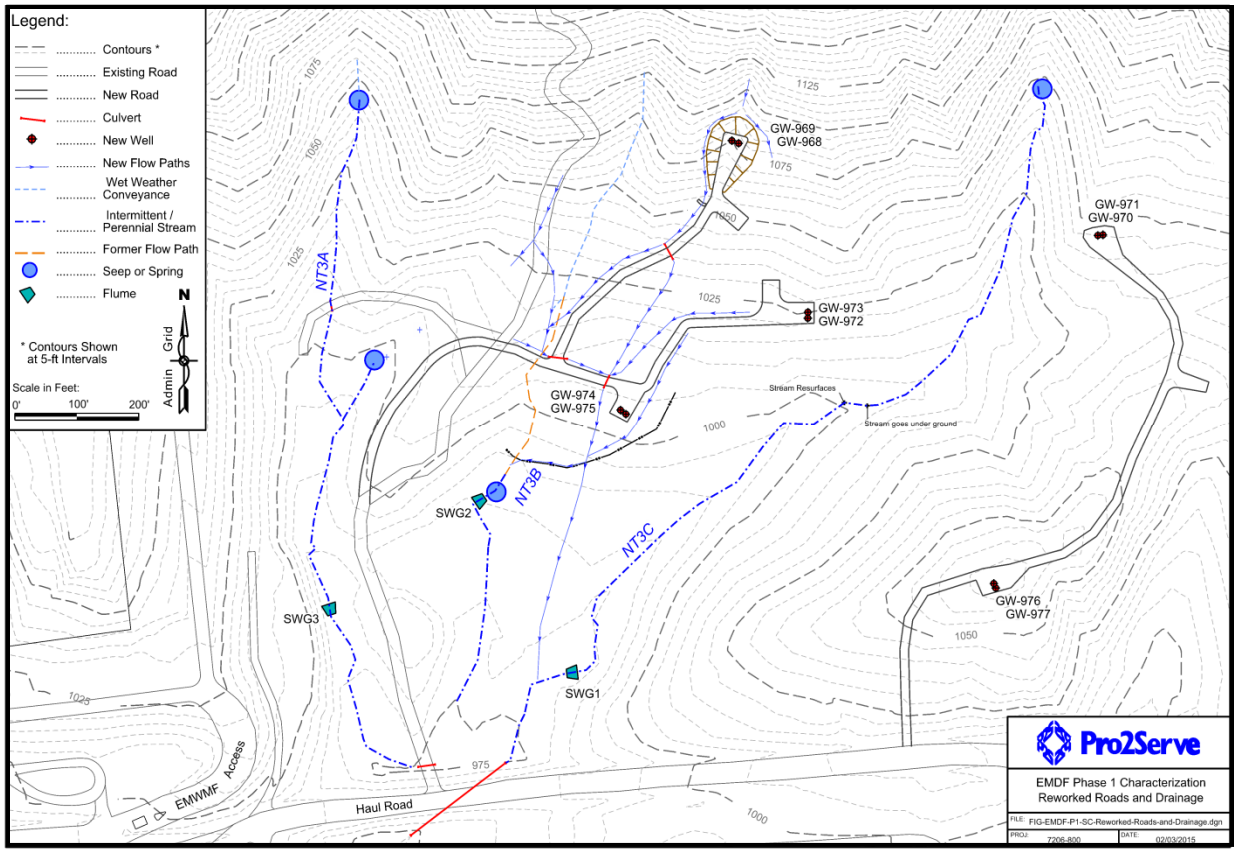



**Figure E-7. Phase I Site Characterization Monitoring Well and Flume Locations**

## 2.2 SITE GEOLOGY

The proposed EMDF site topography and geomorphology, stratigraphy, and geologic structure are discussed below.

### 2.2.1 Topography and Geomorphology

This discussion of site topography and geomorphology are based primarily on Lietzke, et al. (1988), who reported on an intensive investigation of the West Bear Creek Valley (WBCV) site for the Low-Level Waste Disposal Development and Demonstration Program. Additional geologic data and interpretations for the EBCV disposal area are from Bechtel National, Inc. (BNI) (1984) and the BCV RI (DOE 1997). The WBCV and EMDF sites share common geology, hydrologic and geomorphic history, and hydrogeology, such that the Lietzke et al. (1988) findings, while differing in specifics, can be generally applied to the proposed EMDF site.

The proposed EMDF site, like the WBCV site, is on the south flank of Pine Ridge. Pine Ridge is underlain by the Rome Formation and lower units of the Conasauga Group, and has a very steep scarp (north-facing) slope, and a concave, very steep (approximately 30° or 1:2) to moderately steep (<15° or 1:4) dip (south-facing) slope, and saw-tooth crest line. The dip slope is broken by a series of lower elevation knolls formed on harder rock units in the lower Maryville Limestone.

The geomorphic history of BCV is characterized by slow structural uplift, downward erosion, and sedimentation of colluvium and alluvium that extends for millions of years. Though the general landforms of East Tennessee have remained relatively constant for millions of years, the present-day land surface

has been affected by changes caused by human activity (farming and associated erosion) and changes related to the dramatic climate fluctuations of the Pleistocene Epoch. These fluctuations, and the advent of farming in Anderson County sometime after about 1795, resulted in periods of increased erosion and deposition (Leitzke, et al 1988).

The current geomorphic surface is stable. Topographic contours are shown on Figure E-8. Slopes on the south flank of Pine Ridge are concave. Upper slopes feature sharp interfluves separated by deep, steep-sided ravines and zero-order and first order stream valleys organized in a trellis pattern typical of dip slopes. Valleys coalesce and open on lower slopes to form broad bowl-shaped valleys drained by first and second-order streams. Streams are moderately incised at the apparent boundary between the Rogersville Shale and the Maryville Limestone. There is no visible evidence of recent mass movement in the area. There are no indications of sink-holes or other surface features related to karst terrain. Though ground water flow in subsurface conduits is well documented on the Maynardville Limestone along the central axis of BCV, there are no mapped sinkholes or other karst landforms in the valley.

A discontinuous subsidiary ridge, apparently supported by resistant beds in the Maryville Limestone, parallels the main spine of Pine Ridge. This subsidiary ridge exhibits the same features as the main ridge.

Extensive colluvium was noted along the base of Pine Ridge at the WBCV site, and can be expected also to be present at the EMDF site. Alluvium is not expected to be a major component of surficial materials along the north tributaries.

### 2.2.2 Lithostratigraphy

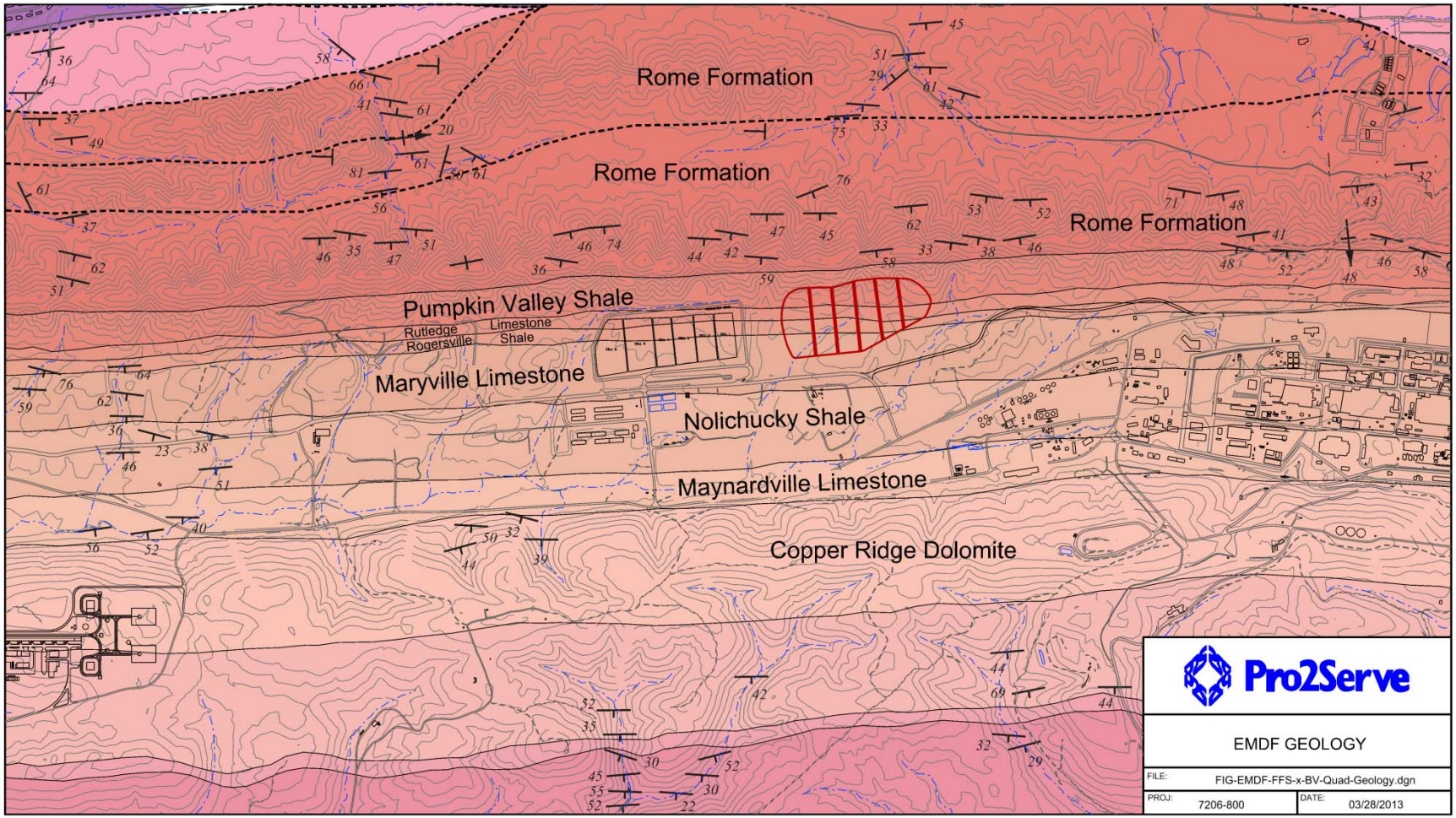
The site is underlain by rock units of the Middle Cambrian Conasauga Group, consisting primarily of moderately to steeply dipping, weakly resistant calcareous shales, mudstones, siltstones and limestones. The Conasauga Group is overlain by the Knox Group and underlain by the Rome Formation. Figures E-8 and E-9 provide a geologic map and representative cross-section for the site, respectively.

Unless otherwise noted, the material presented in the following sections about stratigraphy has been adapted from Hatcher, et al. (1992), Lemizski (2000), Lietzke, et al. (1988), and the BCV RI (DOE 1997).

#### 2.2.2.1 Rome Formation

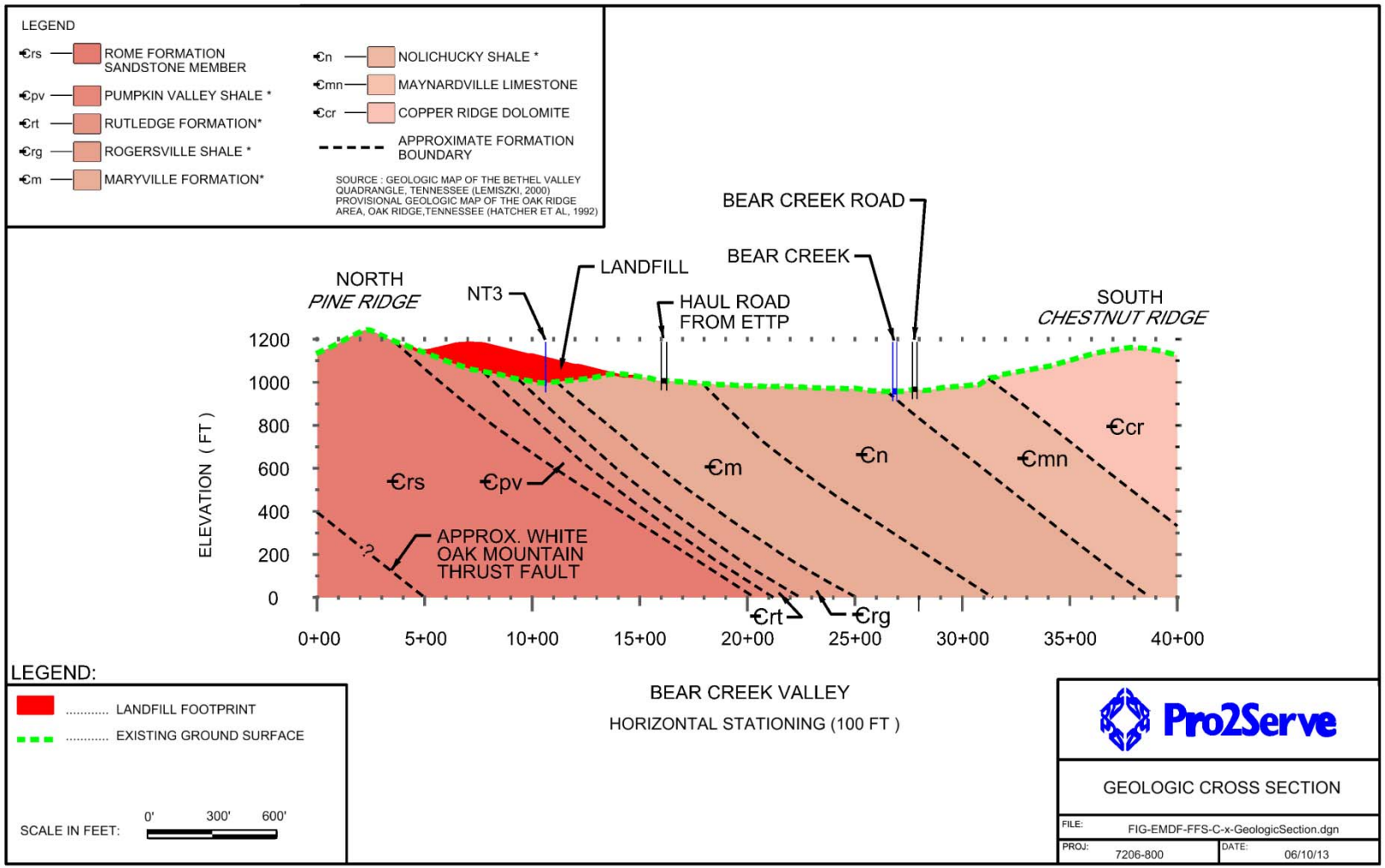
The Rome Formation underlies the Pumpkin Valley Shale and forms the crest of Pine Ridge. The lower Rome Formation is dominantly variegated maroon to yellow-brown or green micaceous fissile shale with thin interbeds of gray clayey limestones and dolomites.

The upper units of the Rome Formation consist of interbedded maroon sandstone, siltstone, and shale. A dolomite bed, present on the Copper Creek thrust sheet and elsewhere in East Tennessee, is not present on the White Oak Mountain thrust sheet underlying the proposed EMDF site. The upper Rome Formation is characterized by greenish-gray, yellow-brown, and olive-green sandstones, interbedded with maroon medium grained quartzose sandstones and siltstones. Glauconite occurs occasionally, and ripple bedding, cross-bedding, bioturbation, flaser bedding, and mud cracks suggest deposition in relatively shallow waters. Shale interbeds are variegated olive green, light brown, and maroon, and are thin-bedded. Massive dolomite units with interbedded dolomitic sandstones also occur within the Rome Formation. The boundary of the Rome Formation with the overlying Pumpkin Valley Shale is marked at the top of the uppermost massive to laminar gray-green sandstone in the Rome Formation.




The EMDF conceptual footprint is shown in red.

**Figure E-8. Geologic Map of the EMDF Area**




Adapted from Hatcher, et al. 1992

**Figure E-9. Generalized Structural-Stratigraphic Cross-Section for the Proposed EMDF Site**

### 2.2.2.2 Conasauga Group

The Conasauga Group in BCV consists of the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone (Lemizski 2000; Hatcher, et al., 1992).

#### *2.2.2.2.1 Pumpkin Valley Shale*

The Pumpkin Valley Shale is a 295360 ft (90109 m) thick maroon, red-brown, to gray mudstone and shale interbedded with siltstone. Glauconite is common to abundant throughout, and bioturbation is pronounced in some beds. The lower Pumpkin Valley Shale is composed of maroon-brown to gray and gray-green thin-bedded to massive highly bioturbated siltstone and mudstone. Glauconite is abundant in the bioturbated layers.

The upper Pumpkin Valley Shale is composed of reddish-brown, reddish-gray, and gray mudstone and shale interbedded with siltstone. Siltstone layers contain abundant glauconite, and is locally cross-bedded.

The Phase I site characterization effort took no cores from the Pumpkin Valley Shale. Geophysical logs from wells GW-968(I) and GW-970(I) indicate that the Pumpkin Valley Shale at this site is dominated by clastic units, most likely shales, mudstones, and siltstones.

#### *2.2.2.2.2 Rutledge Limestone*

In the vicinity of the ORR, the Rutledge is dominantly clastic with limestone interbeds varying in thickness from 70–160 ft (21–48 m). The base is marked by three limestone beds separated by maroon shale and mudstone approximately 20 ft (6 m) thick. The remaining thickness of the Rutledge consists of light gray micritic to coarsely crystalline thin to medium bedded limestone interbedded with dark gray and maroon shales. Limestone beds are bioturbated and non-fossiliferous. Individual beds range from 2–5 ft (0.6–1.5 m) thick. The upper contact with the Rogersville Shale is abrupt.

A core recovered from the Rutledge Limestone in GW-972(I) during the Phase I site characterization found a predominant sequence of interbedded mostly laminated maroon shales and mudstones with occasional siltstones and light to dark gray or white limestone and calcareous siltstone layers. Glauconite laminae are common. The lighter colored laminated limestone/calcareous siltstone layers were never found to exceed about 0.1–0.3 ft (3–10 cm) in thickness. A few shale beds ≤0.5 ft (15 cm) to about 1 ft (30 cm) in thickness occur intermittently within the cored section. The uppermost 4 ft (1.3 m) of the core is completely clastic, the remainder to total core depth is composed of intermittent unweathered limestone and calcareous siltstone laminae.

#### *2.2.2.2.3 Rogersville Shale*

The Rogersville Shale is a massive to very thinly bedded mudstone with siltstone interbeds. It varies from 70 to about 120 ft (21–36 m) in thickness on the ORR. The lower part dark gray mudstone with some maroon shale in the lower part. Siltstone interbeds are glauconitic, gray to gray-green, wavy to lenticular, and exhibit cross-bedding. Siltstone textures fine upwards in graded bedding sequences, and the bases of siltstone layers may show erosional scour marks and bioturbation. According to Hatcher, et al. (1992), a 1–2 ft glauconitic limestone bed may be present in the lower Rogersville Shale.

The upper Rogersville is composed of maroon shale containing thin (< 1 in. thick) partings of wavy, light gray siltstone or clayey limestone lenses. These are often associated with glauconite laminae. The top of the Rogersville is marked by reddish, thick-bedded to massive 3–6 ft (1–2 m) thick mudstone.

Geophysical logs from GW-974(I), installed as part of the Phase I site characterization study indicate that the predominant lithology in the Rogersville Shale at this site is clastic, but that there appear to be two limestone beds, each less than 2 ft thick (65 cm), in the cored interval.

#### *2.2.2.2.4 Maryville Limestone*

The Maryville Limestone on the ORR is informally subdivided into upper and lower units, and its total thickness ranges from 310–520 ft (95–158 m). Lee and Ketelle (1989) report that the Maryville Formation at the WBCV study site is 430 ft thick (down-hole depth, uncorrected for structural dip). The lower unit consists of calcareous mudstones with thin, even to wavy interbeds of calcareous siltstones and oolitic or peloidal calcarenites that occur in 1–2 in. thick upward-coarsening cycles, with mudstones at the base and oolitic beds at the top. Glauconite is present near the tops of some thin limestone beds (Lee and Ketelle 1989). Upward coarsening sequences are highly variable, and the oolitic cap may be missing from individual sequences. Individual beds within the coarsening upward sequences may exhibit upward-fining textures; the top of the sequence often terminates abruptly. The lower unit contains several limestone beds ranging from 20–40 ft (6–12 m) thick. The lower unit of the Maryville Limestone underlies a discontinuous subsidiary ridge on the south flank of Pine Ridge.

The upper unit of the Maryville Limestone contains abundant intraclastic flat limestone pebble conglomerate beds. Beds are medium gray and range from thinly bedded to medium bedded. Intraclastic conglomerates are separated by beds of siltstone, mudstone, and shale. Siltstones are gray to gray-green, locally calcareous, and thinly bedded to laminated. Mudstones and shales are dark gray to black, locally calcareous, and thin to medium bedded.

Thin maroon shales occur in both the lowermost and uppermost section of the Maryville Limestone, suggesting gradational transitions. The contact between the Maryville and Nolichucky is gradational, recognized by increased shale and decreased limestone beds. The Maryville Limestone contains more shale than the Nolichucky Shale in EBCV.

Maryville bedrock weathers to form a saprolite with translocated clay layers and iron and manganese staining. Differential weathering leads to formation of an irregular bedrock surface. Logs of borings drilled into the Maryville Formation presented in MACTEC (2003, boring H-2) and BNI (1984, wells GW-24, GW-25, GW-27, GW-31, GW-32, GW-33, and GW-38) indicate that weathered Maryville saprolite extends from 25 to over 50 ft below grade. A review of these logs suggests that the average depth to competent bedrock is in the 28–32 ft range. However, the MACTEC (2003) H-2 boring log noted severe weathering in some Maryville Formation shale beds at depths of 66–79 ft below grade, while limestone and calcareous shale beds above and below this zone were unweathered.

Core and borehole geophysical data from GW-976(I) indicates that the Maryville Formation is intensely weathered and leached of calcareous material, with an overall brownish hue, from about 25–50 ft below grade. Extensive iron and manganese staining were evident in this zone. Weathered rock transitions to unweathered rock between 50–55 ft below grade, and laminae and relatively thin beds of gray limestone interbedded with reddish shales and siltstones occur to the bottom of the cored interval. Limestones are gray, 0.9–1.8 ft (27–54 cm) thick; some beds are composed of flat-pebble conglomerates. Note that the core did not penetrate the entire Maryville interval, and likely did not encounter either the top or the bottom of the Maryville.

#### *2.2.2.2.5 Nolichucky Shale*

The Nolichucky Shale is dominantly a dark gray to black fissile massive shale with substantial interbedded carbonates, mainly dolomites and limestones. Intraclastic carbonates are common in the lower Nolichucky. The middle portion of the Nolichucky contains oolitic packstone and grainstone. The upper Nolichucky Shale grades from oolitic limestones to mudstones, to fossiliferous and peloidal

packstones and wackstones and gray calcareous shales. Individual beds are sharply delineated, and in the mudstones, exhibit soft-sediment deformation features. Algal structures are also present in the upper Nolichucky Shale. The contact between the Nolichucky Shale and Maryville Formation is gradational. The clay fraction of Nolichucky shales is dominated by illite clay, with lesser amounts of chlorite and kaolinite (Dreise, 2002).

Fractures are the dominant macropores in the saprolite (Driese 2001). Two sets of fractures, one parallel to bedding and the second normal to bedding, are present in the saprolite. Illuviated pedogenic clays commonly partially to completely fill the fractures. Iron-manganese deposits are also common fracture filling materials in the Nolichucky saprolite. Some fractures contain illuviated sand to pebble sized fillings deposited by water moving downward through the saprolite (Dreise 2001). Most of the fracture filling clays and iron-manganese coatings occur in the interval between 1 and 3 ft below grade, which corresponds to a zone of low hydraulic conductivity.

Nolichucky Shale saprolite is brown to olive, acidic, and has a relatively low iron and carbonate content. Saprolite extends to considerable depth due to water penetration along joints and fractures. In contrast with unweathered Nolichucky clays, saprolite clays are dominantly smectite-chlorite and vermiculite; this difference is the result of pedogenic remineralization (Driese, et al. 2001). Depth to competent bedrock is highly variable and gradational, but appears to range from 5 ft to over 50 ft. Numerous boring logs note that the shale becomes increasingly harder and shows less weathering with depth.

#### *2.2.2.2.6 Maynardville Limestone*

The Maynardville Limestone is a thin-bedded to massive limestone, non-cherty and dolomitic in the upper beds, and containing a few shale partings. Hatcher, et al (1992) indicates that thickness varies from 260 ft (79 m) to 415 ft (127 m), while the 1996 siting study (DOE 1996) indicates a thickness of 328 ft (100 m) to 360 ft (110 m) for the East Bear Creek area. The Maynardville Limestone is subdivided into a basal unit, the Low Hollow Member, and an upper unit, the Chances Branch Member.

The Low Hollow Member is characterized by evenly thin-bedded to massive fine to medium grained dolomitic calcarenite with interbeds of oolitic calcarenite and intermittent shale partings. The massive lower beds of the Low Hollow Member contain abundant stylolites, while oolitic beds are more common near the top of the sequence.

The Chances Branch Member consists of thin- to medium-bedded tan to light gray dolomite, thin-bedded dolomitic calcarenite and micrite, and oolitic calcarenite. The top of the Chances Branch Member is marked by thin- to thick-bedded dolomite and dolomitic calcirudite with evidence of bioturbation.

Residuum formed on the Maynardville is saprolitic (i.e., retains sedimentary and structural features, such as beds and fractures), deeply weathered (>5 ft/1.5m to competent rock) and clay-rich near the Maynardville – Nolichucky contact, but thinner (± 3 ft/1m to competent rock) near Bear Creek due to erosion. Pinnacles and ledges are common within the weathered Maynardville residuum. Soils developed on Maynardville parent materials exhibit a strongly marked, sticky $B_t$ (clay) horizon.

### 2.2.2.3 Knox Group

The Knox Group is the principal aquifer system on the ORR, and consists of five dolomite formations. Only the Copper Ridge Dolomite, the basal unit of the Knox Group, is described here because it forms the south side of BCV.

The Upper Cambrian Copper Ridge Dolomite is 800–1,100 ft (250–350 m) thick and consists of massively bedded cherty dolomite characterized by brownish-gray medium to coarsely crystalline dark-brownish gray dolomite that has a petroleum-like odor on freshly exposed surfaces. The upper portion of the Copper Ridge Dolomite is medium to light grey, becomes more fine-grained and more

thick-bedded. Nodular, bedded, and oolitic chert (a type of quartz) become increasingly common in the upper Copper Ridge, as do thin siliceous sandstone beds.

### 2.2.3 Geologic Structure

The EMDF candidate site is located in the upper plate of the Whiteoak Mountain thrust fault, an imbricate fault with surface traces surfacing on the northeast side of Pine Ridge in Gamble Valley and McNew Hollow, as shown in Figure E-8. The Whiteoak Mountain Thrust fault was formed during the Taconic Orogeny 245–470 million years ago (middle to late Paleozoic Period).

Lee and Ketelle (1989) observed that small and intermediate-scale structural features, such as drag folds and high angle shears are ubiquitous in Conasauga Group units. Deformational features were well developed in the heterogeneous thin to medium bedded units in the Nolichucky and Maryville Formations, and least well developed in the more homogeneous units, such as the Rogersville, Rutledge, and Pumpkin Valley Formations.

Lee and Ketelle (1989) were able to correlate one deformational zone in several wells in the WBCV area. This feature is characterized by extensive drag folds, gouge and shear fractures in the upper Maryville Limestone and lower Nolichucky Shale. The geometry of these features suggest they are boudinage, a structural feature that relates to rock extension (Fossen 2010).

Thrust faults result in repetitive sequences of strata, so that many Conasauga Group units, for example, appear in Melton and BCVs, and again in Poplar Creek Valley northwest of Blackoak Ridge. Bedding plane orientations measured in Rome Group exposures on Pine Ridge near the EMDF site strike approximately N55°E and dip to the southeast. Dip angles in the vicinity of the proposed EMDF range from 33° to 62°, averaging about 46°, as measured in outcrops on Pine Ridge (Lemiszski 2000).

Smaller high-angle reverse and normal faults and extensive fracture systems may be associated with the stress adjustments that result from more or less brittle rock sliding over other rock. Rothschild, et al. (1984) noted that tear faults oriented perpendicular to regional thrust faults were identified in Conasauga Group rocks near the Hydrofracture Facility in Melton Valley. Rothschild, et al. (1984) also indicated that four possible tear faults had been located at Solid Waste Storage Area 7 in Melton Valley. Lemizski (1995) mapped several relatively short normal (tensional) and thrust (compressional) faults associated with folding at the ETTP site. Dreier and Koerber (1990) and King and Haase (1987) identified cross-cutting tear faults in BCV and Pine Ridge based on ridge crest offsets and subsurface data. Many of these ridge offsets are coincident with valleys on the flank of Pine Ridge, and King and Haase (1987) show a possible fault crossing through the proposed EMDF site, apparently on the basis of lineation of ridge off-sets. Evidence of faulting observed in bedrock cores includes slickensides, striations created by rocks sliding against rocks, that was noted in cores from the Maryville and Nolichucky Formation shales in the main plant area (MACTEC 2003) and from the Bear Creek Burial Grounds (BCBG) area (BNI 1984). A number of core logs describe brecciated and gouge zones (BNI 1984), indicating possible fault zones. Hatcher, et al. (1992) interpreted these ridge-crest offsets as indications of folding related to detached blocks (horses) underlying the thrust sheet. Lee and Ketelle (1989) expressly examined the possibility that a tear fault controlled the location of NT-15 at the WBCV site by evaluating core and boring data and trenching through saprolite at the Maryville Limestone – Rogersville Shale contact. They found no evidence of a tear fault or other high-angle fault at that location, and concluded that the location of NT-15 and other streams on the flank of Pine Ridge is related to regional joints or fractures. No confirmed high-angle faults are mapped in the BCV. Moore (1988) noted a few high angle faults near ORNL, but tentatively concluded that "*. . . groundwater conduits can occur along and near faults . . . but that such features are uncommon and may be rare.*"

The multiple episodes of tectonism and structural deformation in the Valley and Ridge have resulted in the formation complex systems of fractures (Hatcher, et al., 1992) in ORR bedrock. A fracture, or joint, is

any essentially planar parting or discontinuity in rock, and occur in all of the lithologies found on the ORR. Fractures are distinguished from faults in that little or no actual movement occurs on fractures. Bedrock under the ORR typically has very low effective matrix porosity, and for this reason, fractures are of primary importance in ground water occurrence and movement, as will be discussed in more detail in the following sections.

The fracture systems on the ORR are the result of multiple tectonic events (see Figure E-10), stress relief resulting from erosional removal of rocks reducing vertical compression on underlying rocks, and from lithology discontinuities across bedding planes. Two orthogonal sets plus a set parallel to bedding planes, illustrated in the top diagram of Figure E-10, are common throughout the ORR.

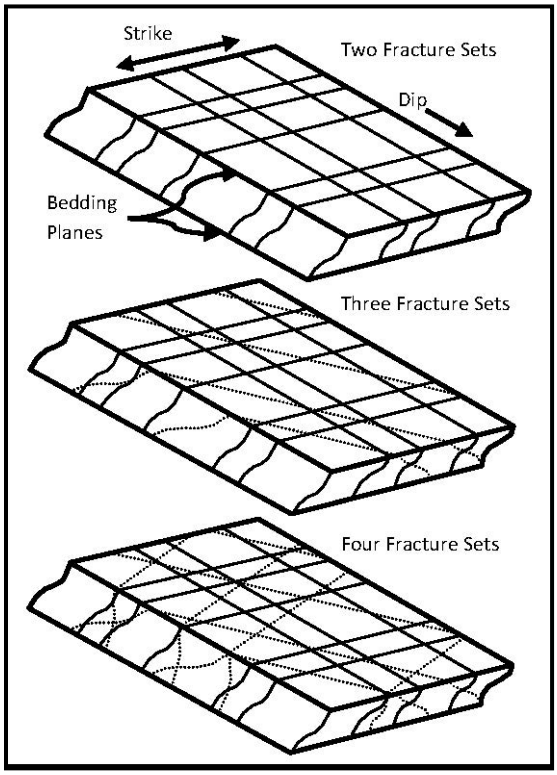



**Figure E-10. Increasing Complexity Added by Multiple Fracture Sets**

One major fracture set consists of bedding planes which dip to the southeast and strike northeast to southwest. Two additional sets are more or less vertical and trend northwest to southeast, parallel to strike, and northwest to southeast, parallel to dip. Other fracture systems that have been documented on the ORR trend east northeast to west southwest (Lemizski 1995; BNI 1984) or north-south and north-northwest (Moore and Toran 1992). Lemizski (1995) observed that bedding-plane fractures tend to be wider and more open than orthogonal fractures sets, possibly as a result of the stress field formed by erosional off-loading. Eaton et al. (2007) states that lithologic heterogeneity favors the formation bedding plane fractures.

Lee and Ketelle (1989) noted that fracturing is ubiquitous throughout Conasauga Group rocks at the WBCV site, reporting two major fracture orientations. One set trends northwest to southeast, with dips in the 10° to 30° range to the east. The second set exhibits highly variable orientation, but trends roughly

north-south and dips 5°–50° to the west. Bedding planes are oriented northeast to southwest with dips ranging from 10° to approximately 70° to the southeast. Sledz and Huff (1981) and Rothschild, et al. (1984) also noted that fracture systems in the Conasauga Group in BCV were more complex than those in Melton Valley, reflecting multiple phases of deformation. Rothschild, et al. (1984) suggests that a north-south fracture set, possibly related to shear forces, is common to Conasauga rocks in both Bear Creek and Melton Valley.

Regional fracture systems formed by large-scale regional deformational stresses may be over-printed with smaller-scale local fracture systems related to folds and faults, which add complexity to the fracture systems. In some areas, three and even four orthogonal fracture sets may be present, together with bedding planes, as illustrated in the lower two diagrams of Figure E-10.

Moore and Young (1992) used subsurface flow meters to determine fracture density and conductivity in Bethel Valley and BCV. Their data show that fractures >1.2 m long occur mainly within the upper 6.1 m of the saturated zone, whereas fractures <1.2 m long occur both near the water table and at deeper levels. The shorter fractures (65% of the total) have dips of 45° to 82° and probably transmit water chiefly toward cross-cutting tributary streams. The longer fractures (35% of the total) have dips of >82° and probably transmit ground water downslope toward main-valley streams. The thickness of bedrock matrix intervals in the flow meter surveys show that orthogonal fracture spacing is about 0.15–0.73 m and the steeply dipping fractures apparently have the closest spacing. Further, they corroborate the notion that the most conductive zone is near the water table.

Eaton, et al. (2007) and Hart et al. (2006), among others, note that fracture systems are typically discontinuous across lithologic boundaries due to the differences in response to stress. Fractures may terminate at changes in lithology (e.g., at bedding planes), changes in bed thickness, at intersections between different fracture systems, and other discontinuities (e.g., stylolites in carbonates or fault planes, or by simply ending. Orthogonal terminations may be at acute angles or nearly perpendicular. The combination of two orthogonal sets of fractures and bedding plane fractures break the host rock into rectilinear blocks (Lemizski 1995; Solomon et al. 1992). Additional over-printed fracture sets reduce overall block size and shape.

The Phase I site characterization performed geophysical logging, including optical and acoustic televiewer logs, to determine the strike and dip of bedding planes in bedrock; these data were used to construct Schmidt stereo plots to examine trends and anomalies. Bedding planes and bedding-plane parallel fractures typically dip SE at angles ranging from 40° to over 70° and there is relatively little deviation in intra-formational angle or direction. However, two wells exhibit some anomalous differences.

GW-968 and GW-970, both in the Pumpkin Valley Shale, show somewhat different structural characteristics, as shown in Figure E-11.

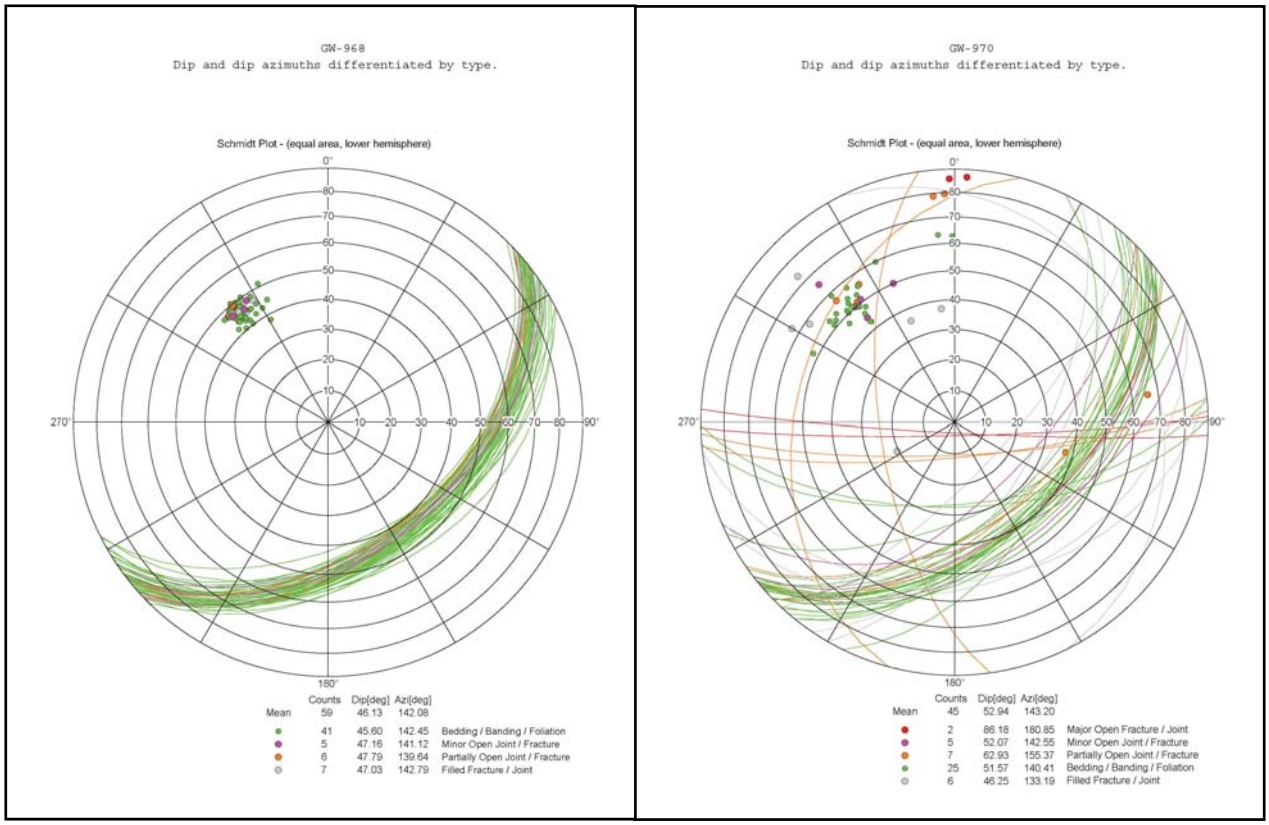



**Figure E-11. Schmidt Stereonets for Wells GW-968 and GW-970**

On the right, the GW-968 stereonet exhibits a tight grouping of planes and poles with essentially no deviations in dip or strike. This tight grouping is also present in GW-972, GW-974, and GW-976, albeit with slightly more scatter in the latter two wells. On the other hand, well GW-970 shows a much greater scatter in planes and poles, even for the dominant dip and strike direction. A few fractures or joints dip south at high angles, and two open fractures that dip west. These multiple fracture orientations are indicative of multiple fracture sets, as well as the possible presence of micro-scale to meso-scale structures.

Plots of bedding planes observed in GW-976 are quite similar to those observed in GW-970, with several fractures or joints that dip south and possibly one healed fracture that dips west. The data from these two wells suggest that the structural characteristics of the east portion of the EMDF site are somewhat more complex than on the west side of the site.

In all televiewer logs the majority of bedding plane and bedding-plane-parallel joints or fractures appeared to be closed, although resolution was not adequate to see very fine openings. A small proportion of fractures appeared to be healed, and calcite-filled fractures were evident in the cores, particularly in the core from GW-976. Open fractures were observed in some cored intervals, as well as in televiewer logs as shown in Figure E-11. Note that identification of open fractures from televiewer logs may be somewhat subjective.

### 2.2.4 Seismicity

There is no evidence of active, seismically capable faults in the Valley and Ridge physiographic province or within the rocks under where the ORR is located (DOE 2011a). Oak Ridge area lies in Uniform

Building Code seismic zones 1 and 2, indicating that minor to moderate damage could typically be expected from an earthquake. Although there are a number of inactive faults passing through the ORR, there are no known or suspected seismically capable faults. As defined in 10 CFR 100, Appendix A, a seismically capable fault is one that has had movement at or near the ground surface at least once within the past 35,000 years, or recurrent movement within the past 500,000 years. The nearest capable faults are approximately 300 miles (480 km) west-northwest of the ORR in the New Madrid (Reelfoot Rift) Fault Zone (DOE 2011a). Historical earthquakes occurring in the Valley and Ridge are not attributable to fault structures in underlying sedimentary rocks, but rather occur at depth in basement rock (Powell, et al., 1994).

Oak Ridge lies within the East Tennessee Seismic Zone (ETSZ), a seismically active area lying roughly halfway between the New Madrid Seismic Zone and the Charleston, South Carolina Seismic Zone. The ETSZ extends from central Alabama to southern West Virginia and is roughly coincident with the Valley and Ridge Physiographic Province. The mechanisms and frequency of occurrence of earthquakes in the ETSZ are not well understood. Some investigators believe that earthquake activity in the ETSZ is declining or ephemeral (Powell, et al., 1994), while other believe that the probability of more intense earthquakes in the region remains significant (Petersen, et al. 2008). More recent evaluation using new or revised modeling approaches suggest that earthquake magnitudes and associated ground motions may be greater than earlier models suggest. (Petersen, et al. 2014)

Hatcher, et al (2012) and Vaughn, et al. (2010) have shown strong field evidence of earthquake-related features, such as fracturing, co-seismic faulting, liquefaction, and similar, that suggests that earthquakes with magnitudes exceeding 6.5 have occurred in the region within the late Quaternary Period, possibly as late as 73,000–100,000 years ago.

Historic earthquakes in the ETSZ typically are of small magnitude and mostly go unfelt by people. However, a number of historic earthquakes have had magnitudes greater than 4.0, and were therefore capable of producing at least some surface damage. According to Stover and Coffman (1993), from 1844 to 1989 East Tennessee has historically experienced 26 earthquakes that were widely felt and seven of these caused at least minor damage. An earthquake that shook Knoxville in 1913 was estimated to have moment magnitude of about 5.0. Another earthquake that occurred in 1930, with an epicenter approximately 5 miles from Oak Ridge, had a Mercalli intensity of V to VII (see Table E-4 for a description of scales). The largest recent seismic event was a moment magnitude 4.7 earthquake that had an epicenter near Alcoa, Tennessee, 21.6 miles southeast of Oak Ridge in 1973. The intensity of this earthquake felt in Oak Ridge was estimated to be in the V to VI (light).

**Table E-4. Earthquake Magnitude and Intensity Scales**

| Moment Magnitude Scale | Modified Mercalli Scale | Intensity Descriptor | Peak Ground Acceleration (g) |
|---|---|---|---|
| < 2.0 | I | Minor | <0.0017 to 0.039 |
| 2.0 – 2.9 | I - II | | |
| 3.0 – 3.9 | II – IV | | |
| 4.0 – 4.9 | IV - VI | Light | 0.039 to 0.092 |
| 5.0 – 5.9 | VI - VII | Moderate | 0.092 to– 0.18 |
| 6.0 – 6.9 | VII - IX | Strong | 0.18 to 0.34 |
| 7.0 and up | VIII - XII | Major to Catastrophic | 0.34 to >1.24 |

Source: USGS 2000

The Oak Ridge region continues to be seismically active, with 50 earthquakes recorded within a radius of 100 km (62 miles) of the ORR since 1973. Approximately 60% of the 50 earthquakes within this radius occurred at depths greater than 6 miles (10 km). The closest of those events occurred on June 17, 1998, with an epicenter within ORR near the ETTP, registering a magnitude 3.3 (USGS 2013a). Two other earthquakes with epicenters beneath the ORR have been recorded since 1973. These occurred on May 2, 1975 (MMI ≈ 2.6) and April 11, 2013 (MMI ≈ 2.2).

### 2.2.5 Geotechnical Characteristics

Two detailed geotechnical studies were completed by Ogden (1993 a, b) and CH2M-Hill (2000) for areas directly east and west of the EMDF site. These reports are summarized in Attachment B to this Appendix. Additional samples were collected and analyzed as part of the Phase I Site Characterization, and these data are reported in Attachment A.

Ogden (1993a) reported on a geotechnical evaluation of a potential site for proposed ORR storage facility Site B, located on the south flank of Pine Ridge between NT-1 and NT-2. A total of 27 borings were installed, and six were cored into bedrock. Four of the 27 borings were used as temporary piezometers, and an additional 15 existing wells from nearby areas were monitored to create water table maps. Ogden (1993b) reports on a similar study conducted at Site C, which is now the EMWMF site. The Site C study installed 52 borings, 11 of which were cored into bedrock, and nine of which were used as piezometers. Both studies collected numerous split-spoon, Shelby tube, and core samples for laboratory testing.

Standard geotechnical tests were carried out on split-spoon and Shelby tube samples for both studies. Tests conducted on all samples included moisture content, unit weight, specific gravity, Atterberg Limits (liquid limit/plastic limit, and plasticity index), visual classification (per Unified Soil Classification System [USCS]), and grain size analysis. Consolidation tests, California bearing ratio, standard Proctor tests, and shear strength tests were conducted on a more limited set of samples.

The studies found that a relatively thin but variable layer of surface soils would need to be removed as unsuitable for construction. Thickness of unsuitable soil was expected to be greater in the small draws and stream valleys. Much of the remaining soil and saprolite could be used as engineered fill, if placed and compacted at the proper moisture content. Larger fragments may have to be reduced or removed.

Both studies recommended a net allowable bearing capacity of 3.0 kips/ft$^2$, which included a safety factor of 3. Standard Proctor densities at 100% compaction ranged from 109–115.4 lbs/ft$^3$, and optimum moisture contents ranged between 14.1% and 18.2%. Shrink-swell potential varied from -3% to -14% (shrink) for soil, and from 5–18% (swell) for weathered and unweathered bedrock.

The Ogden reports further recommend that a series of subsurface drains be installed to remove water during construction, promote drainage of seeps and springs, and to intercept surface water draining from higher on Pine Ridge.

Geotechnical testing conducted by CH2M-Hill (2000) in support of the EMWMF design included sampling in 10 test pits. Laboratory tests included moisture content, moisture density, specific gravity, Atterberg Limits, visual classification, grain size analysis, triaxial strength, and consolidation. CH2M-Hill (2000) reported that soils generally consisted of high plasticity clays (USCS class CH), with a smaller number of samples being low plasticity clays, low plasticity silts, and silty sand. Atterberg liquid limits for the EMWMF site ranged from 39% to 53%. Moisture contents ranged from 10.4% to 26.8%. Modified Proctor results indicated a maximum dry density range from 106 lbs/ft$^3$ to 113 lbs/ft$^3$ at optimum moisture contents of 15% to 17%. Triaxial strength test results for one EMWMF sample indicates an effective friction angle of 31° and cohesion of 159 lbs/ft$^2$. Coefficient of consolidation ($C_v$) was reported as 1.0 ft$^2$/day.

## 2.3 GROUND WATER

All geologic units underlying the ORR are water-bearing to some degree, although the ability of some units to produce water at useful rates is poor. The Knox Group has been termed an aquifer because it is capable of sustaining the high production rates needed for residential, farm, and industrial use. The Maynardville Limestone is often lumped with the Knox Group aquifer (Hatcher, et al. 1992) because it can sustain useful production rates. Brahana, et al. (1986) note that the Knox Group is the most important aquifer in East Tennessee.

The remaining geologic units under the ORR have been termed aquitards, meaning that they contain water, but have less capacity for transmitting water than do aquifers. This is not to say that ground water does not exist in these units, but that these units do not yield water in the quantities normally needed for most water production wells. However, DeBuchananne and Richardson (1956) and Brahana, et al. (1986) note that these aquitards are tapped for residential and other uses throughout East Tennessee, and that units of the Conasauga Group commonly yield from several gallons per minute (gpm) to as much as 200 gpm from cavities.

### 2.3.1 Aquifer Characteristics

Ground water occurs in three types of pores on the ORR: rock matrix, fractures, and cavities or conduits. Porosity is defined as void space in an otherwise solid material, in this case, rock. The volume of pore space is generally given as a percent of the bulk rock. Pores can contain water or gases, and if interconnected with other pores, can transmit fluids under the influence of gravity or induced pressure. Effective porosity is a measure, as a percent of the bulk rock volume, of how well the pores are interconnected. Rock with high porosity but low effective porosity transmit fluids poorly. Worthington (2007), among others, points out that in carbonate aquifers, matrix pores provide long-term storage of water (and contaminants), but little flow; conduits provide rapid flow but little storage, and fractures provide both storage and flow.

#### 2.3.1.1 Matrix pores

Matrix porosity is composed of small voids in the rock that may or may not be well enough interconnected to allow water to flow. Matrix porosity is generally an original feature of sedimentary rocks, but can be modified by post-depositional physical and chemical changes. There are conflicting interpretation regarding the ability of matrix pores to contribute to flow, and most indicate that they do not contribute significantly to flow. However, their ability to absorb and release contaminants make them both reservoirs and sources in contaminated environments.

Matrix porosity of the soil and residuum over Conasauga Group rock units ranges from 30–50%, typical of clayey materials (Driese, et al. 2001; Solomon, et al. 1992, Moore 1988). Moore (1988, 1989) indicates that specific yield, the amount of water that will drain under gravity alone, is only about 10%, but further states that effective porosity is only 0.2%. Conversely, Dorch, et al. (1996) reported effective porosity ranged from 26.8–39% for weathered Nolichucky Shale saprolite, and that the proportion of effective porosity decreased with depth, in tandem with a decrease in the degree of weathering.

Much of the effective porosity in very shallow soil and residuum (i.e., the stormflow zone) is due to outside influences, for example, plant roots and animal or insect burrows. These large aperture pores, termed mesopores, compose only about 0.2 % of the soil volume, but account for over 90% of flow in the storm-flow zone (Solomon, et al. 1992; Moore 1989).

#### 2.3.1.2 Fractures

The majority of ground water flow on the ORR occurs in fractures (Solomon et al. 1992; Moore 1988). Overall, fracture spacing and density was found to be highly complex and anisotropic, because some

fracture sets and orientations are more well developed than others. Sledz and Huff (1981) attempted, without success, to use linear regression to find relationships between fracture length, density, lithology, and bed thickness. Results indicated little correlation between the parameters evaluated. They found fracture densities in the Pumpkin Valley Shale in BCV as high as 100–200 fractures per meter in some Conasauga Group rocks. The mean range of fracture density in siltstones is 6–45 fractures per meter, and 12–28 fractures per meter in shales. They also noted that Conasauga Group shales exhibit greater fracture densities in thinner lamina, but in siltstones the density of fractures decreased as bed thickness increased. Moore and Toran (1992) reported an average orthogonal fracture spacing of 13.75 in. (35 cm). Lee and Ketelle (1989) reported numerous and ubiquitous fractures in cores from the WBCV site, noting that fracture density is higher in the Maryville and Nolichucky Formations than in the rest of the Conasauga Group.

Fractures may propagate over long distances, particularly along bedding planes or in massively bedded rocks, but are more typically on the order of a few inches to a few feet long (Dreier, et al. 1993; Moore 1988; Sledz and Huff 1981). Sledz and Huff (1981) reported that mean joint length in Pumpkin Valley shales was nearly constant at 4.7 in. (12 cm); in siltstones fracture length varied 1–30 in. (2–76 cm). Further, fracture length increased in thinner beds and lamina of shales, and fracture length increased as bed thickness increased in siltstones. Lemizski (1995) and Dreier, et al. (1993) noted that bedding plane fractures tend to be much longer and wider than orthogonal fractures. Eaton, et al. (2007) notes that *". . . few if any vertical fractures will propagate across all layer interfaces"* where rock layers are characterized by differences in response to tensile stresses. This serves to increase ground water flow path tortuosity.

Aperture is a critical measure of a fracture's ability to conduct water. Moore and Toran (1992) give a geometric mean fracture aperture of 0.005 in. (0.12 mm) for ORR rock units, and since porosity is the ratio of aperture to spacing (35 mm), porosity averages about 0.34%. Bedding plane fractures tend to be wider and more open than the vertical fractures (Lemizski 1995; Solomon, et al. 1992). Sledz and Huff (1981) indicated that, for the Pumpkin Valley Shale, apertures in outcrop and in unweathered bedrock ranged between 0.005 in. and 0.28 in. (0.1 mm and 0.7 mm). They further observed that joints in competent rock were much narrower than those in saprolite. Lemizski (1995) indicated that fracture aperture did not necessarily correlate with other fracture dimensions, such as length.

Moore and Young (1992) conducted flow meter studies on isolated lengths of wells to examine fracture density and behavior. They report higher fracture height and density, and wider aperture, in the top 10 ft of the saturated zone with lower height and density, and narrower apertures, in deeper zones. Moore and Toran (1992) estimated that a recharge boundary was indicated in about 85% of the injection tests conducted on the ORR. This supports the concept that a relatively small number of master fractures control flow.

In carbonates, such as dolomite and especially limestones, fractures are typically solution-widened, and this dissolution process often forms cavity systems near the base of the carbonate bed (Lemizski 1995). Worthington & Ford (2009) found that for fractures in carbonates, porosity varied from 0.001% to 1%, but hydraulic conductivity varied from 100 cm/s to 0.01 cm/s. Thickly bedded limestones having a more homogeneous lithology are most susceptible to this process (Lemizski 1995; Solomon, et al, 1992; Moore 1988). Cavities are discussed in greater detail below.

Fracture width in saprolite is increased relative to bedrock due to weathering (Driese, et al. 2001; Dorsch and Katsube 1996). For example, Driese, et al. (2001) report that fracture aperture in sandstone saprolite ranges from 0.005–0.5 mm, but in shale and siltstone saprolite the range is 0.005–1.5 mm, and in limestone saprolite the range is 0.005–2.0 mm. White & White (2005) modeled a three pore system (matrix, fracture, and conduit) and found that while the largest portion of flow in karstic aquifers occurs in conduits, the main portion of storage is in fractures. Further, they found that fracture aperture is more

important than fracture spacing, and that fractures will dominate flow if apertures approach 1 cm or if gradient is very low so that no preferred pathway develops. Low ground water gradients may also indicate that a preferred pathway (e.g., a trunk fracture) has already developed, and steep gradients may be due to topography (e.g., recharge under a ridge) or to subsurface flow barriers (e.g., a decrease in open fractures across a lithologic boundary).

Fractures are often partially to completely filled with mineral deposits, including calcite, pyrite, and coatings of iron and manganese (DOE 1997; Lee and Ketelle 1989; BNI 1984). Driese, et al. (2001) document extensive filling in saprolite fractures at the base of the soil zone due to translocated clays. These clays and associated iron and manganese deposits choke the fractures, forming a leaky seal between the storm-flow zone and the deeper vadose zone. Logs of wells cored as part of the assessment of the BCBG (BNI 1984) clearly indicate the presence of open, partially-filled, and filled fractures in Conasauga Group rocks. These fillings are formed by minerals crystallizing from solution in waters moving through the fracture. Fracture fillings reduce the aperture and therefore, the ability of the fracture to store and conduct water. Lemizski (1995) found that the apertures of filled and open fractures were essentially the same, suggesting that fracture fillings had been dissolved from the open fractures.

Numerous open and healed fractures were identified in Phase I site characterization wells by optical and acoustic televiewer logs from all deep and in the cores from GW-972 and GW-976. Open fractures from shallow depths commonly were parallel to bedding planes, with sparse cross-bedding fractures and exhibited iron and manganese staining, and there was a general weathered appearance to the shallow rock. Fractures crossing bedding planes were less common. At deeper depths, there were fewer open fractures. Deeper fractures exhibited fewer weathering effects, although a few were notably iron-stained.

Healed (calcite-filled) fractures were very common in the Maryville Formation core from GW-976, particularly below a depth of about 55 ft, but were sparse in the GW-972 core. Healed fractures in GW-976 tended to be oriented roughly vertical to bedding and were often short and truncated by clayey laminae. In contrast, healed fractures in GW-972 core tended to cross multiple thin beds.

#### 2.3.1.3 Cavities

Cavities in bedrock are typically formed by chemical solution and/or mechanical abrasion (the term cavities is used here to encompass any form of void in the rock without reference to cause). White and White (2001) note that karst develops best in purer end-member limestones, those with low amounts of insoluble sands and clays, stating that *". . . shaley limestones are rarely cavernous"* (p. 12). It is also worth noting that conduit formation in formations characterized by interbedded shales and limestones is inhibited and generally confined to the purer limestones. They go on to note that shaley limestones often act as aquicludes.

The proposed EMDF site overlies lower Conasauga units that are apparently not susceptible to conduit development. According to Moore (1988) cavities in the Conasauga Group have been reported only in the Maryville Limestone, Nolichucky Shale, and Maynardville Limestone, all of which contain limestone beds. However, discussion of conduits is important because the conduits of the Maynardville Limestone carry a large proportion of the flow along the center of the EBCV, and which are fed in part by the fracture systems in the clastic rocks of the lower Conasauga Group and the Rome Formation along Pine Ridge. A review of available lithologic logs and data summaries (BWXT 2003) for wells and borings in EBCV indicate that cavities are rarely, if ever, encountered in the stratigraphic units that underlie the proposed EMDF site. An analysis of cavities by formation for 222 wells in BCV numbered between GW-601 and GW-833, based on information provided in data summaries (BWXT 2003), found that the majority of conduits or cavities in BCV occur in the Copper Ridge and Maynardville Formations, especially adjacent to formation boundaries. Of the 58 Nolichucky wells reviewed, only two wells encountered cavities. Forty-nine wells that penetrate the remaining Conasauga formations did not

encounter any cavities. While not conclusive, these data clearly indicate that the vast majority of cavities, and hence conduits, occur in the Copper Ridge, Maynardville, and Nolichucky formations, and that the stratigraphic boundaries at the top and bottom of the Maynardville Limestone are more susceptible to conduit formation than the formation interior.

No cavities were encountered in bedrock cores or by drilling for the 10 monitoring wells installed for the EMDF Phase I site characterization. This is as expected, since the majority of bedrock is either clastic, or limestone with significant clastic content. Maryville Formation limestones in the GW-976 well core contained no evidence of dissolution features. While these observations are not conclusive, the do indicate that conduits are not likely to be present at the EMDF site.

Soil pipes are a special case of cavity that form in clay soils as a result of mechanical erosion along subsurface zones of weakness. Soil piping can occur anywhere in the lower portion of the soil column, but are more generally found at the soil-bedrock interface. Moore (1988) and BNI (1984) noted the presence of soil piping in Conasauga Group regolith, particularly at the base of the regolith. A small cavity was reported in weathered shale and sandstone while drilling the borehole for GW-46 at the EMWMF (BNI 1984). This may be evidence for soil piping. As noted above, no cavities were detected by EMDF Phase I site characterization drilling.

### 2.3.2 Hydraulic Conductivity and Results of Tracer Tests

Various methods have been used to estimate the rate of flow in ORR aquifers. Hydraulic conductivity is a measure of how well water can move through a given rock area, and with water table gradient, can be used to estimate flow velocity. Tracer tests offer one means of direct ground water flow rate measurement, although they require either a large number of sampling points, or knowledge of or good predictions of flow patterns.

#### 2.3.2.1 Range of Hydraulic Conductivity

Hydraulic conductivity is difficult to measure in fractured or karstic aquifers, and its significance as a measure of gross hydraulic behavior is arguable. Where fracture aperture is relatively wide or conduits are present hydraulic conductivity cannot be accurately estimated because flow is non-laminar (laminar flow is a basic assumption of the Darcian hydraulic conductivity equations). Micro-scale hydraulic conductivity may also be measured on core samples in a laboratory, at the meso-scale by field testing, and at macro-scales by calibrating ground water models to measured conditions across a region. All of these methods produce relevant data (Hart, et al 2006; van der Kamp 2001); however, the most useful for the purposes of this report are those measured at meso-scales and macro-scales.

Although matrix porosity may be large for some lithologies, permeability in the clastic and carbonate rocks underlying BCV tends to be very small, because effective porosity is very small. On the ORR, hydraulic conductivities range from $10^{-9}$ cm/s in deep wells to essentially infinite in large open cavities. Hydraulic conductivity varies by lithology, degree of weathering, and depth. Tables E-5 and E-6 summarize hydraulic conductivity data from several sources and compare the values to those used in Preliminary Waste Acceptance Criteria (PreWAC) modeling described in Appendix H.

**Table E-5. Mean Hydraulic Conductivity by Formation Compared to Preliminary WAC Model Input**

| Stratigraphic Unit | Connell and Bailey (1989) | | EMDF Phase I | Summary Data from PreliminaryWAC Model | | |
|---|---|---|---|---|---|---|
| | Regolith | Unweathered Rock | Bedrock Only | Geometric Mean Hydraulic Conductivity (cm/s) | | |
| | Hydraulic Conductivity(cm/s) | Hydraulic Conductivity (cm/s) | Hydraulic Conductivity (cm/s) (Well Number, Test Depth Range Below Grade) | Dip Direction ($K_x$) | Strike Direction ($K_y$) | Vertical Direction ($K_z$) |
| Maynardville Limestone | 2.22E-05–4.8E-02 | 1.09E-05–2.48E-02 | Not tested | 6.71E-06 | 5.64E-05 | 6.71E-06 |
| Nolichucky Shale | 1.31E-05–1.15E-03 | 1.62E-07–2.80E-03 | Not tested | 8.44E-07 | 7.35E-06 | 8.44E-07 |
| Maryville Limestone | 1.06E-05–7.34E-04 | 1.59E-07–7.34E-04 | 1.2E-05 (GW-976, 68-78 ft) | 4.52E-07 | 3.94E-06 | 4.52E-07 |
| Rogersville Shale & Rutledge Limestone | 1.83E-05–9.88E-05 | 1.62E-07–1.94E-04 | Results indeterminate | | | |
| Pumpkin Valley Shale | 1.55E-05– 4.13E-04 | 1.62E-07–2.96E-04 | 3.1E-05 (GW-968, 23-33 ft); 1.5E-04 (GW-970, 44-54 ft) 3.1E-05 (GW-970, 52-62 ft) 1.4E-05 (GW-970, 65-75 ft) | 5.02E-07 | 4.37E-06 | 5.02E-07 |
| Rome Formation | — | 2.89E-06–2.60E-03 | Not tested | 7.06E-07 | 6.14E-06 | 7.06E-07 |
| Deep Bedrock, undifferentiated | — | 7.06E-09–4.94E-08 | Not tested | — | — | — |

**Table E-6. Summary Hydraulic Conductivity Data by Depth in Conasauga Formation Rocks at the WBCV Site Compared to Preliminary WAC Model Input**

| Depth Range (ft) | | Golder Associates (1989, p. 12) | | | Preliminary WAC Model | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $K_x$ ($K_{Dip}$) (cm/s) | $K_y$ ($K_{Strike}$) (cm/s) | $K_z$ ($K_{Vert}$) (cm/s) | Model Layers | Thickness (ft) | $K_x$ ($K_{Dip}$) (cm/s) | $K_y$ ($K_{Strike}$) (cm/s) | $K_z$ ($K_{Vert}$) (cm/s) |
| Shallow | 0–50 ft | 1.0E-04 | 2.0E-04 | 1.0E-06 | 1 - 3 | 10 - 25 (variable) | 4.61E-05 | 2.30E-04 | 4.61E-05 |
| Intermediate | 50–300 ft | 2.0E-05 | 4.0E-05 | 2.0E-07 | 4 - 8 | 20 | 2.07E-06 | 2.07E-05 | 2.07E-06 |
| | | | | | 9 | 150 | 7.37E-07 | 7.37E-06 | 7.37E-07 |
| Deep | >300 ft | 2.0E-06 | 4.0E-06 | 2.0E-08 | 10 | 200 | 2.02E-07 | 2.02E-06 | 2.02E-07 |
| | | | | | 11 | 300 | 1.99E-08 | 1.99E-07 | 1.99E-08 |

Moore and Young (1992) calculated the effective porosity, specific yield, hydraulic conductivity, and transmissivity of the permeable fractures from a combination of borehole flow meter surveys and injection and pumping tests. The geometric mean of transmissivity for permeable fractures is $9.7\times10^{-5}$ $cm^2/s$, and the geometric mean of hydraulic conductivity is $1.4\times10^{-4}$ cm/s. Average hydraulic conductivity and transmissivity are nearly the same between depths of 7–55 ft (2.1–17 m), but probably are smaller at deeper levels. For a fracture spacing of 3 in. to 30 in. (0.15–0.73 m), the specific yield of a permeable interval is likely to be in the range $9.2\times10^{-5}$ to $7.5\times10^{-4}$ (specific yield is dimensionless). Within 20 ft (6 m) of the water table, average specific yield is probably in the upper half of this range because more fractures occur at these levels. At deeper levels, some fractures are closely spaced, but the average specific yield may be in the lower half of the calculated range. Saprolite conductivity has a wider range, from $10^{-2}$–$10^{-5}$ cm/s, than bedrock, and this has been attributed to an increase in fracture width due to weathering and demineralization (Driese, et al. 2001; Dorsch and Katsube 1996; Moore 1989).

CH2M-Hill (2000) reported permeability test results for soils as ranging from $2.9\times10^{-6}$ cm/s to $5.8\times10^{-8}$ cm/s. Phase I Site Characterization (see Attachment A for details) performed slug tests in wells completed in shallow soil/saprolite, as well as and laboratory tests on Shelby tube samples from selected soil zones. Slug test results ranged from $1.46\times10^{-6}$ cm/s to $1.22\times10^{-7}$ cm/s. Shelby tube hydraulic conductivity test results were similar, ranging from $6.5\times10^{-6}$ cm/s to $3.9\times10^{-7}$ cm/s. Nine packer tests were performed in Phase I bedrock wells to determine hydraulic conductivities for intervals selected on the basis of borehole televiewer logs and in-hole flow tests. Hydraulic conductivities from these tests ranged from $1.5\times10^{-4}$ cm/s to $1.2\times10^{-5}$ cm/s, as shown in Table E-5. Note that the hydraulic conductivity values reported for the EMDF site represent an upper bound due to the limitations of the testing apparatus used, as is explained in greater detail in Attachment A.

Hydraulic conductivity in Conasauga Group rocks is anisotropic, with higher conductivity in the strike parallel direction than in the down-dip direction or across beds. Anisotropy is the result of differences in fracture orientation, propagation and development. Qualitatively, the relationship of strike-parallel, dip-parallel, and cross-strata hydraulic conductivity is $K_{strike} >> K_{dip} > K_{cross\text{-}strata}$ on a whole-rock basis. Anisotropy can be measured by the tendency of tracers and contaminant plumes to elongate in the direction of strike, or by observing the elongation of draw-down cones during pump tests. Some estimates of the degree of anisotropy in BCV and UEFPC, presented in Table E-7, range from 1:1 to 38:1, but most fall between 2:1 and 10:1. Bailey and Lee (1991) conducted a sensitivity analysis of anisotropy by varying hydraulic conductivity values for strike and dip flow and comparing the actual ground water head at numerous wells with that predicted by their model. The EMDF Phase I site characterization did not attempt to assess anisotropy.

They found that anisotropy of 1.1 to 1.25:1 provided the best matches between modeled and actual ground water head. They further state that preferential flow along strike is not indicated in BCV, except in the Maynardville Limestone. However, results of tracer tests conducted in Conasauga Group units other than the Maynardville Limestone also exhibit flow anisotropy. Evans, et al. (1996) used a particle tracking model to investigate anisotropy in BCV. They found empirically that particle tracks best mimic the S-3 Ponds contaminant plume at an anisotropy ratio of 10:1. Sensitivity analysis indicated that anisotropy ratios lower than 10:1 provided better fits to the contaminant plume than did ratios higher than 10:1.

**Table E-7. Hydraulic Anisotropy in the Conasauga Formations**

| Ratio of Strike-Parallel to Dip-Parallel Hydraulic Conductivity | Test Method | Analytic Method | Reference |
|---|---|---|---|
| 1:1 | Ground water flow model calibrated to actual conditions in portions of EBCV | Finite-difference model | Bailey and Lee, 1991 |
| 2:1 | Pumping tests at depths of 3 m and 33 m in Maryville Limestone, BCV | Gringarten & Witherspoon Fractured Aquifer Solution | Lee et al. 1992 |
| 38:1 | | Papadopulos Infinite Aquifer Solution | |
| 4:1 | Pump test in Conasauga Group, Melton and Bear Creek Valleys | Gringarten & Witherspoon Fractured Aquifer Solution | Davis et al. 1984* |
| 8:1 | Pump test | Unknown | Golder Associates (1989c) as reported by Schreiber (1995) |
| 10:1 | Ground water flow model calibrated to actual conditions in EBCV | MODFLOW | Evans, et al. 1996 |
| 5:1 | Pump test in Conasauga Group | Gringarten & Witherspoon Fractured Aquifer Solution | Smith and Vaughn 1985* |
| 3:1 | Model Calibration; Conasauga Group, UEFPC | Numerical model | Geraghty and Miller 1990* |
| 30:1 | NaCl tracer test in Bear Creek Valley | Papadopulos Infinite Aquifer Solution | Lozier et al. 1986* |
| 5:1 | Nitrate plume and head modeling, Conasauga Group, BCV | Numerical model | Tang, et al. 2010 |

* Sources cited by Lee, et al. 1992. Full bibliographic citations for Lee, et al. 1992 and Tang, et al. 2010 are provided in the References to this Appendix.

As noted above, use of single point hydraulic conductivity data to characterize fractures and karstic aquifers is problematic. Sara (1994, p. 6-4 to 6-5) states that:

> *"The hydraulic conductivity of the fracture system of the rock mass as a whole is almost always of more interest than the ability of a single fracture to transmit water, for the typical scale of a facility assessment. The hydraulic conductivity cannot be estimated, of course, unless the mass of rock is sufficiently large. The hydraulic conductivity of the mass as a whole depends on the collective hydraulic conductivity of each of the fractures of an interconnecting system. . ."*

In other words, it is not the hydraulic conductivities measured in individual wells or stratigraphic zones, but the average hydraulic conductivity of the whole-rock mass, or continuum, that determines ground water flux. Freeze and Cherry (1979, p. 73) state that this continuum approach is *". . . valid as long as fracture spacing is sufficiently dense that the fractured medium acts in a hydraulically similar fashion to granular porous media."* Freeze and Cherry (1979) further state that flow in an elementary representative volume of fractured rock can be analyzed using standard Darcian porous-media methods with anisotropy. Shapiro (2003) agrees, stating that the bulk rock properties control flow at large and small scales, and that highly conductive fractures exert influence primarily at smaller scales. Worthington (2003, p. 30), in reference to modeling, states that *"The simplest and most commonly-used approach has been to assume that fractures may be locally important, but that fracture density is great enough that the aquifer can be treated as an equivalent porous medium, and modeled using a package such as MODFLOW."* This is the approach taken in PreWAC modeling for the EMDF presented in Appendix H.

#### 2.3.2.2 Results of tracer tests

Tracer tests are conducted by introducing a unique tracer (dye, chemical, radionuclide, or particulates) into an aquifer and monitoring possible flow paths or discharge points to determine if and when the tracer first arrives, when the peak concentration occurs, and how long it takes the tracer to recede. Tracer tests are commonly used in fractured and karstic aquifers because they are strongly anisotropic and flow paths are difficult to determine. A number of tracer tests have been conducted in Conasauga Group units on the ORR, and the results of several are briefly summarized below. Not all of these tests were in BCV, but all are illustrative of Conasauga Group tracer flow characteristics.

Goldstrand and Haas (1994) reported on two tracer tests conducted in the Maynardville Limestone in UEFPC during low-flow and high-flow conditions. The tests simply noted whether the dye appeared at a monitoring station, and did not address first or peak arrival. The initial test, conducted in July–October 1990, used fluorescein dye injected into a well screened in the Maynardville Limestone on the south-central side of the main Y-12 Plant. Eight of the 39 springs, surface water sites, and wells that were monitored had confirmed detections of dye, while four others had possible detections. Most of the sites where dye was detected were in UEFPC Valley, Scarborough Valley, or in a small stream on the south flank of Chestnut Ridge. Two possible detections occurred in EBCV near the BCBG area. Calculated first arrival times ranged from 36 to 843 ft/day.

The second test used the same injection well, but only monitored 35 wells, surface water sites, and springs. Well GW-734, at the eastern edge of the Y-12 Plant Site in UEFPC Valley, has a large cavity in the Maynardville Limestone, was therefore added to the monitoring program. The test used multiple dyes and was conducted from March to August, 1992. Results of the second test were equivocal because detections were only slightly above detection limits in most cases, and there were some naturally-occurring fluorescent compounds that may have interfered with dye detection. The dyes arrived at different times, and were not always detected together, possibly due to different sorption characteristics. Estimates of ground water flow velocities from the second test ranged from 14–1,000 ft/day for the Calcofluor White dye and from 47–1,314 ft/day for the Rhodamine WT.

Lee, et al, (1989) conducted dye tracer tests at the WBCV site using Rhodamine WT dye injected in a shallow well screened in weathered Maryville Limestone in April 1988, and observation wells were monitored biweekly through June 1989. Observation wells and piezometers were screened in weathered shale and in unweathered bedrock. Fifteen falling head tests, seven in the vadose zone and eight in the bedrock, and 12 straddle packer tests were conducted to determine hydraulic conductivity. Hydraulic conductivities ranged from $9.0\times10^{-4}$ to $1.94\times10^{-6}$ cm/s. Mean hydraulic conductivity is $4.56\times10^{-5}$ cm/s for saprolite and $6.72\times10^{-5}$ cm/s for bedrock; the difference is not considered significant. Hydraulic conductivity results for limestone and shale were essentially the same.

Tracer movement was found to be predominantly strike-parallel and not simply in the direction of steepest gradient. The near-field tracer plume was long and narrow, while the distal end bifurcated. The dye remained in the saprolite and was not detected in bedrock, possibly because the vertical hydraulic head in the test area was upward. The rate of tracer movement was initially very rapid (6–8 ft/day) then declined to a more steady-state value of less than 0.5 ft/day. This may have been related to declining water table elevations. The long, narrow plume and initial high movement rate is interpreted as being due to migration in a high-conductivity conduit, followed by migration in lower-conductivity fractures.

Tracer studies at the WBCV site and a site in Melton Valley using dissolved neon and helium were initially reported by Sanford et al. (1996) and Sanford and Solomon (1998). The gases were injected into Maryville Limestone saprolite. Important findings from these two tracer tests are that solute tracer plumes tend to develop along strike, with little transverse dispersion; and solute transport rates are strongly influenced by matrix diffusion. In both tracer tests, transport rates, for a given relative concentration contour decreased with time and distance from the injection well, and the low concentration "front" of the plumes tended to migrate at rates hundreds of times faster than the high concentration region. Both of these types of behavior indicate a high degree of longitudinal dispersion, which is typical of systems in which matrix diffusion in a complexly fractured medium is dominant.

Schreiber (1995) reported on two tracer tests conducted in the Nolichucky Shale at the WBCV site. A helium injection tracer test conducted from March 1994 September 1994 showed a distinct strike oriented flow pattern, with first arrival in a shallow (26 ft) and deep (70 ft) along-strike well pair in mid-May 1994, but concentrations remained low through the duration of the study. The strike-parallel flow velocity, based on first arrival, was 0.28 m/day (approximately1 ft/day). Helium also was detected both up and down dip. A bromide tracer test was conducted from April 1994 to September 1994. First arrival occurred in mid-June in a shallow along-strike well, giving an initial velocity of 0.23 m/day (0.75 ft/day), similar to the helium test results. Bromide was not detected in other wells.

Webster (1996) conducted tracer studies using tritium in Conasauga Group rocks at Waste Area Grouping (WAG)-4 and WAG-6 from 1977 through 1982. Both sites are on Conasauga Group bedrock, mainly the Pumpkin Valley and Nolichucky Shales. Observation wells were evenly spaced around a circle 12 ft from the injection well, and screened at a depth of roughly 30 ft in the saprolite regolith. Water table elevations at WAG-4 were typically 15–16.5 ft below grade, and at WAG 6, 23–26 ft below grade. Initial measurements detected tritium in all of the observation wells, and the wells with the highest tritium concentrations were directly down-gradient and strike-normal relative to the injection well. Concentrations at the three downgradient wells increased to a maximum 5–14 months after injection and the maximum concentration remained roughly the same or declined slightly over the duration of the project. Over time, the initial elongate plumes at each site widened and became more circular, and the center of tracer mass moved slightly down-gradient and widened over time. Matrix diffusion retarded tracer movement by uptake in small blind fractures and pores, and maintained high tracer concentrations by diffusing back into the flowing ground water in fractures over time.

McKay, et al. (2000) conducted tracer test in Maryville Limestone saprolite at the WBCV site using colloidal tracers (latex microspheres and three bacteriophages). Colloidal tracers were introduced into a

21 ft deep well in shale saprolite under normal ground water gradient and samples were collected from multiple wells downslope, normal to strike. All tracers were detected at distances of up to 45 ft, and two of the tracers were found in all downgradient wells. Tracers arrived rapidly as a distinct pulse, followed by one to six days of high concentrations, then a rapid decline. Flow rates calculated from arrival times ranged from 15 to over 650 ft/day. Two of the bacteriophages tracers were detected in a few wells up to five months after injection, indicating retention of colloids in matrix pores and small fractures.

Results of tracer tests provide substantial insight into water movement as well as contaminant transport processes. First arrival velocities from as low as 6 ft/day to as high as 1,314 ft/day have been observed in tests conducted in the ground water zone of Conasauga Group units, but peak concentrations took much longer to arrive. Solomon et al. (1992) also noted that peak concentrations arrived considerably later than the first arrival. The orders-of-magnitude difference between first and peak concentration arrival velocities indicates that the peak arrival is retarded by longitudinal dispersion and uptake in matrix pores and fine fractures. Solomon et al. (1992) suggests that the relatively short distances used in many tracer tests underestimate the effects of longitudinal dispersion.

### 2.3.3 Ground Water Flow

Several lines of evidence converge to indicate that ground water flow systems on the ORR are local, not regional, and defined largely by topography and streams. The BCV drainage basin is confined by the relatively high local topographic relief, anisotropic ground water flow in the steeply inclined beds of the underlying bedrock, tributary flows in the north and south tributaries and underlying master fractures, with discharge to Bear Creek and interconnected cavity conduits in the Maynardville Limestone. Evidence for this is found in differences in ground water chemistry and depths to the brine aquiclude in Melton Valley, Bethel Valley, and BCV; reduced hydraulic conductivity with depth; and from flow nets based on water table head measurements. Flow on the flanks of Pine Ridge occurs mainly in fractures, with little contribution by open conduits. Fracture-dominated flow on the slopes of Pine Ridge drain to Bear Creek directly and through multiple open interconnected conduits in the Maynardville Limestone under the valley floor.

Ground water occurrence and flow under the ORR has been divided into unsaturated, saturated, and aquiclude zones (Solomon, et al. 1992; Moore and Toran 1992). Within BCV, transient flows occur in the unsaturated storm-flow and vadose zones on steep ridge flanks, and base flow occurs in shallow, intermediate and deep flow zones under ridge and the valley bottom. A very deep aquiclude that is inferred to exist at depths exceeding 500 ft may have some localized interaction with shallower zones, but is generally considered to mark a no-flow boundary.

#### 2.3.3.1 Unsaturated Zone

The unsaturated zone is subdivided into the storm flow zone and the vadose zone.

##### *2.3.3.1.1 Storm-flow Zone*

Precipitation falling on the land surface is distributed in one of four ways: by direct evaporation and transpiration by vegetation (evapotranspiration), as runoff to streams, by infiltration to ground water, or by storage in the soil or bedrock. The largest portion of precipitation is temporarily stored in the soil or depressions (puddles) and released to the atmosphere by evapotranspiration (direct evaporation and transpiration by vegetation). A smaller portion, on the order of 10% of infiltrating water (Driese, et al. 2001; Moore 1988, 1989) passes through the vadose zone to be stored in soil or saprolite, or to eventually reach the water table. The second largest portion of precipitation is lost via runoff, most of which flows through the storm-flow zone.

Because little or no overland flow occurs in forested areas except during very heavy rains, a large proportion of rain entering the soil is conducted down-gradient via the storm-flow zone to discharge to streams or temporary springs. This has been found to be true in steep forested slopes in humid climates, for example, on the ORR (Clapp, 1989), in the Shenandoah National Park, Virginia (Scanlon, et al. 2000), and Japan (Sidle, et al. 2000), and in other areas, such as karst terrains in semi-arid environments (Wilcox, et al. 2008). Clapp (1989) used a modeling approach to estimate that overland flow, subsurface storm-flow and ground water discharge yielded 6.2, 46.6, and 47.2% of the total annual runoff, respectively, in Center Seven Creek. The storm-flow zone flows only in response to rain, and flow ceases in a matter of hours or days. The storm-flow zone is more pronounced on ridge crests and side-slopes, but merges with the water table near streams. The storm-flow zone is a temporary perched water table, typically 3–10 ft (1–3 m) deep, characterized by generally high organic content, roots and root channels, and bioturbation by worms and small fauna. A study by Driese, et al. (2001) demonstrated that the base of the storm-flow zone is marked by a low-permeability layer of accumulated clays and mineral deposits.

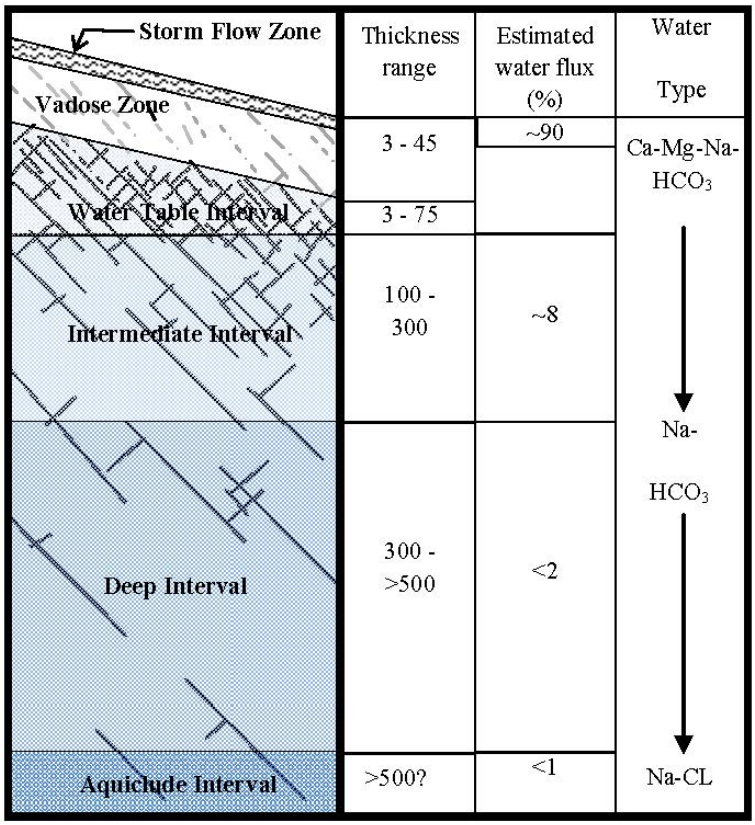
The position and drainage area of the storm-flow zone is an important consideration in landfill design, because storm-flow must be intercepted and diverted around the disposal cell in order to limit erosion of the cover and infiltration into the buried waste. This is typically accomplished through the use of upgradient French Drains and diversion ditches. Many previous Resource Conservation and Recovery Act of 1976 (RCRA) type covers at ORR were ineffective because storm-flow was not intercepted effectively and continued to cause saturation or "bath tub effect" in waste trenches due to water underflowing the caps (Melroy, et al. 1986). Construction of the EMDF would remove the storm-flow zone beneath the landfill footprint and divert shallow storm-flow around the EMDF using a relatively impervious, geomembrane-lined surface ditch in combination with French drain, both constructed on the upgradient side of the landfill.

#### *2.3.3.1.2 Vadose Zone*

The vadose zone is defined as the region of soil or bedrock in which water pressure is negative, meaning that capillarity will hold water in storage until saturation is reached. The vadose zone is the region of water table flux (rise and fall) that exists between the storm-flow zone and the saturated zone everywhere in the ORR except near perennial streams, where saturated conditions may intersect the storm-flow zone. The vadose zone is typically < 60 ft (20 m) thick beneath Pine Ridge (Solomon, et al. 1992). Water in the vadose zone migrates vertically to the water table or is taken up by plant roots and transpired (Solomon, et al. 1992; Moore 1988; Moore and Toran 1992). Flow in the vadose zone is episodic when it occurs, and requires sufficient water to overcome the effects of capillarity and to fill empty pores. Flow occurs in fractures and matrix pores in saprolite as pathways. The lower boundary of the vadose zone is the capillary fringe, a thin zone of near-saturation in fine-grained regolith created by capillary rise of water from the saturated zone beneath.

### 2.3.3.2 Saturated Zone

The saturated zone includes shallow, intermediate, and deep flow zones; the majority of ground water flow occurs within the shallow zone. The boundaries between these levels occur at different levels in different parts of the ORR (Moore and Toran 1992) and their placement is commonly based on ground water chemical compositions. Hydrogeochemical processes involving exchange of cations on clays and other minerals result in a change from calcium bicarbonate ($Ca\text{-}HCO_3$) to sodium bicarbonate ($Na\text{-}HCO_3$) and ultimately to a sodium chloride (Na-Cl) type water at depth. These geochemical zones reflect ground water residence times and reduction of water flux with depth. Figure E-12 illustrates this conceptual model.




Adapted from Solomon et al. (1992)

**Figure E-12. Conceptual Model of Ground Water Zones in BCV**

#### *2.3.3.2.1 Shallow Aquifer Zone*

The shallow zone begins at the water table, which begins at the base of the capillary fringe and extends to depths of 75–100 ft (Solomon, et al. 1992). The water table is commonly found at or near the bedrock-regolith boundary. According to Solomon, et al. (1992), most fluctuation and flow occurs in the upper 3–15 ft of the saturated zone because of the relatively high density of open fractures. Moore (1988) indicates that hydraulic conductivities in this zone are one to two orders of magnitude higher than in underlying bedrock.

The water table is 36 ft (<1-2 m) deep near perennial stream channels but may be 15–45 ft (5–15 m) deep beneath ridges underlain by the Rome Formation and Conasauga Group formations (Moore and Toran 1992). The depth to ground water water at the proposed EMDF site (before construction) ranges from very near the land surface on the valley floor during wet periods to >55 ft on the flank of Pine Ridge. In dry seasons, the water table generally occurs near the regolith – bedrock contact, for which the geometric mean of depth to water in October is 12.5 ft (4.1 m) (Moore 1988).

The hydraulic gradient of the water table interval is generally from Pine Ridge in the north to the south west towards Bear Creek and locally towards tributaries. Hydraulic head data collected in multiport wells in BCV and interpreted by Dreier et al. (1993), Moore and Toran (1992), Lee and Ketelle (1989), among others, demonstrate that stratigraphy and geologic structure control valley-wide hydraulic head distributions and flow patterns. Schreiber (1995) reported that in shallow wells, the ground water gradient averaged south-southwest, but flow direction average west to west-southwest, reflecting stratigraphic anisotropy. In general, recharge is topographically driven from the ridges. Hydraulic head patterns show

convergent flow to the Maynardville Limestone in the valley floor indicating that it serves as the hydraulic drain for BCV. Flow is locally directed in both horizontal and vertical dimensions by bedding planes, much like rainwater on a street is directed by the presence of a curb. It is likely that flow converges in one or more master fractures, including bedding planes, which discharge to springs and Bear Creek outside of the EMDF area. Within the Maynardville, flow is generally horizontal to the west and strike-parallel, with local upward and downward components.

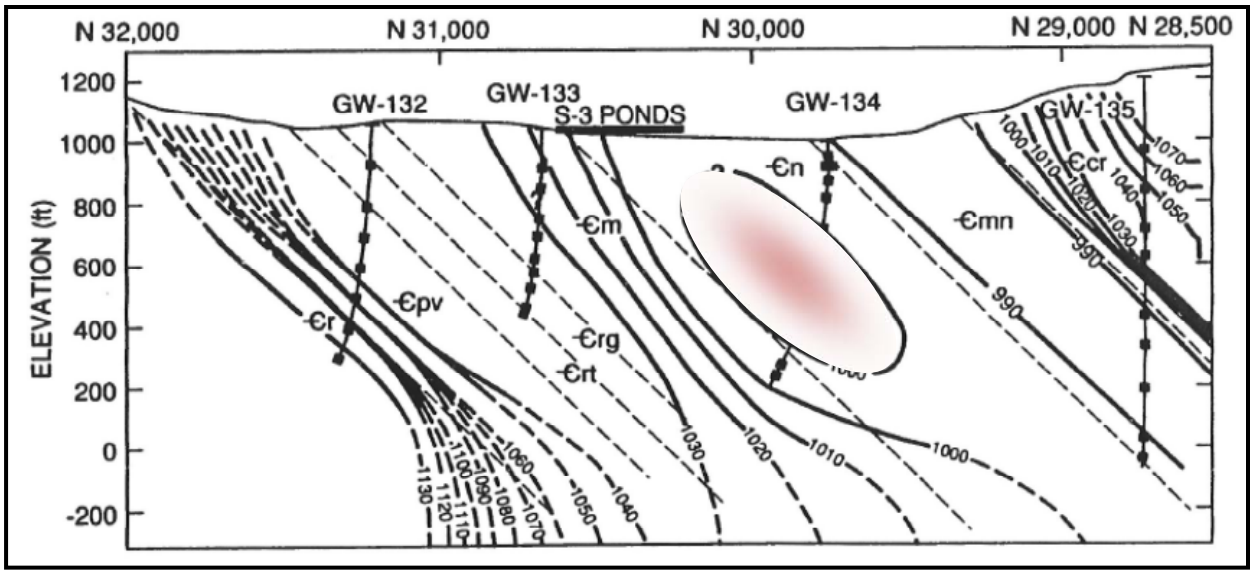
Dreier et al. (1993) mapped hydraulic head distributions across EBCV, as shown in Figure E-13, that indicate an upward gradient beneath the disposal site in the Conasauga Group and probable discharge to the Maynardville Limestone. There is an isolated high pressure zone in the Nolichucky Shale that appears to be a relic of higher density fluids flowing down dip from the S-3 Ponds. On the opposite side of the valley, the gradient is vertically downward from the Knox Aquifer to the Maynardville Limestone. The Maynardville Limestone has a conspicuously lower hydraulic head than adjacent stratigraphic units above that indicates that it, with Bear Creek, serves as the drain for the valley as a whole. Bailey and Lee (1991) modeled flow in BCV and found a similar head distribution, as shown in Figure E-14.

Vertical gradients are generally upward and flow toward the reduced hydraulic head in the Maynardville Limestone (Dreier et al. 1993). The nitrate plume from the S-3 Ponds (DOE 1997) and chlorinated volatile organic compound (VOC) contaminant plumes from the Boneyard/Burnyard (BY/BY) and BCBG areas (DOE 1997; BNI 1984) have been reported to extend down-dip in the Maynardville and Nolichucky formations, but these are density-driven flows, and not the result of downward vertical ground water flows. However, flow meter surveys conducted in BCV by Moore and Young (1992) found that natural downward flows occurred in most of the 70 wells measured. Flow rates ranged from 0.01 gpm to over 1.25 gpm; induced flow rates were somewhat lower.

BNI (1984) conducted surveys of vertical and horizontal flow in Conasauga Group rocks in the BCBG and BY/BY areas and found that flow orientation and sense (upward or downward) were variable and depended on depth, lithology, and fractures and cavities. In general, vertical flow was consonant with the local water table gradient based on head measurements, and horizontal flow was toward streams. Several measurements made in wells screened in the Nolichucky Shale indicated horizontal Darcy velocities in the 10s of ft/day, although most were less than 5 ft/day.

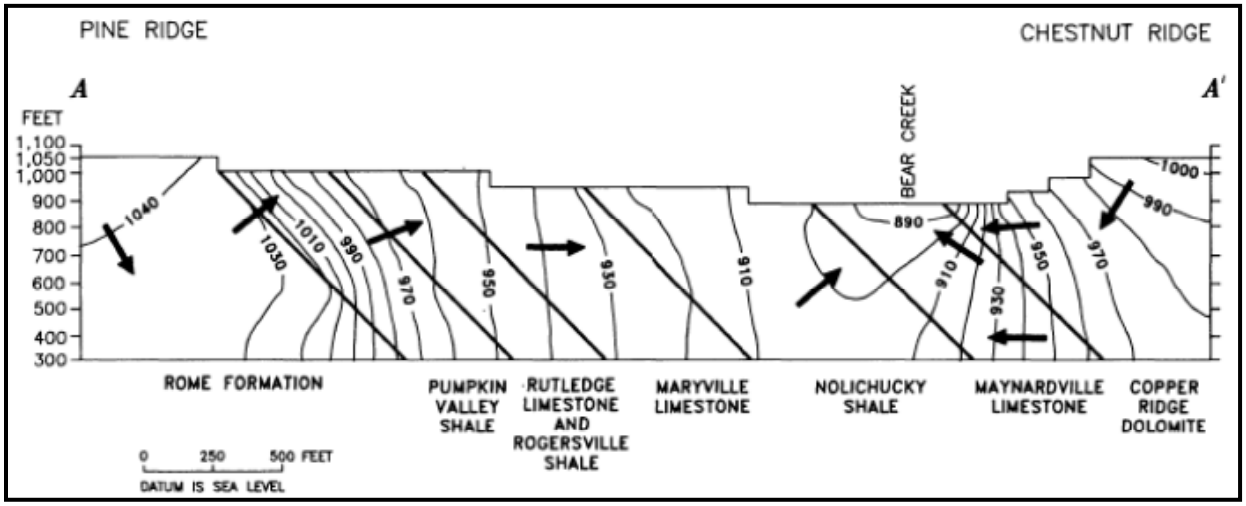
Ground water monitoring wells installed during the EMDF Phase I site characterization were equipped with pressure transducers set to record essentially continuous level data. Level data are converted to elevations and used to construct water table maps. Figure E-15 is a map of synoptic water levels at the EMDF site on December 25, 2014. The water table conforms to topography. Note that while all deep wells encountered water, only four of the five shallow wells reached the water table. Well GW-977 on the Maryville spur ridge was drilled to auger refusal at 25.5 ft (8.4 m) below grade, but did not find water.

The water table typically fluctuates with rainfall and climate, and the magnitude and speed of response is directly related to the type of pore system being monitored. At one end of the spectrum are wells completed in relatively impermeable matrix pore-dominated zones (i.e., zones with few open fractures, in which the water table elevation does not respond directly to rainfall events, but instead shows a long-term, low-amplitude rise and fall that corresponds to wet-dry seasonal changes). At the other end of the response spectrum are wells that are completed in cavities or in conduit-flow regimes, such as in the Maynardville Limestone, which typically exhibit a rapid short-lived rise in water level in response to moderate to heavy rainfall. Water level rises average over 16 ft (5.3 m). This is termed quickflow because the rise and subsequent decline to base flow levels occurs over a matter of hours to days (Shevnell, et al. 1995). Water levels in wells completed in enhanced fractures, but in not actual cavity systems, exhibit rainfall responses somewhere between these two extremes. Response to rainfall events can be seen even in relatively deep wells, indicating connectivity between shallow and deep fracture systems. However, these responses may be pressure pulse and not true ground water movement.




Adapted from Dreier, et al. (1993). Arrows indicate ground water flow directions. The high pressure area (rose color) in the Nolichucky Shale is likely related to higher densities of the contaminated leachate from the S-3 Ponds.

**Figure E-13. Hydraulic Head Distribution across EBCV**




Source: Bailey and Lee, 1991. Numbered contours indicate head distribution and arrows indicate flow directions. Cross-section is near the BCBG.

**Figure E-14. Cross-Sectional Representation from a Computer Model of Ground Water Hydraulic Head and Flow Patterns for EBCV**

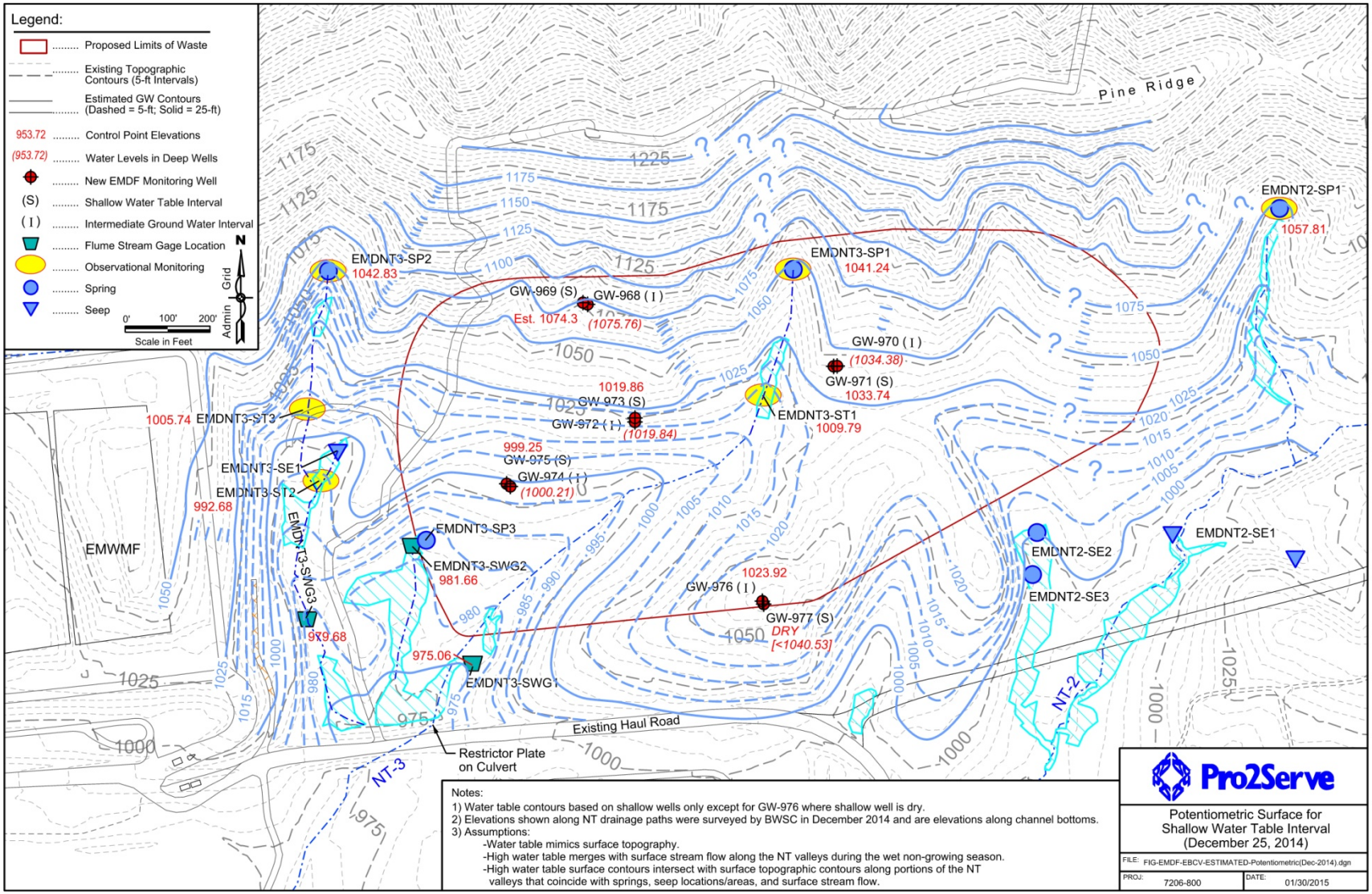



**Figure E-15. Ground Water Table Elevations for the Proposed EMDF Site on December 25, 2014**

The water table in companion well GW-976 is typically 40–45 ft (13–15 m) below grade, although a stable water level was not reached until mid-January 2015.

Water table elevations in most of the Phase I wells respond rapidly to precipitation, as shown in the hydrographs of Figure E-16. Hydrographs show that initial water table response occurs within a few hours of the onset of precipitation and crests slowly. Post-event declines are slow and relatively constant. Hydrographs for shallow and deep monitoring well pairs typically track very well; the hydrographs for the GW-972/-973 well pair exactly match. Hydrographs for well pairs GW-970/-971 and GW-974/-975 show slight separation in, but still tracking, shallow-deep water levels. Separation is not consistent. For the GW-974/-975 well pair, the deep water level is slightly higher than the shallow water level, as might be expected in an area of high topographic relief. However, the separation is reversed in the GW-970/-971 well pair which is located at a higher topographic position than GW-974/-975.

GW-968/-969 water levels are anomalous, mainly because both wells have been artesian at times. GW-968 water levels were at the top of casing until the casing was extended on December 23, 2014. GW-969 became artesian in late December, and water levels remained at the top of casing until it, too, was extended in late January 2015. Note that the GW-968/-969 well pad was excavated in a draw, and that the artesian water level elevations are roughly equal to the former ground surface elevation.

Hydrographs for GW-968/-969 since January 26 show some anomalous short-term spikes that cannot be explained. GW-970 exhibits similar, but less pronounced, responses at the same times. These do not correlate to any seismic or nearby construction activity.

EMDF Phase I site characterization included heat pulse flow meter testing. These tests are conducted at borehole locations with indications that flow may occur, such as fracture traces or wash-out zones. Heat pulse flow meters detect vertical flow, such as may occur between two normally separated zones. In general flow meter testing detected very little natural flow. A flow rate of 0.03 gpm (0.11 l/m) is the lowest quantifiable flow rate using this technique. Thirty-nine flow tests were conducted, but only four tests detected flows of greater than 0.03 gpm (0.11 l/m), 10 tests indicated slight but unquantifiable flows rates, and the remaining 25 test showed zero flow. Quantifiable flow was observed in GW-970 (three zones at 45, 50, and 57 ft below grade) and GW-976, (1 flow zone at 75 ft below grade), but the highest flow rate was 0.62 gpm (2.35 l/m). Two points should be considered: (1) that flow between vertically separated zones can only occur if there is a difference in head between the two zones, and (2), numerous very small flows over a long vertical interval can result in significant flux. All the wells except GW-976 (and GW-977, which is dry) recover relatively rapidly after being stressed (e.g., by a packer or slug test).

#### *2.3.3.2.2 Intermediate and Deep Aquifer Zones*

Sparse stratigraphically controlled fracture networks at intermediate to deep depths in the saturated zone probably transmit most of the water that reaches intermediate to deep zones from shallower depths along strike toward tributary streams, while the remainder flows down-dip and through fractures, discharging to main valley streams, such as Bear Creek (Moore and Toran 1992). The top of the intermediate zone is marked by a change in the dominant anions from Ca, Mg, Na-$HCO_3$ to Na-$HCO_3$, and extends from approximately 100 ft to over 275 ft, where the transition to the deep zone is marked by a gradual increase in Na-Cl (Haase, et al. 1987; Bailey and Lee 1991). SAIC (1997) shows that the nitrate plume emanating from the S-3 Ponds extends to depths of approximately 500 ft below grade in EBCV.

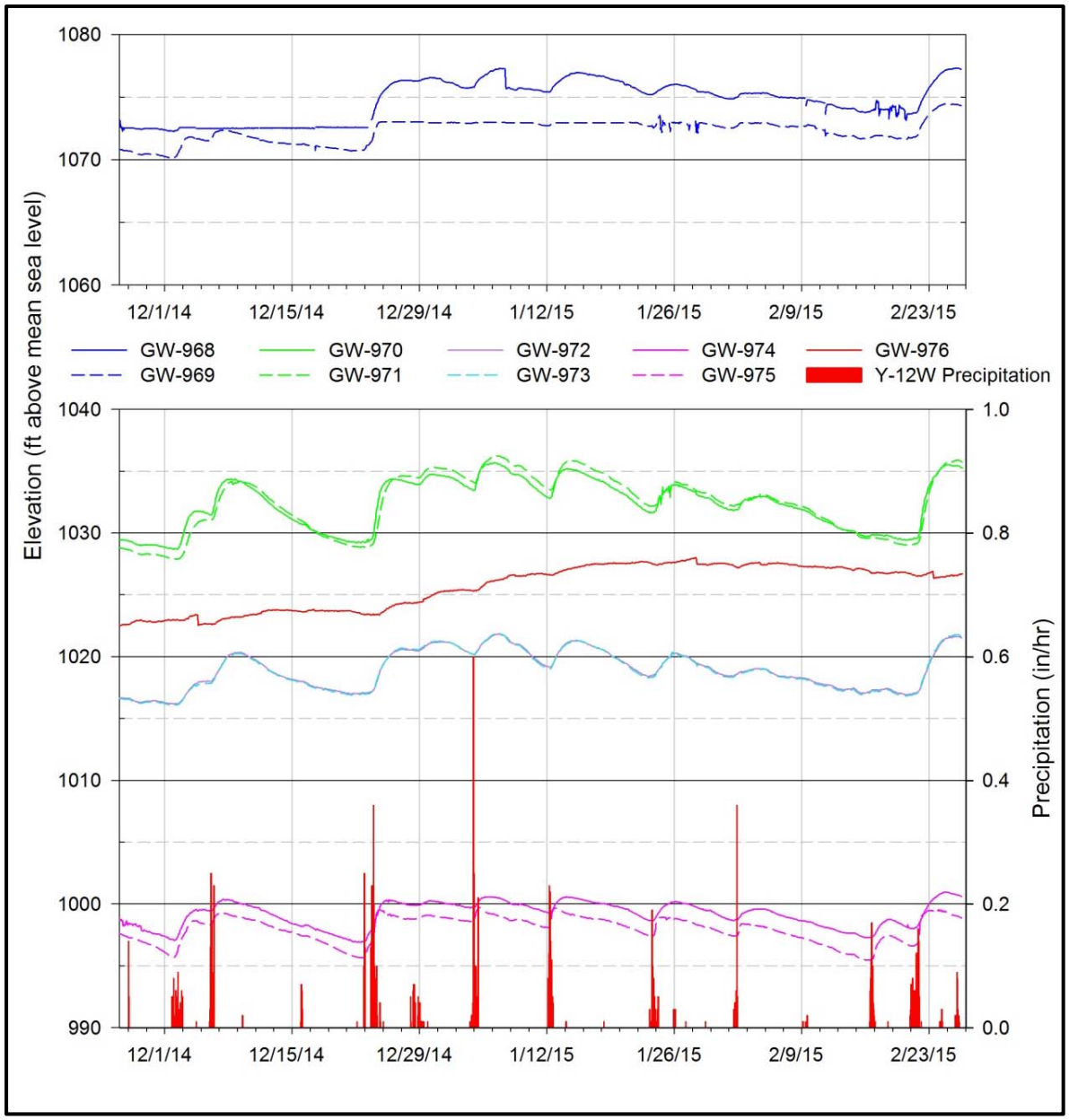



**Figure E-16. Water Table Fluctuations Measured during Phase I Site Characterization**

Moore and Toran (1992) postulate that flow paths in the deeper ground water zones are longer and less tortuous than in shallower rocks. Unlike the shallower flow zone, gradient and flow direction are both southerly in the deep zone (Schreiber 1995). They also indicate that very little water flows through the deeper ground water zone, and that water flux decreases with depth. According to Solomon, et al. (1992), the deep zone hosts very little ground water flow. This very low flux can be explained by the reduced number of open fractures and consequent reduced hydraulic conductivity and increased friction, as well as by the difference in water density.

The intermediate and deep aquifer zones are distinguished from the shallow zone by a change from a calcium-magnesium-bicarbonate chemistry to a chemistry dominated by sodium-bicarbonate ($Na\text{-}HCO_3$) ions (Moore and Toran 1992). The transition from $Ca\text{-}Mg\text{-}HCO_3$ to $Na\text{-}HCO_3$-dominant water is abrupt, occurring between depths of 80 ft (26 m) to 200 ft (67 m) in the Nolichucky Shale underlying BCV (Haase 1991), which suggests a well defined flow boundary (Haase 1991). Dreier, et al. (1997) noted that this water type is common to all Conasauga Group formations at intermediate and deep depths except in the Maynardville Limestone, and appears to be unrelated to stratigraphic changes. The Maynardville Limestone and adjacent Copper Ridge Dolomite exhibit both an $Na\text{-}HCO_3$ water type with distinct zones of $Ca\text{-}Mg\text{-}Na\text{-}SO_4$ water. These sulfate-rich water zones appear to be related to the presence of gypsum beds in the carbonate units. Table E-8 summarizes this geochemistry information for the Conasauga Group.

**Table E-8. Geochemical Zones in the Conasauga Group Formations**

| Interval or Zone | Bear Creek Valley (Haase 1991) | | | Bear Creek Valley (Bailey and Lee 1991) | | Melton Valley (Haase, et al. 1987; Nativ, et al. 1997) | | |
|---|---|---|---|---|---|---|---|---|
| | Depth (ft) | Type | pH | Depth (ft) | Type | Depth (ft) | Type | pH |
| Shallow | 75 ft | Ca, Mg-$HCO_3$ | NA | < 50 | Ca, Mg-$HCO_3$ or $SO_4$ | < 75 | Ca, Mg-$HCO_3$ or $SO_4$ | 6.5 – 7.5 |
| Intermediate | NA | NA | NA | 50 – 500 | $Na\text{-}HCO_3$ (with some Na-Cl and $Na\text{-}SO_4$) | 75 - 275 | $Na\text{-}HCO_3$ | 6.0 – 8.5 |
| Deep | NA | NA | NA | | | 75 - 530 | $Na\text{-}HCO_3$ to Na-Cl | 8.0 – 10.0 |
| Brine (aquiclude) | >530 | Na-Cl | NA | NA | NA | 590 (GW-121) | Ca-Na-Mg-Cl + $SO_4$ | 11.6 |

This change in ground water chemistry is interpreted to be the result of rock-water interactions and diagenesis of minerals. The rate at which the ground water reaches chemical equilibrium with source minerals is important in the diagenetic evolution of $Na\text{-}HCO_3$, indicating that the ground water is reaching equilibrium with the host rock. If clay alteration is an important control on ground water geochemistry, then $Na\text{-}HCO_3$ type water may mark the transition between the actively circulating shallow zone and stagnating ground water in deeper zones (Solomon et al. 1992).

Studies performed by Dreier, et al. (1993) in deep boreholes in the Conasauga Group and the Copper Creek Dolomite of the Knox Group in EBCV indicate that deep ground water chemistry trends from $Na\text{-}HCO^3$-dominated water to increasing Na-Cl content between 550 ft below grade near Pine Ridge to over 1,150 ft below grade in the Maynardville Limestone on the south side of BCV. This trend is associated with an increase in total dissolved solids and pH that appears to be related to long-term rock-water reactions. Haase (1991) states that these deep transitional waters are saturated with respect to calcite and dolomite.

#### 2.3.3.3 Aquiclude

The aquiclude is so named because the extremely high salinity of this water indicates that little or no ground water movement occurs. The aquiclude is well defined in the Conasauga Group of Melton Valley, but is less well documented in BCV.

Dreier, et al. (1993) and Haase (1991) provided detailed water chemistry data for four wells positioned across strike in EBCV and drilled to depths between 557 ft and 1,196 ft below grade. Both reports noted an abrupt increase in total dissolved solids to about 28,000 ppm, increase in pH to the 8.5–10.0 range, and change from Na-$HCO_3$ as the dominant ion pair to dominance of sodium chloride (Na-Cl) below 1,150 ft. This increase occurred just below a major fracture zone. Haase (1991) noted that the deep sodium-chloride ground water in four deep wells sampled for this study was saturated with respect to calcium and magnesium, and contained barium at near-saturation concentrations, which is indicative of long residence time and little or no recharge by fresher water.

A report by Nativ et al. (1997) indicates that the presence of tritium[3] and modern carbon-14 in some deep brine samples from the Conasauga of Melton Valley suggests that some meteoric water commingles with the brine at depths. They also report that ground water flow has been measured by down-hole flow meter in various deep boreholes below 750 ft (250 m). Based on these considerations, Nativ (1997) postulates that flow occurs in the deep brine, and that at least some meteoritic water is transported to depth. Moline, et al. (1998) refute this interpretation, noting that the persistence of brine over geologic time provides a strong indication that deep ground water circulation is minimal, and that deep rocks exhibit very low hydraulic conductivity values, on the order of $10^{-7}$ to $10^{-9}$ cm/s, which suggests either absence of numerous permeable fractures.

Observed responses to seasonal and storm-driven changes in the water table measured in some deep wells could be responses to pressure pulse, rather than actual flow. Further, the presence of shallow water signatures (comparatively low total dissolved solids, tritium, and relatively high percentages of modern carbon) may be induced by drilling, well installation and development, open bore hole circulation, or purging prior to sampling. Development and purging of deep wells is hampered by extremely low flow rates and long recovery times (Moline, et al. 1998).

While some ground water exchange may occur between water beneath the halocline and shallower ground water zones, it is volumetrically very minor and does not appear to play a significant role in regional flow patterns. As noted above there is a significant difference in density between the shallow ground water and the brine. The density of uncontaminated water, or water contaminated at low concentrations by dissolved constituents, is around 1.01 g/cc; the density of sea water is 1.022 g/cc, and brine is over 1.20 g/cc. It would require a great deal of hydraulic head or pressure to drive fresh water into the brine zone. The S-3 Ponds nitrate plume, which extends to depths of more than 400 ft is acknowledged as a density-driven plume, with a density range between 1.06 and 1.12 g/cc (DOE 1997). This is sufficient to drive the plume below the fresh water aquifer, but above the brine zone. Thus, density differences prevent downward penetration of the brine of shallow ground water. This analogous to the fresh water sea water boundary that develops in coastal aquifers.

### 2.3.4 Ground Water Indicator Parameters

Continuous monitoring of temperature, specific conductivity, pH, and oxidation-reduction potential (ORP) was conducted in all nine Phase I site characterization monitoring wells that encountered ground

[3] Although some tritium is produced in the atmosphere by cosmic rays, it is mostly the result of atomic testing, and its presence in deep ground water suggests that there have been recent additions of shallow water. Tritium has a half-life of 12.3 years and it would therefore be expected to have decayed to undetectable concentrations if ground water migration times were very long.

water (GW-977 is dry). Temperature data is reliable, but the pH, specific conductivity, dissolved oxygen, and ORP instrumentation did not perform as well as expected, and the resulting data sets are not robust.

Ground water temperature in six of the nine wells exhibited a clear seasonal downward trend from the inception of monitoring in early December 2014 through February 2015.

Distinct step changes in response to precipitation events were evident in seven of the nine wells. Step changes in some wells occurred within a few hours of the onset of rain, indicating rapid influx of meteoritic water, while other wells experienced step changes over one or more days after precipitation ceased. Temperature trends in two wells, GW-970 and GW-976, did not respond to precipitation until GW-970 started showing a decline in late February 2015. This may have been caused by snow-melt.

Plots of pH vs. specific conductivity show a clear differentiation between deep and shallow monitoring wells. GW-972, GW-974, and GW-976 have higher pH and specific conductivity than any of the other wells, which may be attributable to the presence of limestone beds or clastic units with calcareous cements. Mean pH and specific conductivity were higher in deep wells than shallow wells in all four well pairs. Both pH and specific conductivity responded to the influx of meteoritic water in shallow wells, but not deep wells, with the exception of GW-968.

### 2.3.5 Ground Water Contaminants

No contaminated ground water or soil is known to occur on or under the proposed EMDF area. According to the BCV RI (DOE 1997), ground water contamination at sites near the EMDF site consists of:

- Radioactive constituents (gross α and β, $^{238}U$, $^{235}U$, $^{234}U$, $^{232}Th$, $^{230}Th$, $^{228}Th$, $^{213}Pb$, and $^{40}K$) in a shallow ground water plume from BY/BY that underlies NT-3.
- Chlorinated solvents in a plume extending down-dip in the Nolichucky from the BY/BY.
- Nitrate and uranium in two shallow-to-deep ground water plumes (one in the Nolichucky Shale, the other in the Maynardville Limestone) emanating from the S-3 Ponds.
- Low concentrations of chlorinated VOCs in shallow ground water at the Oil Landfarm and Sanitary Landfill 1.

The BCV RI (DOE 1997) provides greater detail on the nature and extent of contamination in EBCV prior to the remedial action that was completed at the BY/BY in accordance with the BCV Phase I ROD.

The BCV Phase I ROD does not identify remediation levels to be attained in Zone 3, but states that source area remedial actions are expected to improve ground water quality. Zone 3 ground water monitoring is conducted in Picket B Wells GW-704 and GW-706, and RCRA wells GW-008, near the Oil Landfarm, and GW-046, near the BCBG (DOE 2012).

Well GW-008, the closest monitored well to the EMDF area, is screened at a depth of about 25 ft. Low (< 40 μg/L) and steady concentrations of several chlorinated VOCs, and higher variable concentration of perchloroethene, have been observed since monitoring began in 1999 (DOE 2012). Other contaminants were not reported from GW-008. Well GW-046 also exhibited variations in chlorinated and non-chlorinated VOC concentrations, but at levels an order of magnitude higher than in GW-008. Both wells exhibit seasonal variations. Increased annual rainfall caused a general increase in all VOC concentrations for 2009 and 2010, but concentrations declined to pre-2009 levels by late 2011.

Picket wells GW-704 and GW-706, completed in the Maynardville Limestone, are monitored for nitrate, trichloroethene (TCE), $^{99}Tc$, and uranium isotopes. Contaminant concentrations vary seasonally in response to changes in precipitation. Concentrations of $^{234}U$ and $^{238}U$ have exhibited a declining trend since 1999, such that recent concentrations are at or below 20 pCi/L. TCE and nitrate concentrations are

also declining. Recent TCE concentrations are below 30 ug/L, and nitrate concentrations are below 20 mg/L. $^{99}$Tc concentrations also declined. Ground water chemical concentrations and flux vary in direct relation to precipitation.

## 2.4 SURFACE WATER HYDROLOGY

Surface water features relevant to the proposed EMDF site include tributaries near the site and Bear Creek. Bear Creek drains west to the Poplar Creek, and then to the Clinch River (Watts Bar Reservoir). The elevation difference between upper BCV and the Watts Bar (pool elevation 741 ft) is approximately 250 ft.

### 2.4.1 Water Budget

A water balance or budget is an estimate of how much water enters and is lost from a defined watershed during a stated period of time. Several investigations have attempted to quantify water budgets for drainage basins on the ORR, and results indicate wide variation in runoff and infiltration values. Runoff has been estimated to vary from about 5% to over 50% of precipitation. Healy, et al. (2007) indicates that, on average in North America, about 31% of precipitation is lost as runoff.

Water input is usually considered to be equal to the amount of precipitation (rain and snow), but may also include surface water and ground water inflow from other subbasins or, because ground water and surface water drainage areas are not always coincident, across surface water divides.

The general equation of state is (Healy, et al. 2007; CCL 2001):

$$\Delta S = P + GW_{in} - GW_{out} - ET - R,$$

where:

$\Delta S$ = change in storage (ground water and depression storage)
P = Precipitation
$GW_{in}$ = Ground water inflow
$GW_{out}$ = Ground water outflow
ET = Evapotranspiration
R = Runoff

When the water budget is estimated on an annual basis, it is common to assume that the change in storage over a year is negligible (i.e., $\Delta S = 0$); therefore, water input and output balance (CCL 2001).

Precipitation and stream flow can be measured with relatively good accuracy. As noted in Section 1.4.1, mean annual precipitation is 52.6 in. water equivalent. Runoff can be measured using a number of different techniques, but the most accurate is by measuring flow through a weir.

Evapotranspiration, the total amount of water that is transferred from the earth's surface to the atmosphere by direct evaporation and plant transpiration, is difficult to measure. Potential evapotranspiration is often estimated using mean monthly temperatures, which can result in overestimates of actual water losses. For example, the growing season in the Oak Ridge area is about 220 days long, from early April to early November. During the growing season, calculated evapotranspiration can exceed the rate of precipitation, resulting in soil-moisture deficits. During the winter months, however, precipitation exceeds evaporation, and transpiration is negligible, so that there is a net surplus of water in the system.

Moore (1988) and Borders, et al. (1994) provided an evapotranspiration estimate of 30 in. annually for the Oak Ridge region. This suggests that roughly 55–60% of water that enters the region is lost to the

atmosphere. This is in line with the mean evapotranspiration losses for North America noted in Healy, et al. (2007). The remaining 40–45% either flows out of the region in streams, is held in reservoirs, or recharges the ground water system. Evapotranspiration is greatest during the growing season when plants are transpiring and when warm weather increases direct evaporation rates.

Ground water inflow is often assumed to be absent or negligible because surface water drainage divides are usually more or less coincident with ground water drainage divides, and recharge is autogenic. The water budgets estimated for the ORR incorporate this assumption.

Estimates of recharge in BCV range from 3.1 in. (DOE 1997) to 9.55 in. (Golder Associates 1989b), as shown in Table E-9. PreWAC model recharge rates range from 7 in./year to 8.75 in./year.

**Table E-9. Water Budget Estimates for Areas of the Oak Ridge Reservation**

| Hydrologic Component | DOE 1997 (BCV RI) | | Golder Assoc 1989b | |
|---|---|---|---|---|
| | Amount | % | Amount | % |
| Reference Area | East Bear Creek Valley | | West Bear Creek Valley | |
| Period | March 1994 – February 1995 | | October 1986 – September 1987 | |
| Precipitation | 46.4 in. (1,178 mm) | 100 | 43.29 in. (1,100 mm) | 100 |
| Surface water flow | 15.5 in. (393 mm) | 33.3 | 6.97 in. (177.0 mm) | 16.1 |
| Evapotranspiration | 27.1 in. (688 mm) | 58.3 | 26.77 in. (680 mm) | 61.8 |
| Ground water Recharge | 3.1 in. (78.6 mm) | 6.7 | 9.55 in. (242.6 mm) | 22.1 |
| Ground water Storage | 0.59 in. (15 mm) | 1.3 | | |

The BCV RI (DOE 1997) and results of ground water tracer studies (Goldstrand and Haas 1994) suggest that the surface divide between the Bear Creek basin and the UEFPC basin may not be the same as the ground water divide. Thus, there is a possibility of extra-basin ground water inflow to the Bear Creek watershed.

Ground water outflow is not directly measurable, and therefore must be estimated using flow nets or computer models. Ground water outflow is supported by precipitation infiltrating through soils from the surface (or outside sources). Estimates done for various drainage basins on the ORR range from about 7% to over 45% (Ketelle & Huff 1984; Clapp and Frederick 1989; Rothchild, et al. 1984; Luxmoore 1983; Solomon, et al. 1992). Often, however, the unmeasurable components of a water budget are lumped, rather than estimated, so that:

$$P - R = (ET + GW_{out} + \Delta S),$$

where the parentheses indicate that ET, $GW_{out}$, $\Delta S$ are not discriminated.

Change in ground water storage can be measured in unconfined aquifers as the change in water level in the vadose zone. Over the period of a year, the change in ground water storage can be considered to be a net of zero, because the surplus precipitation from winter is expended during the summer months.

Results differ considerably, reflecting differences in geology, soils, vegetative cover, and hydrology, as well as some of the underlying assumptions used in the calculations. The data and results of the DOE (1997) and Golder Associates (1989b) studies are from areas that are most similar to the EMDF candidate site, so that the combined percentage of subsurface flow and change in ground water storage range between 8% and 22% of total precipitation. As noted above, change in ground water storage, on a yearly basis, is essentially zero, therefore the amount of infiltration on a yearly basis can vary from about 22% to about 45% of precipitation.

### 2.4.2 Northern Tributaries of Bear Creek

Two small streams, tributaries of Bear Creek, are on or adjacent to the candidate site. These are NT-2 and NT-3, both are second-order streams at their junctions with Bear Creek. NT-2 lies east of the EMDF site and consists of a main branch with two tributaries entering from the west. NT-3 also has a main branch (NT-3c) with two small tributaries (NT-3b and NT-3a) entering from the west; NT-3c crosses diagonally through the EMDF site. Both streams flow southwest through culverts under the Haul Road to join Bear Creek.

Both NT-2 and NT-3 are fed by seeps and springs during high base flow periods (i.e., the wet season) (Robinson and Johnson 1996). NT-2 rises as a spring on the flank of Pine Ridge, roughly at the subcrop of the boundary between the Rome Formation and Pumpkin Valley Shale. A valley to the west of NT-2 is fed by a seep at about the same position relative to slope and boundary subcrop. Several other valleys that flow to NT-2 are fed by seeps.

Rosensteel (2015) performed hydrologic determination surveys for the three branches of NT-3 according to the requirements of TDEC Rule 1200-4-03-.05(9) and *Guidance for Making Hydrologic Determinations* (TDEC 2011, version 1.4). Stream segments were mapped with a Trimble GeoXT global positioning system. This survey found that 450 linear feet of NT-3a and NT-3b exhibited the characteristics of wet weather conveyances. The remaining segments of NT-3a and NT-3b, and all of NT-3c, a total of 2,780 linear feet, are classified as streams. Results are shown in Figure E-17.

NT-3a above the from the headwater spring is a wet weather conveyance. From the spring to the wetland at the Haul Road NT-3a is a perennial or intermittent stream. It receives discharge from the EMWMF diversion ditch during rain events. Its bed is gravelly upstream from a small gravel access road to EMWMF monitoring well GW-916, but cuts through sediments from there to the downstream wetlands.

NT-3b was a wet-weather conveyance upstream of the EMD-NT-3-SP3 spring prior to the downburst and timber recovery, with sections of defined channel and swales without a defined channel. Much of this wet-weather conveyance was eliminated by logging operations. Subsequent access road construction rechanneled flow, with discharge directed to NT-3b near the spring. From EMD-NT-3-SP3 to the wetland at the Haul Road, NT-3b exhibits a small channel with perennial to intermittent flow. Discharge is dispersed as it enters the lower wetland.

NT-3c is an intermittent to perennial stream throughout its length. NT-3c arises at a headwater spring in a narrow draw on the flank of Pine Ridge and flows in a defined channel to the wetlands near the Haul Road. Some segments of the channel are incised 4–5 ft.

Both NT-2 and NT-3 have small wetlands along portions of their main channels. The wetlands near the Haul Road appear to have expanded as a result of a flow restrictor plate that was welded across the culvert as part of the restoration of NT-3 adjacent to the BY/BY.

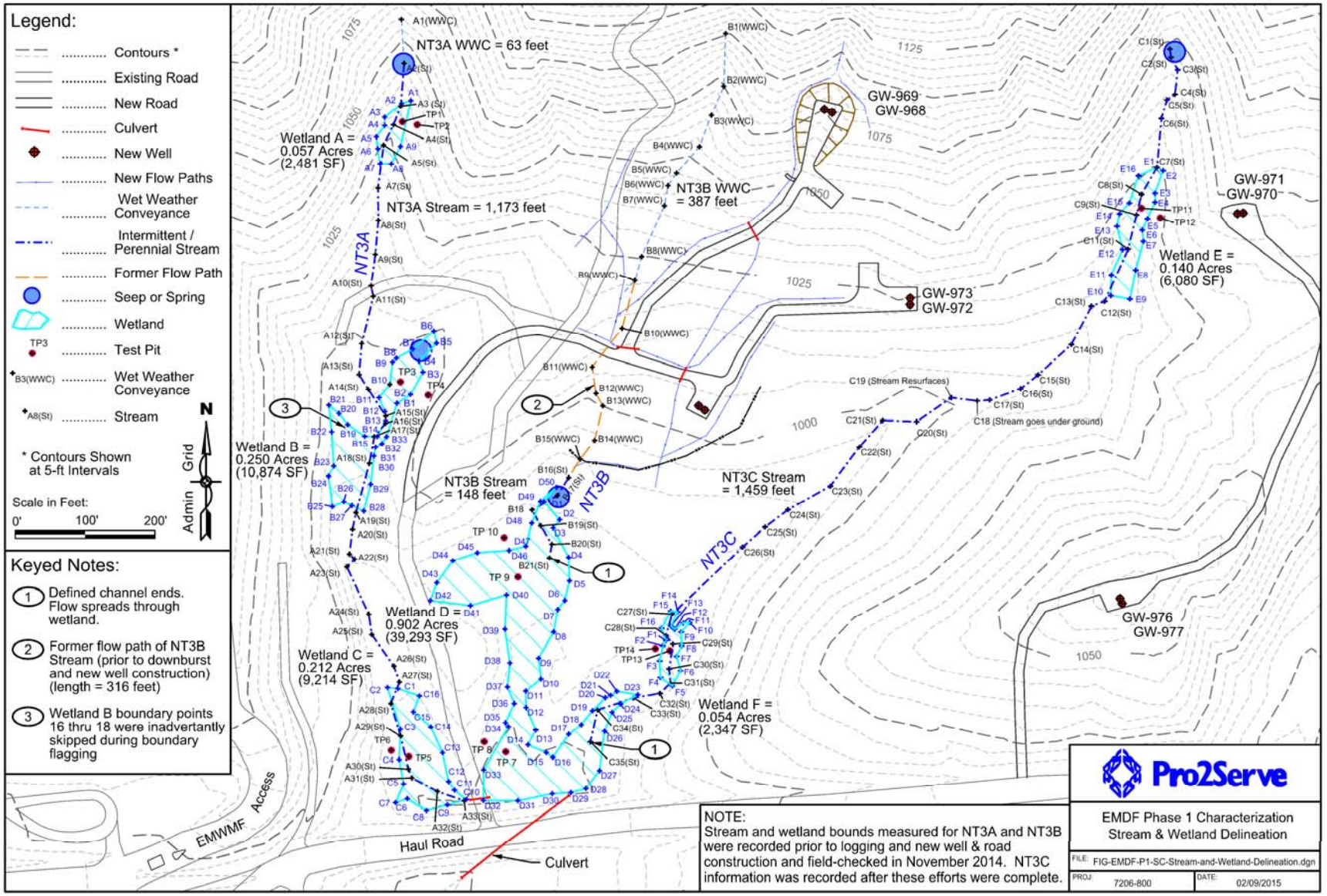



**Figure E-17. Streams and Wetlands in the NT-3 Drainage Basin**

#### 2.4.2.1 Stream Flow Characteristics

During seasonal high water table conditions, the primary water sources to the tributaries are springs and seeps that discharge from the contact of the Rome and Pumpkin Valley formations and ground water seepage. Both NT-2 and NT-3 are intermittent streams (Robinson and Johnson 1996; Robinson and Reavis, 1996), meaning that they are dry during the annual dry season (August–October). However, in the BCV RI (DOE 1997) it was noted that NT-2 maintained continuous flow at a downstream weir from March 1994 through January 1995 (i.e., for a period overlapping the USGS study period). Flow is continuous during the wet season (November – April). Portions of Bear Creek are also largely dry during the fall dry season above NT-8, about 1.3 miles to the west of NT-3.

Flow in NT-2 during a one week wet season measurement period in March 1994 was approximately 0.16 $ft^3/s$ both at its confluence with Bear Creek and at a point roughly 1,800 ft upstream (Robinson and Reavis, 1996). During this time, NT-2 also had dry reaches. Springs and seeps were found by Robinson and Johnson (1996) to be dry during the late summer and early fall dry season, coincident with lack of base flow in the streams.

Flow in NT-3 during the same measurement period ranged from 0.2 to 0.4 $ft^3/s$ in the upstream segments to 1.16 $ft^3/s$ at its confluence with Bear Creek (Robinson and Reavis, 1996). NT-3 had no dry reaches during this time.

Continuous stream flow measurements in flumes were performed as part of the Phase I site characterization. Cutthroat flumes were installed in a lower reach on each of the three branches of NT-3 and instrumented to provide continuous water level data which are used to calculate flow rate. Because flood-stage flow rates are of concern in designing the underdrain, the flumes are capable of accurately measuring large flows, but are not accurate at very low flow (i.e., base flow) conditions. These flumes are identified as SWG-1 for the eastern and longest branch, SWG-2 for the central and shortest branch, and SWG-3 for the western branch of NT-3.

Total rainfall during the three-month reporting period from December 2014 through February 2015 is similar to long-term averages and does not constitute a particularly dry or wet condition relative to climatic normals. The largest and most intense precipitation events recorded during the reporting period are not high magnitude events in terms of historical precipitation frequencies. Storms of similar magnitude are expected to occur several times in an average year in the vicinity of the EMDF site.

Estimated total surface runoff relative to precipitation inputs analyzed for nine runoff events was within a reasonably expected range for the winter wet season. Results indicate that flows respond rapidly to rainfall, as expected, and return to base flow conditions within two to four days after rainfall stops. The western two NT-3 branches responded more rapidly that did the eastern branch, which has a much greater catchment area. Base flow in all three branches is less than about 0.06 cfs (1.7 l/s), which is in good agreement with flows reported by Evaldi (1984) and Robinson and Johnson (1996). For example, during a storm on December 23–24, 2014 that dropped 2.6 in (6.6 cm) of rain, the east branch of NT-3 experienced a maximum flow of 9.6 cfs (271.8 l/s). Maximum flow in the west branch of NT-3 was 2.17 cfs (61.45 l/s) and in the central branch it was 0.64 cfs (18.1 l/s) during this same storm. A storm that dropped 1.35 in (3.44 cm) of rain on December 6, 2014 resulted in maximum flow rates of 2.95 cfs at SWG-1, 0.45 cfs at SWG-2, and 0.99 cfs at SWG-1. The storm actually created four peak flows in SWG-2 and SWG-3, which were set to measure at 20-min. intervals; the SWG-1 level transducer was set to collect data at 1-hr intervals and recorded only two peaks. SWG-2 and SWG-3 showed little difference in timing for the maximum peak, but SWG-1 experienced a roughly three-hour lag. The four peak flow recorded for SWG-2 and SWG-3 likely were due to passage of squalls, and had SWG-1 been set to record at 20-minute intervals, it also would have shown four peaks. Flows in all three streams declined nearly to

base level within about 12 hours of last rainfall. This behavior is consistent with rapid storm-flow zone and surface flows, with little direct recharge of deeper ground water.

#### 2.4.2.2 Gaining and Losing Reaches

Both NT-2 and NT-3 exhibit gaining and losing reaches during high base flow conditions (Robinson and Reavis 1996). During high base flow conditions, the upper reaches of the tributaries gain flow, but the lower reaches may either have no gain or may be losing flow. Under low-flow conditions the tributaries can be dry throughout their length.

#### 2.4.2.3 Tributary Chemistry Indicators

Ranges of values for four stream chemistry indicator parameters are provided in Table E-10. In general, low base flow measurements were collected from standing pools in otherwise dry streams, as the high temperatures suggest. The pH ranges from slightly acidic to slightly alkaline, and does not appear to vary with the distance from source. Specific conductivity tends to increase linearly from source to confluence at Bear Creek; the highest values occur at the mouth of each stream during both high-flow and low-flow periods. Temperature during high base flow is in the range that would be expected for the time of year. High base flow water temperatures tend to decrease downstream. Dissolved oxygen concentrations are highly variable. No chemistry parameter measurements were recorded for wetlands on NT-2 and NT-3.

Phase I site characterization results for the three-month monitoring period (December 1 through February 26) provide data for a wet non-growing season. Precipitation for the period is very close to the 30-year average. Observed variations in surface water temperatures were consistent with trends in air temperature and with temperatures measured at the six observational monitoring sites. Temperatures recorded at the three spring observational monitoring sites were typically 1–3° C higher than water temperatures at the surface water gauging stations.

Specific conductivities recorded at the surface water gauging stations ranged from approximately 0.05–0.35 mS/cm over the reporting period, and are in line with values report in Evaldi (1984). The pH values at the surface water gauging stations generally ranged between 6 and 7. Continuous records of specific conductivity from the surface water gauging stations were consistently higher than specific conductivity values measured at the six observational monitoring sites. The pH values measured at the six observational monitoring sites were generally similar to or slightly lower than pH at the surface water gauging stations.

Variations of surface water specific conductivity and pH during runoff events were complex and variable among the three surface water stations and among events. Increases in surface flow due to precipitation cause rapid decreases in specific conductivity and pH, consistent with the arrival of relatively dilute, slightly acidic runoff at the surface water gauging stations.

It should be noted that a portion of surface water flow from the EMDF bypassed the flumes due to the way the site was graded after timber recovery. Flow from an area between the center and east branches of NT-3 discharged to NT-3 east downstream of the SWG-1 flume. Therefore, flow volumes are not entirely representative of the site.

#### 2.4.2.4 Tributary Contaminants

Surface water samples are collected annually at two locations in NT-3 as part of the on-going Water Resources Restoration Program to measure the uranium isotopic composition, nitrate, $^{99}$Tc, and VOCs (DOE 2012). These contaminants are associated with releases from the BY/BY, Hazardous Chemical Disposal Area, Sanitary Landfill, Oil Landfarm that leach to NT-3, and a nitrate plume from the S-3 Ponds that has migrated in the Nolichucky Shale to discharge to surface water. As reported in DOE (2012), a sample collected at monitoring station NT3-1E immediately downstream of the culvert

under the Haul Road did not contain measureable uranium, nitrate, $^{99}$Tc, or VOCs. Samples collected at the NT-3 integration point all contained measurable uranium and one sample contained a trace of nitrate.

**Table E-10. Summarized Water Chemistry Parameters for NT-2 and NT-3**

| Stream | Measurement Period | Type | pH | Specific Conductivity ($\mu$ S/cm) | Temperature (°C) | Dissolved Oxygen (mg/L) |
|---|---|---|---|---|---|---|
| NT-2 | High base flow | Stream (18 sites) | 5.9–7.9 | 27–902 | 8.0–12.0 | 9.8–11.0[a] |
| | | Spring (1 site) | 7.2 | 29 | 12.0 | NA |
| | | Seeps (13 sites) | 5.1 – 7.5 | 25 – 88[b] | 8 0 – 12.0 | 2.4 – 10.8 |
| | Low base flow [c] | Stream (7 sites) | 6.9 – 7.9 | 77 – 2,030 | 18.0 – 22.5 | 6.5 – 8.2[d] |
| NT-3 | High base flow | Stream (12 sites) | 5.4 – 8.1 | 39 – 760 | 8.5 – 14.5 | NA |
| | | Spring (1 site) | 6.6 | 62 | 12.0 | 8.8 |
| | | Seeps (3 sites) | 5.4 – 6.4 | 41 - 66 | 9.5 – 12.5 | 5.0 – 9.5 |
| | Low base flow [c] | Stream (5 sites) | 7.4 – 7.6 | 73 - 642 | 19 – 20.5 | NA |
| | | Spring (1 site) | 7.1 | 84 | 18.5 | 7.4 |
| | | Seeps (1 site) | 6.9 | 92 | 17.5 | 8.2 |

Source: (Robinson and Johnson 1996). Data collected during March and September, 1994.
[a] Four measurements at downstream end.
[b] Eight measurements
[c] Low base flow measurements are assumed to be from isolated pools with little or no flow, since both streams are indicated to be dry during the low base flow period.
[d] Five measurements, from near head to near confluence

No $^{99}$Tc or VOCs were detected in these samples. Uranium ($^{234}$U and $^{238}$U) concentrations at the NT-3 integration point declined steadily from 1999 through 2007, then began to increase again. Continuous flow-paced sampling was resumed at NT-3 because the uranium levels exceeded the 4.3 kg/year flux standard set in the ROD. Differences between the pre-remediation and post-remediation isotopic composition of uranium suggests that contributions are from a different source than the BY/BY (DOE 2012).

Prior to the completion of remedial actions in 2003, NT-3 was heavily affected by contaminants, mainly uranium and mercury, leaching from the BY/BY. NT-3 is sampled for four quarters near the end of each Five-Year Review period and analyzed for TDEC ambient water quality criteria, and uranium flux is measured quarterly each year. Water at the NT-3 sampling station generally meets ambient water quality criteria (AWQC), but exceeded the AWQC for heptachlor for one of the four quarterly samples collected during 2010. The annualized uranium flux continues to exceed the NT-3 goal of 4.3 kg/year. These contaminants are most likely from the BY/BY, Hazardous Chemical Disposal Area, or Unit 6 Landfill on the east side of NT-3.

Biological monitoring indicates that benthic diversity remains low and that there are fewer pollution-intolerant benthic taxa than in nearby reference streams. Fish communities in NT-3 exhibit slightly lower or similar total richness as compared to reference streams.

### 2.4.3 Bear Creek

Bear Creek flows west in BCV from its head waters near the S-3 Ponds to ultimately discharge to East Fork Poplar Creek near ETTP. Bear Creek is located south of the proposed EMDF site and is briefly discussed here because it receives waters from NT-2 and NT-3, and because it is the surface expression of the BCV drainage system.

The local base level for BCV is the Bear Creek flow system. This system is a 3-dimensional system in which the complex conduit system in the Maynardville and Bear Creek function as an integrated drain for the valley. At any given time, flow will occur in at least some level in the Maynardville Limestone conduits, and in Bear Creek where it lies on the Nolichucky or is not locally connected to the cavity system. The upper reaches of Bear Creek go dry and lose flow to the subsurface during low flow periods. As flow increases, more of the Maynardville cavity system will be recruited to handle the flow, until flow volumes are sufficient to cause open flow in Bear Creek. The BCV drain can be viewed as a series of stacked conduits, of which the open stream channel is simply the uppermost. It therefore is a hydraulic boundary for the majority of ground water and surface water flow.

#### 2.4.3.1 Stream Flow Characteristics

Daily flows at Bear Creek Kilometer (BCK) 11.54, just downstream of the confluence of NT-3 with Bear Creek, were obtained from the Oak Ridge Environmental Information System database for the period from 2006 through 2011. The average daily flow is 0.55 $ft^3/s$, the median daily flow is 0.18 $ft^3/s$, and the range is from no flow (dry) in summer to 32 $ft^3/s$ in the winter-spring wet season.

#### 2.4.3.2 Gaining and Losing Reaches

The upper reaches of Bear Creek may be gaining, losing, or neutral, depending on high and low base flow conditions (Robinson and Reavis 1996). Under high flow conditions, Bear Creek is a losing stream at the confluence with NT-2 but becomes gaining as it passes the BY/BY to its confluence with NT-3. It then becomes a losing stream as it passes Sanitary Landfill 1.

Robinson and Reavis (1996) found that under low base flow conditions, many reaches of Bear Creek above the water gap in Pine Ridge were losing or dry. This is particularly true of the reaches above the confluence of NT-4, although there is a slight gain inflow below the confluence with NT-3, even though

no flow was recorded in NT-3 itself. This is interpreted, as noted above, to be the result of discharge through cavity systems underlying the tributary.

### 2.4.3.3 Bear Creek Water Chemistry

Table E-11 provides a summary of Bear Creek water chemistry indicators. The pH of water in the upper reaches of Bear Creek averages close to 8 SUs, based on 135 measurements at six stations (BCK 9.47, 11.54, 11.84, 12.34, 12.38, and 12.47) at various times between 1998 and 2009. Specific conductivity, a measure of total dissolved solids, is highly variable, ranging from <1 µS/cm to 2,738 µS/cm in samples taken at the same locations and times. In general, the average specific conductivity by measurement station decreased downstream, and the exception, BCK 12.34, is near the former S-3 Ponds and likely to be affected by S-3 contaminants.

**Table E-11. Summary of Bear Creek Water Chemistry Indicators**

| Station* | N | Period | pH (SU) | Specific Conductivity (µS/cm) | Temperature (°C) | Dissolved Oxygen (ppm) | Redox Potential (mV) |
|---|---|---|---|---|---|---|---|
| BCK 9.47 | 21 | 2/98 – 8/06 | 8.06 | 395 | 15.7 | 10.2 | 132.1 |
| BCK 11.54 | 10 | 3/02 – 8/06 | 7.96 | 552 | 17.5 | 8.2 | 109.1 |
| BCK 11.84 | 9 | 3/02 – 8/06 | 7.98 | 675 | 16.2 | 8.9 | 106.7 |
| BCK 12.34 | 66 | 10/01 – 9/09 | 7.47 | 994 | 16.7 | 8.4 | 134.6 |
| BCK 12.47 | 26 | 3/98 – 9/03 | 7.6 | 653 | 16.5 | 8.1 | 102.7 |
| Upper BCV | 21 | 2/98 – 9/09 | 7.65 | 801 | 16.5 | 8.6 | 125.8 |
| Uncontaminated river water** | | | 6.5 – 8.5 | 50 – 50,000 | NA | | |

* Station 12.38 had only two measurements and was therefore not included in the summary table.
** Hem, 1989

### 2.4.3.4 Bear Creek Contaminants

Eastern reaches of Bear Creek are impacted by contaminants originating in the former S-3 Ponds and the various waste management units in Zone 3. The uranium flux goal set by the Phase I ROD is ≤34 kg/year at the integration point (BCK 9.2) and ≤27.2 kg/year at BCK 12.34. The goal for BCK 9.2 was not met during any year since 2000; the goal at BCK 12.34 was achieved during five of the past 10 years, but was not met in 2010 or 2011. Trends in uranium loadings in upper Bear Creek are positively correlated to annual rainfall amounts. A significant portion of the gain in flux appears to be due to inputs from the former burial grounds area. Large increases in uranium flux are observed at BCK 9.2 in response to increased annual precipitation (2004, 2006, 2010); this is apparently due to uranium influx from the BCBG in NT-8. Uranium flux at BCK12.34 also tracks precipitation, but is more subdued.

Nitrate and cadmium contaminants emanating from the former S-3 Ponds have formed two ground water plumes in EBCV, and some of this contaminated ground water is discharged to the upper reaches of Bear Creek (DOE 2012; DOE 1997). Nitrate concentrations are inversely related to rainfall because of dilution.

Average annual nitrate concentrations have remained below the industrial use preliminary remediation goal of 160 mg/L, although some measurements from particularly dry periods have exceeded this amount (DOE 2012). Nitrate concentrations decrease downstream from the S-3 Ponds area.

Cadmium concentrations significantly exceed the 0.25 μg/L AWQC at BCK12.34 during the years 2001–2010, but meet the AWQC at BCK 9.2 (DOE 2012).

Southworth, et al. (1992) noted that reductions in Bear Creek contaminant loads occurred after waste stopped being placed, and the results of remedial effectiveness sampling since 1999 confirm this trend (DOE 2012). However, uranium continues to exceed the ROD goal.

## 2.5 CONCEPTUAL MODEL

The conceptual model for the proposed EMDF is based on work done previously on the ORR by Hatcher, et al. (1992), Solomon, et al. (1992), and many others. They documented a distinctly anisotropic ground water flow system that occurs in highly fractured clastic-dominated bedrock or in solution-enhanced fractures and conduits in carbonate units. Anisotropy is the result of the tendency of fractures to develop parallel to the strike of tilted bedrock units, and flow tends to move parallel to structural and topographic features. However, this work did not fully explain how ground water flowing along strike, as for example on the south flank of Pine Ridge, would be redirected across stratigraphic boundaries to reach trunk streams on valley floors. The conceptual site model outlined below provides a possible mechanism for cross-stratigraphic flow.

The major features of the conceptual site model are:

- Strike-parallel local ground water flow concentrates on tributary streams and postulated underlying fracture systems.
- Cross-stratigraphic flow then occurs by ground water discharge to surface water (the north tributaries) and/or flow through master fractures beneath tributaries.
- Flow in tributaries and fractures discharges to the tiered valley drain composed of Bear Creek and Maynardville conduits.

This concept, if proven, indicates that the EMDF ground water monitoring system should target the tributary/fracture exit pathways, because these locations are where contaminant releases would concentrate after the EMDF is closed and water tables are lowered. This would, by extension, provide a means to capture and remediate contamination, should any be detected.

Ground water flow through more distributed fractures and matrix pores is not eliminated in this concept, but is considered to be volumetrically minor compared to tributary stream/fracture flow paths.

Ground water in saprolite matrix and fractures and bedrock fractures in Conasauga Group units flows with the strike-parallel gradient in each unit to the nearest tributary. Fractures in Conasauga rocks and saprolite define a flow system that, at a large scale, behaves similarly to a heterogeneous matrix system in which it is the aggregate or bulk characteristics that control ground water flow. The majority of flow from ridge flanks is directed towards the valley axis by the north tributaries and vertically upward from deeper ground water to discharge into the Bear Creek – Maynardville Limestone drainage system by the pressure head from surrounding ridges. A small amount of diffuse flow from soils and sediments may also contribute to stream flow.

Worthington and Ford (2009) describe a process whereby dissolution along fractures in carbonate aquifers self-organizes ground water flow into networks consisting of one or more trunk conduits, smaller branch or tributary conduits, and fractures not yet solution-enhanced as illustrated conceptually in Figure E-18. Although many of the bedrock units at the EMDF site are shaley and therefore less

susceptible to dissolution, this concept appears to be applicable. This concept is supported by White & White (2005, 2003), who note that ground water flow in carbonate aquifers focus into a few localized pathways at an early stage of development. This focusing is more efficient in areas of higher gradients (White & White 2003). In this concept, the trunk conduit or pathway forms along some preferred path, such as a fracture, and becomes dominant when it achieves break-through at a larger conduit or stream (Worthington 1999, 1991). At this point, flow in the trunk conduit becomes turbulent, further increasing conduit size and permeability in a positive-feedback process.

Over time, the network of conduits becomes increasingly widespread, complex, and finer as dissolution continues to develop the tributary system, presumably, to match the amount of water that must flow through the system. The concept is roughly analogous to development of surface streams, but results in finer conduits in headwaters areas than would be found in surface stream systems because no overland flow can occur in subsurface systems. Unorganized wide-area flow may occur locally, but is not a major flow pathway.

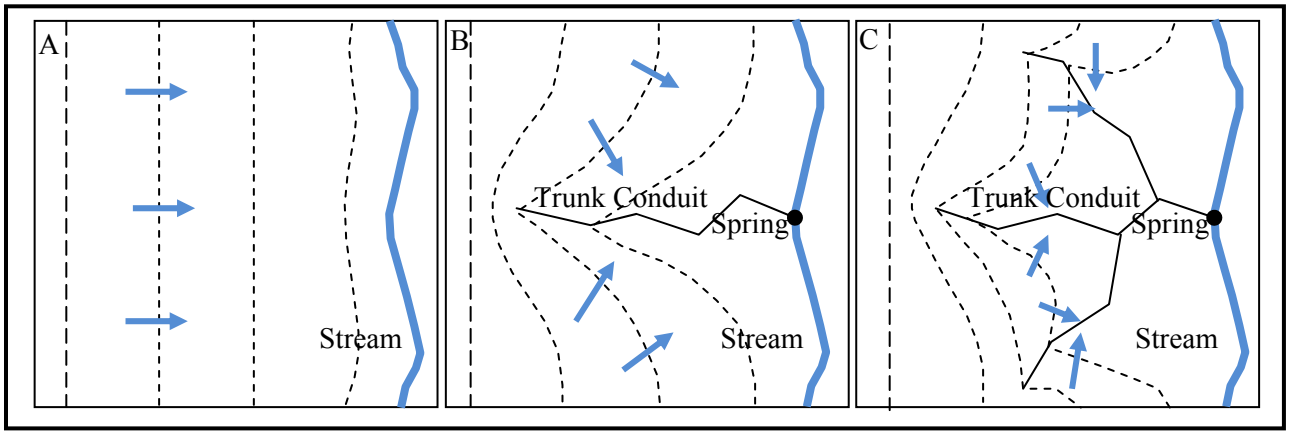



**Figure E-18. Conceptualization of Development of Self-Organized Permeability in Carbonate Aquifer**

The larger-aperture conduits occupy a relatively small fraction of the bulk volume of the aquifer, but because of their large size and integration, carry most of the water. However, although cavities, presumably capable of conduit flow, have been documented in the Nolichucky and Maryville formations, it is by no means clear that these convey the majority of ground water flow, but it is likely that they convey much of the strike-parallel flow.

It can be argued that this model of self-organized permeability is not suitable for a mixed carbonate-clastic bedrock that is structurally tilted at 45° from horizontal, because clastic rocks, such as shale and siltstone, do not dissolve, and because the tilted beds present barriers to flow. However, the model can be fitted to the proposed EMDF site by substituting fractures in clastic rocks for conduits while still including conduits in carbonate rocks, and by recognizing that the dominant cross-strata fractures or joints that are exploited by NT-2 and NT-3 also function as subsurface drains. These fractures or joints would undergo enhanced weathering due to the concentration of ground and surface water. The strong anisotropy of saprolite and bedrock hydraulic conductivity will result in a more rectilinear ground water drainage system than the surface water drainage area exhibits, but the drainage areas should be roughly the same.

The valley drain is a complex three-dimensional system in which Bear Creek and strike-parallel underflow and overflow conduits in the Maynardville Limestone function together. Bear Creek flows

more or less continuously over non-karst bedrock, but loses flow to subsurface conduits where it crosses karstic rocks. Underflow conduits in the Maynardville Limestone continuously convey base flow, while overflow conduits and Bear Creek carry high flows during the wet season and heavy rainfall events. Figure E-19 is a graphical representation of this conceptual model. Water readily moves in and out of the Bear Creek channel and stacked subsurface conduits. This is demonstrated by the numerous losing and gaining reaches in Bear Creek. The amount of water in the system dictates which conduits are recruited to conduct flow, as demonstrated by the documented occurrence of quickflow in the Maynardville, and since large segments of the stream go dry in summer, but flow continuously during the winter wet season.

The shape of the shallow BY/BY alpha plume in ground water, as reported in DOE 1997, and modeling conducted as part of this RI/FS (see Appendix H) support this concept.

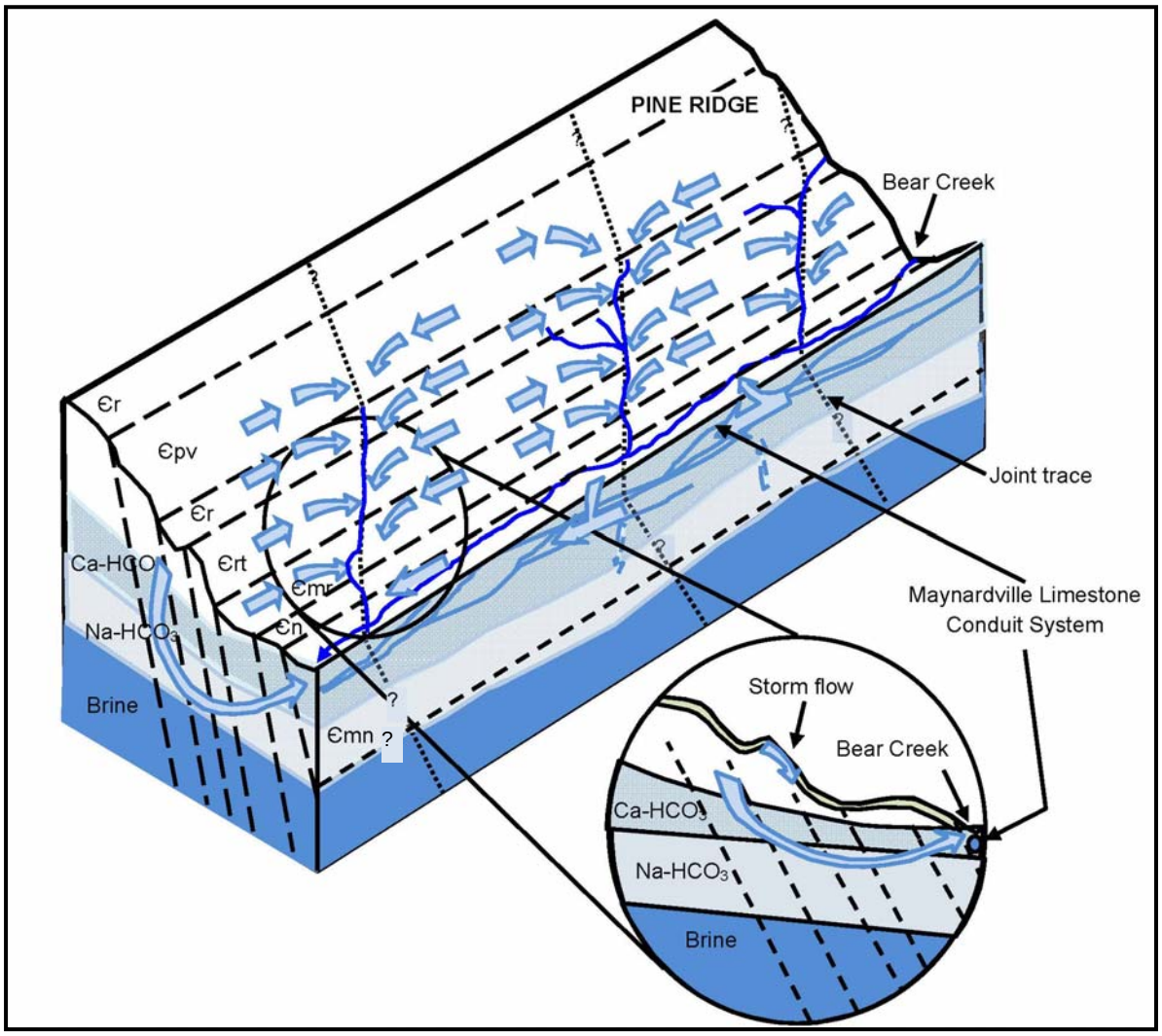


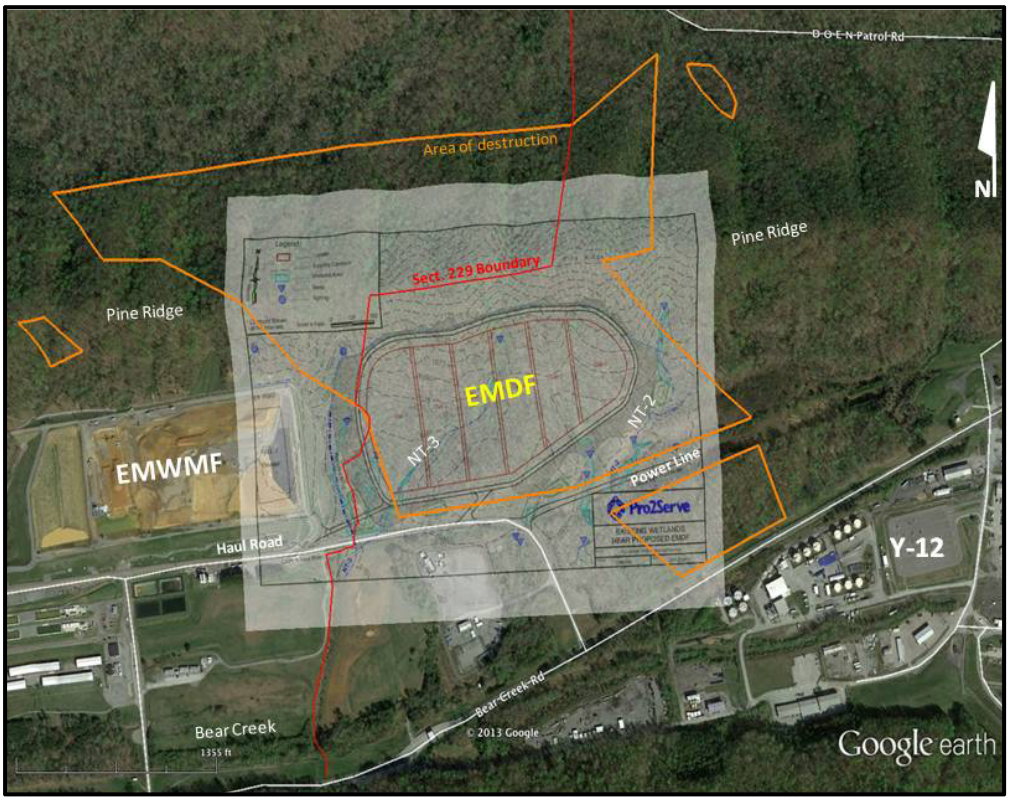

**Figure E-19. Block Diagram Illustrating Conceptual Ground Water Flow Model for the Proposed EMDF Site**

## 2.6 ECOLOGICAL SETTING

The proposed EMDF site is characterized by deciduous hardwood forests, intermittent streams, springs, and seeps, and small wetlands.

### 2.6.1 Recent Changes in Site Conditions

A severe down burst or microburst occurred over the crest of Pine Ridge at a point roughly between the EMWMF and EMDF sites on May 19, 2013. Wind speeds of greater than 85 miles per hour, as estimated by the National Weather Service (Mori, pers. comm., June 5, 2013), were directed down both flanks of Pine Ridge causing extensive wind throw. Figure E-20 shows the approximated outlines of the damaged areas (Byrd, pers. comm. 2013). Approximately 75% of the EMDF area in the NT-3 and NT-2 watersheds was severely impacted by this event, and the remaining forest along the upper slopes of Pine Ridge was heavily damaged. Numerous trees fell or were snapped off throughout the EMDF area, but destruction was particularly heavy and widespread along the east branch of NT-3 and over into the lower valley of NT-2. The forest in the NT-3 basin was essentially obliterated. According to the National Oceanic and Atmospheric Administration Enhanced F-Scale Damage Indicators (NOAA 2013), uprooted or snapped hardwood trees indicate wind speeds between 91 and 134 miles per hour. The Y-12 West Tower meteorology station recorded a wind speed of 75 miles per hour during the storm. The Y-12 West Tower is roughly 0.5 mile from the EMDF site, outside the damaged area.




Map courtesy Greg Byrd, ORNL Natural Resources Division

**Figure E-20. Area of Severe Wind Impacts due to the May 19, 2013 Downburst**

DOE conducted a timber recovery operation over the damaged area which removed the majority of saleable timber in the damaged area. Subsequently, additional clearing and access road construction was completed to support site characterization efforts. Figure E-21 is an aerial photograph of the site taken after road construction was completed.

A second major change is due to construction of a new haul road to support construction of the planned Uranium Processing Facility (UPF). Two wetlands along NT-2 were expanded as mitigation for other wetland areas that have been impacted by UPF haul road construction. Figure E-22 shows an October 2014 photograph of an NT-2 wetland that had been remodeled and expanded as part of the UPF project.

After timber recovery and access road construction was completed.
Access roads generally follow logging roads.

**Figure E-21. EMDF in September 2014**

**Before** **After**

**Figure E-22. Before and After Photos of the NT-2 Wetland**

### 2.6.2 Aquatic Habitats and Sensitive Species

The proposed EMDF would occupy or touch on areas that include perennial and ephemeral streams and small wetlands, as shown previously in Figure E-17.

#### 2.6.2.1 Wetlands

Six small wetlands have been delineated in the NT-3 watershed, and four wetlands were identified in the NT-2 watershed in or adjacent to the EMDF site.

NT-2 receives flow from five small valleys, and four of these host forested wetlands in broad level bottoms upstream and downstream of the Haul Road. As noted above, the NT-2 wetlands have been significantly impacted by construction of the UPF Haul Road.

Rosensteel (2015) and Rosensteel and Trettin (1993) delineated the six wetlands in the NT-3 drainage, as shown in Figure E-17. Five wetlands (wetlands A, B, C, D, and F) are included in Reference Area (RA)-5, the Quillwort Temporary Pond wetland, named for the Carolina quillwort (*Isoetes caroliniana*) that was observed in the area. Baranski (2009) noted that the Carolina quillwort might be a rare species, but it is not la Federal or state-listed species of concern. The RA-5 wetland was formed, in part, as a result of water backed up by a partial restrictor plate[4] covering the mouth of the NT-3 culvert before it passes under the Haul Road. This wetland has a combined gross area of approximately 1.37 acres (Rosensteel 2015).

Rosensteel and Trettin (1993) classified the small wetlands along the lower reaches of the three NT-3 branches as forested wetlands in tributary bottoms with dense understory, while the wetlands near the heads of NT-3a and NT-3c are classed as "forested wetland in depression at tributary head." Baranski (2009) ranked the ORR natural areas and reference areas on several factors, and found that RA-5 ranked among the lowest priority sites. RA-5 may be an important amphibian breeding ground (Parr, pers. comm., 2012).

NT-3a and NT-3c have small wetlands in their headwaters, which are classed as emergent wetland at narrow sloped headwall spring. Robinson and Johnson (1996) noted that all upland wetland sites were dry during the September 1994 measurement period. Rosensteel (2015) found clear evidence of wetland soils, vegetation, and hydrology at both sites. The wetland on upper end of NT-3a covers an area of about 0.06 acres and the wetland near the headwaters of NT-3c covers about 0.14 ac.

#### 2.6.2.2 Aquatic Resource Monitoring in Bear Creek

Bear Creek is designated as Oak Ridge Research Park Aquatic Natural Area (ANA)-2 (Parr 2012; Baranski 2009). The stream habitats of upper Bear Creek and its tributaries are used infrequently by aquatic biota because of headwater contamination originating from waste disposal sites near the Y-12 Plant (Southworth, et al. 1992), and because the large segments of Bear Creek and its tributaries are commonly dry during the late summer and early fall months (Robinson and Reavis, 1996; Robinson and Johnson 1995).

In general, the diversity and abundance of aquatic fauna were found to increase with distance from the contaminated headwaters (Southworth, et al. 1992). This may also be due, in part, to increases in stream depth and continuity of flow. A total of 126 benthic invertebrate taxa were recorded in Bear Creek, including crustaceans, aquatic worms, snails, mussels, and insects. Southworth et al (1992) collected

[4] This restrictor plate was installed during the restoration of NT-3 south of the Haul Road after the BY/BY cap was constructed.

representatives of 11 orders of insects, including springtails, mayflies, dragon flies and damselflies, stoneflies, crickets and grasshoppers, alderflies and caddisflies, butterflies and moths, beetles, true flies, and true bugs.

Benthic fauna appear to be more sensitive to contaminants than the fish communities; species intolerant of pollution (mayflies, stoneflies, and caddisflies) are absent in the upper reaches of Bear Creek and are increasingly more common downstream. Southworth, et al. (1992) notes that mayflies, highly sensitive to heavy metal pollution, are almost totally absent in all but the lower reaches of Bear Creek. Upstream areas are numerically dominated by midge larvae, which is typical of polluted streams (Southworth et al. 1992).

Nineteen species of fish were recorded in Bear Creek during surveys in 1984 and 1987, and data provide evidence of ecological recovery in Bear Creek since 1984 (Southworth, et al. 1992; Ryon 1998). Studies have concluded that much of Bear Creek contains a limited number of fish species that appear to have robust populations (high densities and biomass). Fish surveys near the headwaters demonstrate a stressed condition without a stable, resident fish population (Southworth, et al. 1992). A weir located in the creek near Highway 95 acts as a barrier to movement, preventing redistribution of fish species from the lower portions of Bear Creek. Four fish species predominate in the upper reaches of Bear Creek (above kilometer 11) include blacknose dace (*Rhinichthys atratulus* Hermann, 1804), Tennessee dace (*Phoxinus tennesseensis* W.C. Starnes & R.E. Jenkins 1988), creek chub (*Semotilus atromaculatus* Mitchell, 1818), and stoneroller (*Campostoma anomalum* Rafinesque, 1820). Ryon (1998) noted the presence of creek chub and blacknose dace in NT-3. By comparison, 14 fish species occur downstream from SR-95.

Biological monitoring of stream sites in BCV watershed has been conducted since 2004 to measure the effectiveness of watershed-scale remedial actions (DOE, 2012). Biological monitoring includes contaminant accumulation in fish, fish community surveys, and benthic macroinvertebrate community surveys. Data from BCV are compared to reference sites on similar sized creeks outside the ORR. Additionally, annual monitoring has been conducted on NT-3 south of the Haul Road to document the progress of stream restoration after the BY/BY remediation was completed (Petersen, et al. 2009).

Fish are collected twice a year at sampling locations BCK 3.3, BCK 9.9, and BCK 12.4 and analyzed for a suite of metals and polychlorinated biphenyls (PCBs) (DOE 2012). Mean mercury concentrations in rockbass (*Ambloplites rupestris*) from lower Bear Creek increased in 2011, averaging 0.79 µg/g in fall 2010 and 0.68 µg/g in spring 2011. These mercury levels are over three times higher than those found in the same species from the Hinds Creek reference site and are above the EPA-recommended fish-based AWQC of 0.3 µg/g. Redbreast sunfish (*Lepomis auritus*) collected along the stretch of Bear Creek between BCK 4.6 and BCK 9.9 had average mercury concentrations of 0.39 µg/g in fall 2010 and 0.29 in spring 2011. These concentrations are comparable to those seen in Fiscal Year 2010. Redbreast sunfish feed on lower trophic level prey than rockbass, and typically have between 15–40% lower mercury levels.

Concentrations of nickel, cadmium, and uranium in stoneroller minnows were highest in upper Bear Creek and decreased with distance downstream (DOE 2012); Southworth, et al. (1992) reported similar findings. Cadmium and uranium concentrations in fish from the lower end of the creek were higher than reference values in 2011. Nickel concentrations were similar to those from fish from the Hinds Creek reference site. PCB concentrations in stoneroller minnows in fall 2010 and spring 2011 averaged 2–4 µg/g, continuing the long-term trend of elevated levels in fish. As with metals, PCB levels in minnows decrease downstream.

Fish communities in Bear Creek have generally been stable or slightly variable in terms of species richness (DOE 2012). The number of species present at sites BCK 3.3 and BCK 9.9 is similar to or higher than the Mill Branch reference stream. The BCK 9.9 sample site has seen a steady increase in species richness, in part because the downstream weir was bypassed, allowing more upstream migration of fish

species. The number of species at BCK 12.4 and NT-3 fish communities is below that of a comparable reference stream (Mill Branch kilometer 1.6), particularly during dry seasons. This has been attributed (DOE 2012) to the greater proportion of stream flow that is provided by contaminated ground water.

East Bear Creek (measurement stations BCK 9.9 and 12.4, above and below NT-3) and NT-3 continue to support fewer pollution-intolerant benthic macroinvertebrate taxa than nearby reference streams, particularly during the fall dry season (DOE 2012), and TDEC (2012) indicates that both of its measurement sites at BCK 9.6 and BCK 12.3 are slightly to moderately impaired, respectively, but neither meet the state macroinvertebrate index score for this region. These findings agree with observations made by Southworth, et al. (1992) that the number of pollution intolerant species, and overall species richness, increases with distance downstream. Farther downstream at BCK 3.3, results continue to indicate that the condition of invertebrate community is comparable to reference conditions. This is especially encouraging because BCK 3.3 is downstream of most of the contaminated ground water discharges in the Bear Creek (DOE 2012). Most contaminant levels also decrease downstream.

The Tennessee dace, a major constituent of the fish population above the weir at Bear Creek km 4.55, is a Tennessee-listed in-need-of-management species and its habitat is protected by the state of Tennessee. Ryon (1998) did not observe Tennessee Dace in NT-3 sampling, but does indicate that NT-2 south of the Haul Road should be capable of supporting small fish populations, including Tennessee dace. Peterson, et al. (2009) indicated that Tennessee Dace had occasionally been observed in NT-3 south of the Haul Road.

No federal- or state-listed threatened or endangered aquatic species have been observed in Bear Creek or its tributaries (Southworth, et al. 1992).

#### 2.6.2.3 NT-3 Stream Ecology

The lower reaches of NT-3 were highly impacted by remedial actions at the BY/BY. Remedial actions included removal of soils, capping, hydraulic isolation, and re-configuring and lining the channel of NT-3 from approximately the south side of the Haul Road culvert to approximately 100 ft upstream from the confluence of NT-3 with Bear Creek. Remedial actions to remove contaminated soils from the BY/BY were completed in 2003; stream restoration was completed at the same time. The stream was restored with low-amplitude meanders and the banks seeded with native grasses and other species.

Surveys of NT-3 stream and riparian habitats downstream from the Haul Road were conducted from 2004 through 2011 to assess the effectiveness of BY/BY remediation (DOE, 2012; Peterson, et al. 2009). Note that stream surveys have not been conducted north of the Haul Road, and there has been no detailed assessment of stream quality for NT-3 in the footprint of the EMDF. In-stream and riparian habitats have shown generally improving conditions over that time, but have not yet met the metric goals set for stream and riparian habitat. Continued successional changes in vegetation to more shrub and tree species is expected within the restoration area over time. Surveys included measures of in-stream habitat within established stream transects and adjacent riparian habitat.

As noted above, NT-3 near the BY/BY is roughly a 1–2 ft (0.5 m) wide in summer, but flows outside the channel at some bends during some high flows and allows for some riparian wetland development. Channel morphology was relatively stable, but showed some normal adjustments (aggrading/degrading and slight meander migration). Stream sediments consist of poorly sorted gravel substrate, with cobbles, sand, silt, and clays in some reaches. Filamentous algae is present in some areas of the stream. Clear water and many fish were observed in pools during the 2011 survey.

Riparian vegetation coverage is improving, and the difference in mean canopy cover from 2008 (3.4%) to 2011 (13.2) is marked, even thought the mean percentage of ground cover declined slightly, from 94.2–88.6%, over the same period. The mean number of plant species per transect also declined, from

15.8–13.6. This is apparently due to an invasive plant species (*Lespedeza cuneata*) that out-competes native species.

NT-3 water quality measures (pH, DO, temperature) were generally found to be similar to a reference stream, but specific conductance was found to be higher (DOE 2012).

Peterson, et al. (2009) reported that evidence that the macroinvertebrate community in NT-3 is degraded relative to nearby reference sites, and that no major changes occurred over the period from 2004 through 2008. The average number of species per sample and taxonomic richness of the pollution-intolerant mayflies, stoneflies, and caddisflies in NT-3 were consistently two to three times lower than in reference streams. Differences between NT-3 and reference sites in the number of species of mayflies, stoneflies, and caddisflies were greatest in October, when stream flow was least. These results indicate that conditions in NT-3 become less suitable for invertebrate species that normally inhabit small headwater streams as summer progresses, probably due to poor in-stream habitat quality and poorly developed riparian zone (Peterson, etc al. 2009). A well-developed mature riparian zone moderates diurnal and seasonal swings in stream temperature and reduces the flow rate and suspended solids load associated with storm-water runoff. This increases chemical and physical instability in the stream, preventing the recovery of species with less tolerance for impaired water quality. Improved riparian conditions should lead to improved aquatic conditions.

According to Peterson, et al. (2009), only a single fish species, the western black-nose dace (*Rhinichthys obtusus*) has been routinely observed in NT-3. Largescale stonerollers (*Campostoma oligolepis*), creek chubs, or Tennessee dace have been occasionally observed. Conversely, between four and nine fish species are commonly found in nearby reaches of upper Bear Creek. This may be due to the shallow stream depth under normal conditions, poor substrate conditions, and tendency of the stream to go dry in late summer.

An aquatic life stream survey was conducted in May 2013 in NT-2 and NT-3 as part of the EMDF site characterization (Schacher 2015a). This survey used direct observation, and kicknet and rock and debris sampling to collect biologic samples. Samples were then examined under a microscope and identified using dichotomous keys and appropriate references. The survey found the following Orders of aquatic taxa in NT-2 and NT-3:

- Aquatic taxa collected/identified from NT-2:
  - Ephemeroptera (mayflies; 1 family represented, Leptophlebiidae)
  - Plecoptera (stoneflies; 2 families represented)
  - Tricoptera (caddisflies; 2 families represented, Hydropsychidae, Philopotamidae) [Note: based on collection of unique caddisfly cases, 2-3 more families of this order inhabit this stream]
  - Coleoptera (riffle beetles, 1 family represented)
  - Odonata/Anisoptera (dragonflies, 2 families represented)
  - Diptera (true flies, 2 families represented)
  - Megaloptera (hellgrammites, 1 family represented)
  - Annelida (aquatic segmented worms)
  - Hydracarina (water mites)
  - Crustacea/Decapoda (crayfishes)
  - Vertebrata/Amphibia/Caudata (salamanders)

- Aquatic taxa collected/identified from NT-3:
  - Ephemeroptera (mayflies; two families represented: Ephemerellidae, Leptophlebiidae)
  - Plecoptera (stoneflies; one family represented: Nemouridae)
  - Tricoptera (caddisflies; three families represented: Hydropsychidae, Philopotamidae, Limnephilidae) (Note: based on collection of unique caddisfly cases, 2–3 more families of this order inhabit this stream.)
  - Coleoptera (riffle beetles, one family represented)
  - Odonata/Zygoptera (damselflies, one family represented)
  - Diptera (true flies, four families represented)
  - Megaloptera (hellgrammites, alderflies, two families represented)
  - Annelida (aquatic segmented worms)
  - Hydracarina (water mites)
  - Crustacea/lsopoda (sow bugs)
  - Crustacea/Decapoda (crayfishes)
  - Vertebrata/Amphibia/Caudata (salamanders)

The aquatic invertebrates identified in the survey are indicative of very good to excellent water and habitat quality for these two streams. Although crayfish and salamander larvae were found, no fish were collected, nor was any suitable habitat identified. The Tennessee dace was not found in either stream.

### 2.6.3 Terrestrial Habitats and Sensitive Species

Regional plant communities typify those found in Appalachia from southern Pennsylvania to northern Alabama. The EMDF area was, prior to the May 2013 downburst and subsequent timber recovery, covered with a mature, though not virgin, deciduous forest that showed little or no indication of disturbance during the past 80 or more years.

#### 2.6.3.1 Terrestrial Flora

Much of the upland forest on the ORR, including most of the EMDF site, is a mixed mesophytic forest dominated by oaks (*Quercus* spp.), hickories (*Carya* spp.), and yellow poplar (*Liriodendron tulipfera*), with co- or subdominant beech (*Fagus grandifolia*) and maples (*Acer* spp.). Evergreens such as shortleaf pine (*Pinus echinata*), Virginia pine (*P. virginiana*), and loblolly pine (*P. taeda*) are intermixed in deciduous-dominated forests, and are found in more or less pure stands, especially on recovering disturbed land and in plantations. Other trees that may be present as secondary or understory species include magnolia (*Magnolia grandiflora*), black cherry (*Prunus serotina*) and dogwood (*Cornus florida*) (Kitchings and Mann 1976). Much of the forest is open, with little herbaceous undergrowth. Some areas may have a moderate to dense undergrowth composed of rhododendron or laurel, but these are confined to relatively small niche areas. The herbaceous layer includes ferns, plantains, groundsel, and vines.

Bottomland and wetland sites are characterized by sweet gum (*Liquidambar styracifulia*), sycamore (*Platanus occidentalis*), and black willow (*Salix nigra*), with red maple (*Acer rubrum*), black walnut (*Jugans nigra*), and boxelder (*Acer negundo*). The herbaceous layer may contain sedges (*Carex* spp.), rushes (*Juncus* spp.), cattails (*Typha* spp.), and bulrushes (*Scirpus* spp.).

#### 2.6.3.2 Terrestrial Fauna

Predators including coyote (*Canis latrans*), red and the gray fox (*Vulpes fulva* and *Urocyon cinereoargenteus*, respectively), bobcat (*Lynx rufus*), and weasel (*Mustela frenata*) are widespread

throughout the ORR. Black bears (*Ursus americana*) have occasionally been reported on the ORR, but these appear to be animals in transit, not permanent residents.

White-tail deer (*Odocoileus virginianus*), the only ungulate currently known in the area, inhabit upland and bottomland forests throughout the ORR.

Striped skunk (*Mephitis mephitis*), opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), eastern cottontail rabbit (*Sylvilagus floridanus*), groundhogs (*Marmota monax*) are small omnivores and herbivores common to both forest and field. Numerous members of the order Rodentia are present, including chipmunks (*Tamias striatus*), eastern grey squirrel (*Sciurus carolinensis*), and flying squirrel (*Glaucomys volans*), as well as several species of mice. Shrews and voles are also common throughout the ORR.

Streams and lake banks offer suitable habitat for muskrats (*Ondatra zibethica*) and beaver (*Castor canadensis*). Marsh rice rats (*Oryzomys palustris*) may live in wet areas along open waters that have a dense herbaceous growth of grasses and sedges.

#### 2.6.3.3 Avifauna

The upland forest provides habitat for a large number of resident and migratory bird species. Resident woodpecker species common to mature deciduous forests include yellow-shafted flickers (*Colantes auratus*), redbellied woodpeckers (*Centurus carolinus*), hairy woodpecker (*Dendrocopos villosus*), downy woodpeckers (*D. pubescens*), and pileated woodpeckers (*Hylatomus pileatus*). The common crow (*Corvus brachyrhynchos*) and blue jay (*Cyanocitta cristata*) are also present in the deciduous forest.

Songbirds found in ORR forests are represented by Kentucky warbler (*Oporonis formosus*), pine warbler (*Dendroica pinus*), yellow-breasted chat (*Icteria virens*), and ovenbird (*Seirus aurocapillus*), Carolina chickadee (*Parus cardinensis*), scarlet tanager (*Piranga olivacea*), mourning dove (*Zenaida macroura*) and tufted titmouse (*Parus bicolor*) are considerably less selective. Game birds include turkey and ruffed grouse (*Bonasa umbellus*).

Red-tailed hawk (*Buteo lineatus*) and sharp-shinned hawk (*Accipiter striatus*) are raptors common year-round on the ORR. Turkey vultures (*Cathartes aura*) and black vultures (*Coragyps atratus*) are also common on the ORR. The Northern harrier (*Circus cyaneus*) and broad-winged hawk (*Buteo platypterus*) are migratory visitors.

### 2.6.4 Results of Recent Surveys at the EMDF Site

Surveys for terrestrial rare, threatened and endangered plants and animals and sensitive habitats were conducted by a qualified botanist on January 22, 2013, and May 7–9, 2013, prior to the downburst (Schacher 2015b). Additional surveys were planned but not completed due to the wind damage. Three vegetative cover types were identified: bottomland hardwood forest, mixed hardwood forest, and upland hardwood forest. These cover associations are topographically controlled, and boundaries are gradational. Invasive plants were abundant along the roadside at the south side of the tract but were essentially absent elsewhere on the site.

Bottomland hardwood forest occurs along the creeks at the base of the ridge. This forest is dominated by red maple, yellow poplar, sweet gum, American hornbeam (*Carpus caroliniana*), black willow, and green ash (*Fraxinus pennsylvanica*). Understory shrubs include alder (*Alnus serrulata*) and hearts-a-busting (*Euonymus americanus*). The herb and vine layer is chiefly Christmas fern (*Polystichum acrostichoides*), crossvine (*Bignonia capreolata*), curly dock (*Rumex crispus*), cinnamon fern (*Osmunda cinnamomea*), pink weed (*Polygonum pensylvanicum*), and poison ivy (*Toxicodendron radicans*). Some areas appear to be wet for extended periods and other are only moderately moist.

Bottomland hardwood areas rapidly grade into the mixed hardwoods forest which occurs in drier soils on the lower slopes of Pine Ridge. The mixed hardwood forest is dominated by white oak (*Quercus alba*), black gum (*Nyssa sylvatica* var. *sylvatica*), sassafras (*Sassafras abidum*), hickory (*Carya glabra, C. tomentosa, C. pallida*), yellow poplar, red maple, black cherry (*Prunus serotina*), and persimmon (*Diospyros virginiana*).

The upland hardwood forest extends from the mixed hardwood forest to the top of the ridge. The lower slope is chiefly, oaks (*Quercus alba, Q. falcata, Q. prinus, Q. velutina*), persimmon, black gum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), hickories, sourwood (*Oxydendrum arboreum*), and chestnut oak (*Q. prinus*). As one goes from the lower slope to the upper slope, persimmon and white oak become less prominent and chestnut oak and various hickories, sassafras, and sourwood become dominant. The shrub layer is extremely sparse and open. The shrub layer is mostly hearts-a-busting in the in the lowest areas and grades to huckleberry (*Vaccinium* spp.) and farkleberry (*V. arboretum*) nearer the ridgeline. The herb layer is extremely sparse, consisting chiefly of Christmas fern, crossvine, sawbrier (*Smilax glauca*), and spotted wintergreen (*Chimaphila maculata*).

No habitats were observed on the proposed EMDF site that were deemed "excellent" or "highly suitable" for Federal-listed or State-listed plants. However, habitat was observed that was considered "marginal" or "somewhat suitable" for some of these rare plants. A checklist of 22 status plant species known to occur in either Anderson or Roane counties was used to guide field surveys. Of these, 11 were eliminated on the basis that no suitable habitats occurred on the EMDF site. The 11 remaining species, six are listed as Threatened in Tennessee, and have the potential to occur on the EMDF site. These are:

- Northern bush-honeysuckle (*Diervilla lonicera*)
- Mountain (or Southern) bush-honeysuckle (*D. sessifolia* var. *rivularis*)
- Hairy willow-herb (*Epilobium ciliatum*)
- Fen orchis (*Liparis loeselii*)
- Tuberculed rein orchid (*Platanthera flava* var. *herbiola*)
- White fringeless orchid (*P. integrilabia*)

The Northern bush-honeysuckle is common throughout much of North America, and is only listed in Tennessee. Mountain bush-honeysuckle is not listed outside of Tennessee.

Four of the remaining five species of interest are Tennessee-listed as being of special concern, and the fifth has been de-listed:

- Schreber's aster (*Eurybia schreberi*)
- Mountain honeysuckle (*Lonicera dioica*)
- River bulrush (*Bolboschoenus fluviatalis*)
- Small-headed rush (*Juncus brachycephalus*)

As noted in Section 2.6.1, a severe wind event largely destroyed the forest throughout the central and southern portions of the EMDF site, and heavily damaged the remaining forest along the upper slopes of Pine Ridge. Most of the habitats and forest areas described above are now gone.

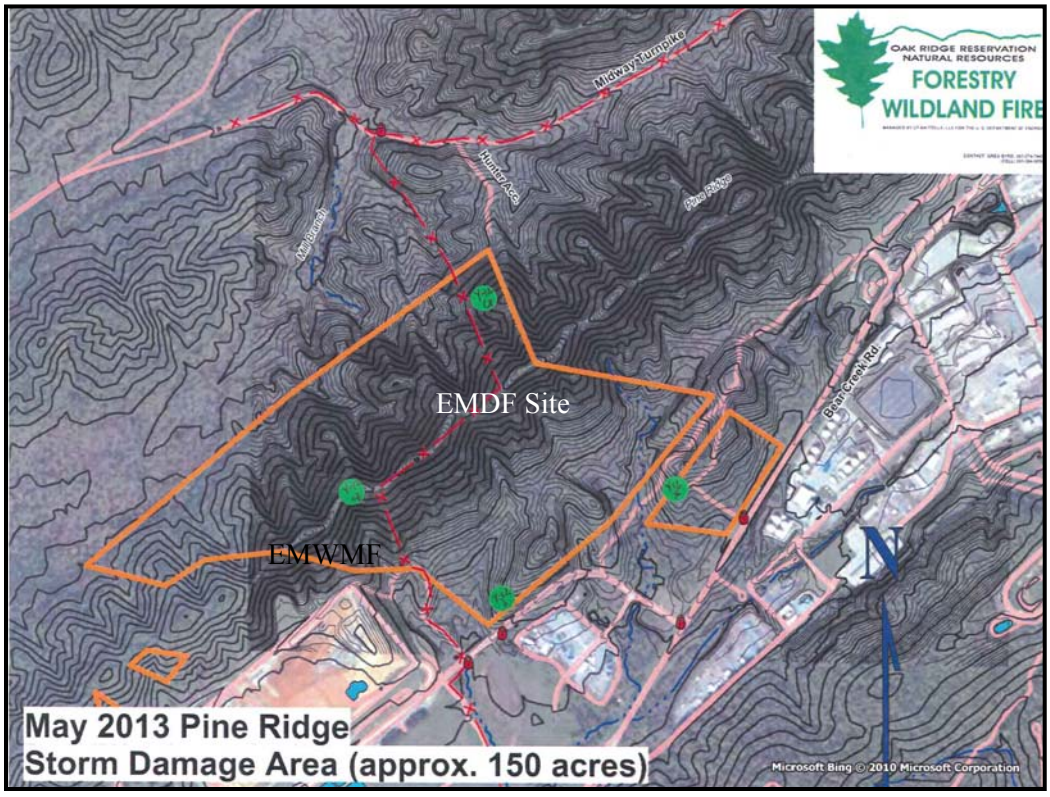
### 2.6.5 Terrestrial Status Species

Few surveys of terrestrial animals have been conducted at or near the EMDF site. Mitchell, et al. (1996) surveyed one wetland area (Site A-10) near the confluence of NT-5 with Bear Creek and a mixed hardwood-pine site along NT-1 (Site A-11, Y-12 meteorological tower), and did not document any threatened or endangered terrestrial vertebrate species. They observed four then-protected bird species at

sites on Chestnut Ridge along South Tributary-2 and Walker Branch. The yellow bellied sapsucker (*Sphyrapicus varius*), listed in Tennessee as in need of management, was sighted at three stations. This species is migratory, breeding in Canada and the northern tier states. The cerulean warbler (*Setophaga cerulea*) was sighted at two sites. This bird is a migratory species deemed as in need of management in Tennessee, but is not federally-listed. A third species is the sharp-shinned hawk, seen at one site. This widespread raptor is not currently a state- or federal-listed species, but is listed as an in need of management species by the state. Finally, a Cooper's hawk (*A. cooperii*) was sighted at one site. This species is not federal- or state-listed, and is not currently listed as being in need of management. Several migratory species, such as the Northern harrier; state-listed as in need of management, but not federally listed have been observed on the ORR, but should not pose a concern at the EMDF site because the disturbed area is small relative to the available undeveloped areas.

An acoustic survey was conducted by ORNL Natural Resources Division personnel to determine what species of bats were present in the windthrow area prior to approving timber recovery (K. McCracken, pers. comm. 2014). Acoustic monitors were placed at the green dots shown in Figure E-23.

The bat survey detected six bat species, none of which were listed threatened, endangered, or In-need-of-management species, as shown by Table E-12.




Orange outlines indicate approximate severe windthrow area.

**Figure E-23. Locations of Acoustic Stations used in the 2013 Bat Survey**

**Table E-12. Results of Acoustic Bat Survey**

| Common Name | Species | Acoustic Detection | Tennessee Status | Federal Status |
|---|---|---|---|---|
| Big brown bat | *Eptesicus fuscus* | X | Not listed | Not listed |
| Eastern red bat | *Lasiurus borealis* | X | Not listed | Not listed |
| Silver-haired bat | *Lasionycteris noctivagans* | | Not listed | Not listed |
| Hoary bat | *Lasiurus cinereus* | | Not listed | Not listed |
| Gray bat | *Myotis grisescens* | | Endangered | Endangered |
| Eastern small-footed bat | *Myotis leibli* | X | Need of Management | – |
| Little brown bat | *Myotis lucifugus* | X | Not listed | Not listed |
| Northern long-eared bat | *Myotis septentrionalis* | X | Not listed | Not listed |
| Indiana bat | *Myotis sodalis* | | Endangered | Endangered |
| Evening bat | *Nycticeius humeralis* | | Not listed | Not listed |
| Tri-colored bat | *Perimyotis subflavus* | X | Not listed | Not listed |

### 2.6.6 Other Natural Resources

Approximately half of the proposed EMDF is within the ORERP. The EMDF will impact primarily forested terrain. There are no known economically significant mineral resources in the EMDF area.

A number of areas on the ORR have been identified as Natural Areas, ANAs, RAs, Aquatic RAs, Special Management Zones, Conservation Easement Areas, Cooperative Management Areas, Habitat Areas, and Potential Habitat Areas. Two of these, RA-5 and ANA-2, will or could be impacted by construction and operation of the proposed EMDF. Figure E-24 shows these features.

## 2.7 CULTURAL RESOURCES

There are no known archeological or historical resources in or near the proposed EMDF site (DOE 1999; Duvall 1998; DuVall 1996; Fielder, et al. 1977). DuVall (1998) conducted a Phase I reconnaissance survey for areas that were being considered for the EMWMF; this survey was designed to fill in coverage gaps in an earlier survey (Bentz 1992, as referenced in DuVall 1998). The surveys covered the entirety of the proposed EMDF site, as shown in Figure E-25. The report stated that all shovel tests were negative, and that there was no visible evidence of archaeologically or historically significant sites. Further, the small streams and steep slopes would not be favorable for habitation. The two Phase I archaeological reconnaissance surveys conducted over the study area conclude that a project conducted in this area will have no impact on any archaeological site or historic building. Therefore, no additional surveys will be conducted unless artifacts or remains are discovered during construction.

Two former residences or farms were located near the confluence of NT-3 with Bear Creek, approximately 1,000 ft south of the proposed EMDF site, prior to World War II. These sites were inspected (DuVall 1996) and reported to contain only scattered remnants of building debris (bricks, stones). Neither of these sites are within or near the anticipated impact areas for the EMDF.

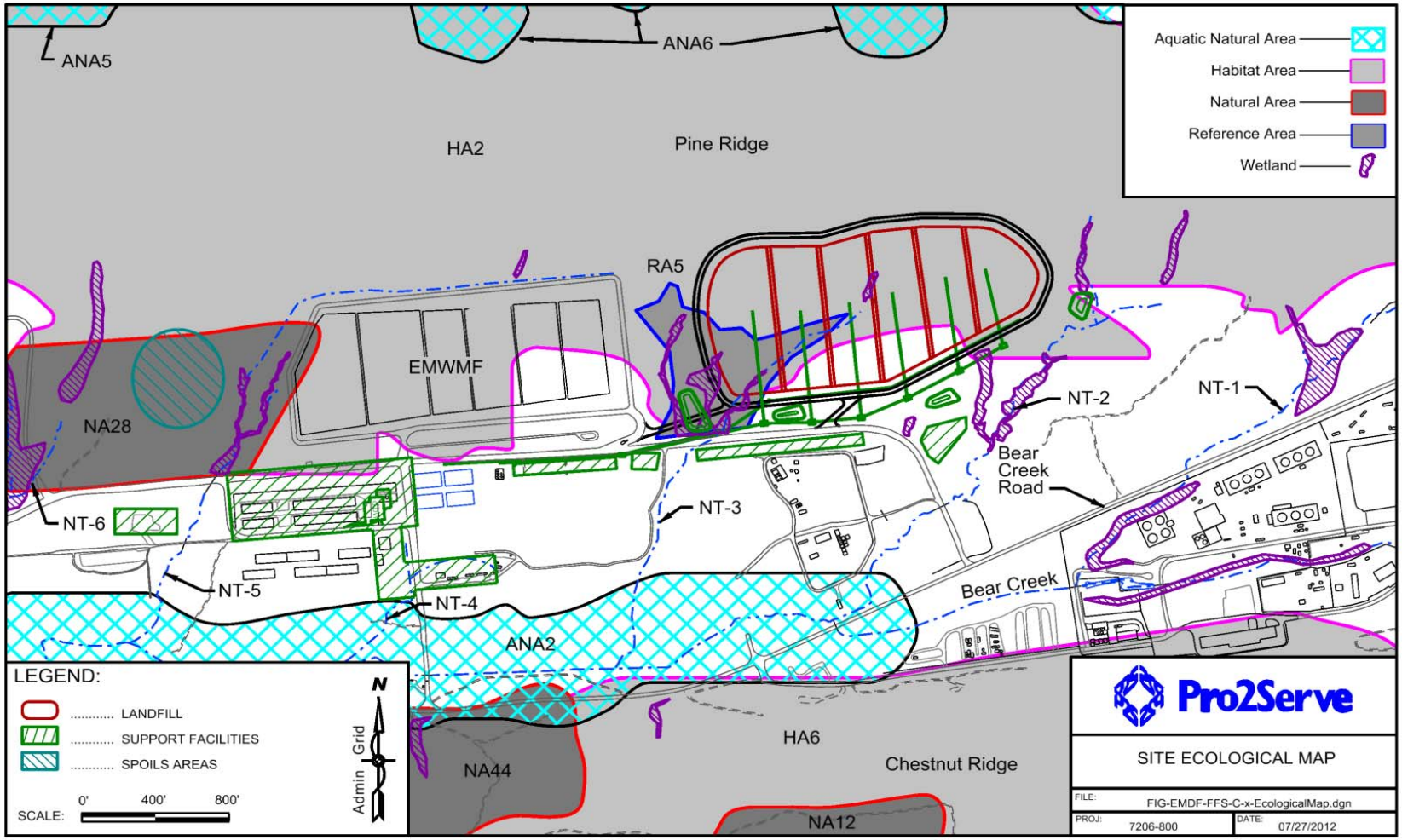



**Figure E-24. Streams, Wetlands, and Resource Areas in the EMDF Area**

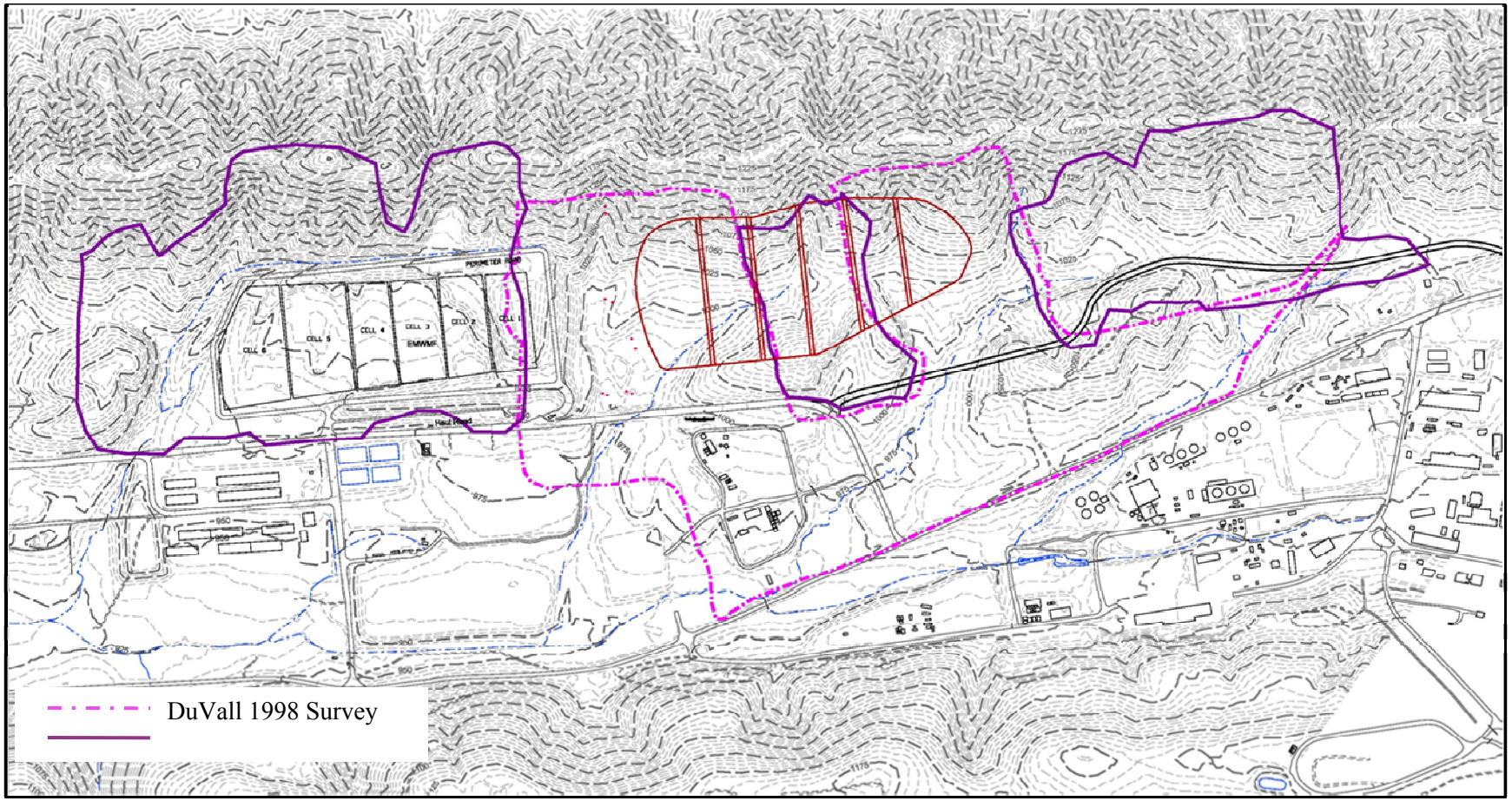



**Figure E-25. Area Covered by Archaeological Reconnaissance Report in DuVall (1998)**

# 3. REFERENCES


BNI (Bechtel National, Inc.) 1984. *The Geology and Hydrogeology of Bear Creek Valley Waste Disposal Areas A & B*. Y/SUB/84-47974C/3.

Borders, D.M., Reece, D.K., Watts, J.A., Frederick, B.J., McCalla, W.L., and Ziegler, K.S., 1994. *Hydrologic Data Summary for the White Oak Creek Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee (January – December 1993)*. ORNL/ER-269.

Brahana, J.V., Mulderlink, D., Macy, J.A., and Bradley, M.W. 1986. *Preliminary Delineation and Description of the Regional Aquifers of Tennessee – The East Tennessee Aquifer System*. USGS Water Resource Investigation 82-4091.

Bureau of the Census. 2010 Census population data. Downloaded from Middle Tennessee State University Business and Economic Research Center at http://frank.mtsu.edu/~berc/census.html/, June 6, 2012.

CCL (Cumming Cockburn Limited) 2001. *Water Budget Analysis on a Watershed Basis*. Ontario Watershed Management Committee, Ontario, Canada.

CDM (CDM Federal Programs Corporation), 1994. *Water Balance Report for the Oak Ridge Y-12 Plant*. Y/SUB/28B-99920C/94-2.

Bailey, Z.C. and Lee, R.W., 1991. *Hydrogeology and Geochemistry in Bear Creek and Union Valleys, Near Oak Ridge, Tennessee*. USGS Water Resources Investigation 90-4008.

BWXT, 2003. *Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley on the U.S. Department of Energy Oak Ridge Reservation*. Y/TS-881-r5

Bryd, Greg, 2013, pers. comm. (e-mail with attachments), July 8, 2013.

CH2M-Hill 2000. *Phase IV Final Site Investigation Report, SSRS Item No. 3.3, Rev.1*, for the Environmental Management Waste Management Facility, prepared by CH2MHill Constructors, Inc, under contract to Waste Management Federal Services, Inc., for Bechtel Jacobs Company LLC, Oak Ridge, Tennessee, March 2000.

Clapp, R.B., 1998. "Water Balance Modeling", Section 5.1 in Huff, D. (ed.) 1998. *Environmental Sciences Division Groundwater Program Office Report of Fiscal Years 1995- 1997*. Environmental Sciences Division Publication No. 4751 , ORNL/M-6520 (ESD Publ. No, 4751), p. 13-14.

Clapp, R.B. and Frederick, B.J., 1989. *Precipitation and Streamflow in the Vicinity of West Chestnut Ridge Near Oak Ridge National Laboratory, Oak Ridge, Tennessee (October 1985 – March 1988)*. ORNL/TM-10936.

Connell, J. F. and Bailey, Z. C. 1989. *Statistical and Simulation Analysis of Hydraulic Conductivity Data for Bear Creek and Melton Valleys, Oak Ridge Reservation, Tennessee*. USGS Water-Resources Investigations Report 89-4062.

Collins, J. L. 2015. *Environmental Management Expanded Disposal Facility Project, Oak Ridge Reservation, Anderson County, Tennessee Assessment of Several Biological Resources of the Proposed Site, Including Site Vegetation; Presence of Rare, Threatened, or Endangered Plant, Vertebrate Animal, and Aquatic Animal Species; and Site Stream Assessment*.

Cunningham, M., and L. Pounds. 1991. *Resource Management Plan for the Oak Ridge Reservation. Volume 28: Wetlands on the Oak Ridge Reservation*. ORNL/NERP-5.

DeBuchananne, G.D., and Richardson, R.M., 1956, *Ground-water resources of East Tennessee*. Tennessee Division of Geology Bulletin 58, Part 1.

DOE 1996. *Identification and Screening of Candidate Sites for the Environmental Management Waste Management Facility, Oak Ridge, Tennessee.* DOE/OR/02-1508&D1.

DOE 1997. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*. DOE/OR.01-1455/V3&D2.

DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2.

DOE 1999. *Cultural Resources Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*. DOE/ORO-2085, Appendix F.

DOE 2000. *Record of Decision for the Phase I Activities in Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1750&D4.

DOE 2008a. *Oak Ridge Reservation Planning: Integrating Multiple Land Use Needs.* DOE/ORO/01-2264.

DOE 2008b, *Proposed Plan for the Bear Creek Burial Grounds at the Y-12 National Security Complex, Oak Ridge, Tennessee*. DOE/OR/01-2383&D1.

DOE 2011a. *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex,* DOE/EIS-0387.

DOE 2012. 2012 *Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee*. DOE/OR/01-2544&D2.

Dorch, J., Katsube, T.J., Sanford, W.E., Dugan, B.E., and Tourkow, L.M., 1996. *Effective Porosity and Pore-Throat Sizes of Conasauga Group Mudrock: Application, Test and Evaluation of Petrophysical Techniques*. ORNL/GWPO-021.

Dorch, J. and Katsube, T.J., 1996. *Effective Porosity and Pore-Throat Sizes of Mudrock Saprolite from the Nolichucky Shale within Bear Creek Valley on the Oak Ridge Reservation: Implications for Contaminant Transport and Retardation Through Matrix Diffusion*. ORNL/GWPO-025.

Dreier, R.B. and S.M. Koerber, 1990. *Fault Zone Identification in the Area Surrounding the Y-12 Plant and Its Waste Management Areas*. Y/TS-656.

Dreier, R.B., T.O. Early, and King, H.L., 1993. *Results and Interpretation of Ground water Data Obtained from Multiport-Instrumented Coreholes (GW-131 through GW-135), Fiscal Years 1990 and 1991*. Y/TS-803.

Driese, S.G., McKay, L.D., and Penfield, C.P., 2001. "Lithologic and pedogenic influences on porosity distribution and ground water flow in fractured sedimentary saprolite: a new application of environmental sedimentology". *Journal of Sedimentary Petrology*, vol. 71, no. 5, p. 843 – 857.

DuVall, G.D., 1998. *An Archaeological Survey of Approximately 125 Acres for the Environmental Management Waste Management Facility (EMWMF) Disposal Area, Oak Ridge Reservation, Anderson County, Tennessee*. BJC/OR-97.

DuVall, G.D. and Souza, P.A., 1996. *An Evaluation of the Previously Recorded and Inventoried Sites on the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-4964.

Eaton, T.T., Anderson, M.P., and Bradbury, K.R., 2007. "Fracture control of ground water flow and water chemistry in a rock aquitard." *Ground Water*, vol. 45, no. 5, pp.601-615.

EPRI, 2008. *White Paper on Seismic Hazard in the Eastern Tennessee Seismic Zone*. Prepared for EPRI by Risk Engineering, Inc., Boulder, CO. May 12, 2008.

Evaldi, R.D. 1984. *Specific Conductance at Selected Sites in 18 Watersheds Near Y-12 Plant, February 15 through April 9, 1984*. USGS (U.S. Geological Survey) Open-File Report 84-625 (with two plates).

Evans, E. K., Lu, C., Ahmed, S and Archer, J. 1996. "Application of particle tracking and inverse modeling to reduce flow model calibration uncertainty in an anisotropic system", *Proceedings of the ModelCARE 96 Conference: Calibration and Reliability in Groundwater Modelling*. Golden, CO, 1996.

Fielder, G.F. Jr., Ahler, S.R., and Barrington, B., 1977. *Historic Sites Reconnaissance of the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-5811.

Fossen, H., 2010. *Structural Geology*. New York: Cambridge University Press.

Freeze, R.A. and Cherry, J.A., 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall.

Golder Associates, 1989a. *Task 7 – Ground water Flow Computer Model*. ORNL/Sub/30X-SA706C.

Golder Associates, 1989b. *Task 6 – Site Conceptual Ground water Flow and Contaminant Transport Model*. ORNL/Sub/30X-SA706C.

Golder Associates, 1989c. *Task 2 – Well Logging and Geohydrologic Testing, Site Characterization, and Groundwater Flow Computer Model Application, Vol. 1*. ORNL/Sub/30X-SA706C.

Goldstrand, P.M., Menefee, L.S., and Dreier, R.B., 1995. *Porosity Development in the Copper Ridge Dolomite and Maynardville Limestone, Bear Creek Valley and Chestnut Ridge, Tennessee*. Y/SUB95-SP912V/1.

Goldstrand, P.M. and Haas, J., 1994. *Comparison of Two Dye-Tracer Tests at the Chestnut Ridge Security Pits, Y-12 Plant, Oak Ridge, Tennessee*. Y/TS-1005.

Haase, C.S., Stow, S.H., and Zucker, C.L. 1985. *Geology of the Host Formation for the New Hydrofracture Facility at the Oak Ridge National Laboratory*. Waste Management Symposium 1985, v. 2, pp. 473-480.

Haase, C.S., Switek, J., and Stow, S.H., 1987. *Geochemistry of Formation Waters in the Lower Conasauga Group at the New Hydrofracture Facility: Preliminary Data from the Deep Monitoring (DM) wells*. ORNL/RAP-6.

Haase, C.S. 1991. *Geochemical Identification of Groundwater Flow Systems in Fractured Bedrock Near Oak Ridge, Tennessee*, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee. Source: info.ngwa.org/gwol/pdf/910155202.PDF.

Hart, D. J., Bradbury, K.R., and Feinstein, D.T., 2006. "The vertical hydraulic conductivity of an aquitard at two spatial scales". *Ground Water*, vol. 44, no. 2, pp. 201-211.

Hatcher, Jr., R. D., P. J. Lemiszki, R. B. Dreier, R. H. Ketelle, R. R. Lee, D. A. Leitzke,W. M. McMaster, J. L. Foreman, and S. Y. Lee, 1992. *Status Report on the Geology of the Oak Ridge Reservation.* ORNL TM-12074.

Healy, R.W., Winter, T.C., LaBaugh, J.W., and Franke, O.L. 2007. *Water Budgets: Foundations for Effective Water-Resources and Environmental Management*. USGS Circular 1308.

Hem, J.D. 1989. *Study and Interpretation of the Chemical Characteristics of Natural Water*. U.S. Geological Survey Water-Supply Paper 2254.

Huff, D.D. and Frederick, B.J., 1984. *Hydrologic Investigations in the Vicinity of the Proposed Central Waste Disposal Facility, Oak Ridge National Laboratory, Tennessee*. ORNL/TM-9354.

Ketelle, R.H. and Huff, D.D., 1984. *Site Characterization of the West Chestnut Ridge Site*. ORNL/TM-9229.

King, H.L. and Haase, C.S., 1987. *Subsurface-Controlled Geological Maps for the Y-12 Plant and Adjacent Areas of Bear Creek Valley*. ORNL/TM-10112.

Kitchings, T. and Mann, L.K. 1976. *A Description of the Terrestrial Ecology of the Oak Ridge Environmental Research Park*. ORNL/TM-5073.

Lee, R.R. and Ketelle, R.H., 1989. *Geology of the West Bear Creek Site*. ORNL/TM-10887.

Lee, R.R., Ketelle, R.H., Bownds, J.M., and Rizk, T.A. 1989. *Calibration of a Ground Water Flow and Contaminant Transport Computer Model: Progress Toward Model Validation*. ORNL/TM-11294.

Lee, R.R., Ketelle, R.H., Bownds, J.M., and Rizk, T.A. 1992. "Aquifer Analysis and Modeling in a Fractured Heterogeneous Medium." in *Groundwater*, vol. 30, no. 4, pp. 589-597.

Lemizski, P.J., 1995. *Mesoscopic Structural Analysis of Bedrock Exposures at the Oak Ridge K-25 Site, Oak Ridge, Tennessee*. K/ER-259.

Lemizski, P.J. 2000. *Geologic Map of the Bethel Valley Quadrangle, Tennessee*. U.S.G.S. Open-File Map GM-130-NE (draft).

Lietzke, D.A., Lee, S.Y., and Lambert, R.E., 1988. *Soils, Surficial Geology, and Geomorphology of the Bear Creek Valley Low-Level Waste Disposal Development and Demonstration Program Site*. ORNL/TM-10573.

Luxmoore, R.J., 1983. "Water budget if an eastern deciduous forest stand". *Soil Science Society of America Journal*, vol. 47, pp. 785–791.

MACTEC Corporation, 2003. *Final Report of Geotechnical Exploration, Natural Phenomena Hazard Seismic Update, Y-12 National Security Complex, Oak Ridge, Tennessee*. RP-NP-900000-A001, Rev. 0.

McCracken, Kitty, pers. comm. (e-mail with attachments), March 10, 2014.

McKay, L.D., Driese, S.G., Smith, K.H., and Vepraskas, M.J., 2005. "Hydrology and pedology of saprolite formed from sedimentary rock, eastern Tennessee, USA". *Geoderma*, vol. 126, pp. 27 – 45.

McKay, L.D., Sanford, W.E., and Strong, J.M., 2000. "Field-Scale Migration of Colloidal Tracers in a Fractured Shale Saprolite." *Ground Water*, vol. 38, no.1, pp. 139–147.

Melroy, L.A., Huff, D.D., and Farrow, N.D. 1986. *Characterization of the Near-Surface Radionuclide Contamination Associated with the Bathtub Effect at Solid Waste Storage Area 4, Oak Ridge National Laboratory, Tennessee*. ORNL/TM-10043.

Moline, G.R.; Rightmire, C.T.; Ketelle, R.H.; Huff, D.D. 1998. "Discussion of Nativ, et al. 1997", *Ground Water, vol. 36, no. 5, pp. 711-712*.

Moneymaker, B.C., 1941. "Subriver solution cavities in the Tennessee Valley." *J. Geology*, vol. 49, no. 1, pp. 74–86.

Moore, Gerald K. 1988. *Concepts of Ground water Occurrence and Flow Near Oak Ridge National Laboratory, Tennessee.* ORNL/TM-10969.

Moore, Gerald K, 1989. *Ground water Parameters and Flow Systems Near Oak Ridge National Laboratory*. ORNL/TM-11368.

Moore, G.K. and Toran, L.E., 1992. *Supplement to a Hydrogeologic Framework for the Oak Ridge Reservation*. ORNL/TM-12191.

Moore, G.K. and Young, S.C., 1992. *Identification of Groundwater-Producing Fractures by Using an Electromagnetic Borehole Flowmeter in Monitoring Wells on the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/ER-91.

Mori, Clint, UCOR, e-mail to Chris Wieland, Pro2Serve, June 5, 2013 regarding weather damage to EMDF area.

NOAA (National Oceanic and Atmospheric Administration) 2013. Enhanced F-Scale Damage Indicators accessed on June 5, 2013 at www.spc.noaa.gov/efscale/ef-scale.html.

Nativ, R. and Hunley, A.E. 1993. *The Deep Hydrogeologic Flow System Underlying the Oak Ridge Reservation*. ORNL/GWPO-003.

Nativ, R., Halleran, A., and Hunley, A. 1997. *The Deep Hydrologic Flow System Underlying the Oak Ridge Reservation – Assessing the Potential for Active Groundwater Flow and Origin of the Brine*. ORNL/GWPO-018.

Ogden 1993a. *Geotechnical Study, ORR Storage Facility, Site "B", Y-12 Plant, Oak Ridge, Tennessee,* Contract No. 88B-99977V, Release C-53, prepared by Ogden Environmental and Energy Services, May 7, 1993, for Martin Marietta Energy Systems, Inc.

Ogden 1993b. *Geotechnical Study, ORR Storage Facility, Site "C", Y-12 Plant, Oak Ridge, Tennessee,* Contract No. 88B-99977V, Release C-53, prepared by Ogden Environmental and Energy Services, May 20, 1993, for Martin Marietta Energy Systems, Inc.

ORNL 2002. *Oak Ridge Laboratory Land and Facility Plan*. ORNL/TM-2002/1.

Parr, P.D., and J.F. Hughes. 2006. *Oak Ridge Reservation Physical Characteristics and Natural Resources.* ORNL/TM-2006/110.

Parr, P. D. 2012. Personal communication, April 13, 2012.

Petersen, M.D., Moschetti, M.P., Powers, P.M., Mueller, C.S., Haller, K.M., Frankel, A.D., Zeng, Y., Rezaeian, S., Harmsen, S.C., Boyd, O.S., Field, N., Chen, R., Rukstales, K.S., Luco, N., Wheeler, R.L., Williams, R.A., Olsen, A.H., 2014. *Documentation For The 2014 Update Of The United States National Seismic Hazard Maps*. U.S. geological Survey Open-File Report 2014-1091.

Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, C.S., Haller, K.M., Wheeler, R.L. Wesson, R.L., Zeng, Y., Boyd, O.S., Perkins, D.M., Luco, N. Field, E.H., Wills, C.J., and Rukstales, K.S., 2008. *Documentation for the 2008 Update of the United States National Seismic Hazard Maps*. U.S. Geological Survey Open-File Report 2008-1128.

Petersen, M.J., Smith, J.G., Ryon, M.G., Roy, W.K., and Darby, J.A. 2009. *Performance Monitoring Report for the Restored North Tributary 3 (NT-3), Bear Creek Valley, Oak Ridge, Tennessee*. ORNL/TM-2009/53.

Pounds, L.R., Parr, P.D., and Ryon, M.G., 1993. *Resource Management Plans for the Oak Ridge Reservation Volume 30: Oak Ridge National Environmental Research Park Natural Areas and Reference Areas - Oak Ridge Reservation Environmentally Sensitive Sites Containing Special Plants, Animals, and Communities*. ORNL/NERP-8.

Pounds, L. R. 1998. *Rapid Assessment of Potential Habitats or Occurrences of Threatened and Endangered (T&E) Vascular Plants on the East Bear Creek Valley Site for a Proposed On-Site Waste Management Facility*, BJC/OR-101 and ORNL/M-6582.

Powell, C.A., Bollinger, G.A., Chapman, M.C., Sibol, M.S., Johnston, A.C., and Wheeler, R.L., 1994. "A Seismotectonic Model for the 300-Kilometer-Long Eastern Tennessee Seismic Zone", *Science*, v. 264, 29 April 1994, p. 686–688.

Robinson, J.A. and Johnson, G.C. 1996. *Results of a Seepage Investigation at Bear Creek Valley, Oak Ridge, Tennessee January – September 1994*. U.S.G.S. Open-File Report 95-459.

Robinson, J.A. and Reavis, L. M. III 1996. *Gaining, Losing, and Dry Stream Reaches at Bear Creek Valley, Oak Ridge, Tennessee March and September 1994*. U.S.G.S. Open-File Report 96-557.

Rosensteel, B. A. 2015. *Wetland Delineation and Stream Determination Report, Proposed Environmental Waste Management Disposal Facility Site, Oak Ridge Reservation, Oak Ridge, Tennessee*.

Rosensteel, B. A., and C. C. Trettin. 1993. *Identification and Characterization of Wetlands in the Bear Creek Watershed.* Y/TS-1016.

Rothschild, E.R., Huff, D.D., Haase, C.S., Clapp, R.B., Spalding, B.P., Farmer, C.D., and Farrow, N.D., 1984. *Geohydrologic Characterization of Proposed Solid Waste Storage Area (SWSA) 7*. ORNL/TM-9314.

Ryon, M.G. 1998. *Evaluation of Protected, Threatened, and Endangered Fish Species in Upper Bear Creek Watershed*. ORNL/M-6567.

Sanford, W.E., Shropshire, R.G., and Solomon, D.K. 1996. "Dissolved gas tracers in ground water: simplified injection, sampling, and analysis". *Water Resources Research*, vol. 32, no. 6, pp. 1635-642.

Sanford, W.E. and Solomon, D.K. 1998. "Site characterization and containment assessment with dissolved gases", *J. Environmental Engineering*, vol. 124, no. 6, pp. 572-574.

SAIC (Science Applications International Corporation), 1997. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*. DOE/OR/01-1455/V1–V6&D2

Sara, M. N., 1994. *Standard Handbook for Solid and Hazardous Waste Facility Assessments*. Boca Raton, FL: Lewis Publishers.

Scanlon, T.M., Raffensperger, J.P., Hornberger, G.M., and Clapp, R.B., 2000. "Shallow subsurface storm flow in a forested headwater catchment: observations and modeling using a modified TOPMODEL." Water Resources Research, vol. 36, no. 9, pp. 2575–2586.

Schacher, W.H. 2015a. *Site Stream Assessment and Evaluation of Potential Project Impacts to Rare, Threatened and Endangered (RTE) Aquatic Animal Species.*

Schacher, W.H. 2015b. *Assessment of Potential Project Impacts to Terrestrial, Vertebrate, Rare, Threatened and Endangered (RTE) Animal Species*.

Schreiber, M. E., 1995. Spatial Variation in Groundwater Chemistry in Fractured Rock: Nolichucky Shale, Oak Ridge, TN, Master's Thesis: University of Wisconsin-Madison.

Shapiro, Allen M. 2003. "Characterizing Fractured Rock: Conceptual Models of Ground-Water Flow and the Influence of Problem Scale." EPA Technical Support Project: Fractured Rock Sessions, Niagara, NY.

Shevnell, L.A., 1994. *Insights into Quick Flow in a Karst Aquifer: Usefulness of Infrequently Collected Geochemical Data from Wells*. Y/TS-1264.

Shevnell, L.A., McMaster, B.W., Demarais, K.M., 1995. *Evaluation of Cross Borehole Tests at Selected Wells in the Maynardville Limestone and Copper Ridge Dolomite at the Oak Ridge Y-12 Plant*. Y/TS-1166.

Sidle, R.C., Tsuboyama, Y., Noguchi, S., Hosoda, I., Fujeida, M., and Shimizu, T. 2000. "Stormflow generation in steep forested headwaters: a linked hydrogeomorphic paradigm." *Hydrological Processes*, vol. 14, pp. 369 – 385.

Sledz, J.J. and Huff, D.D., 1981. *Computer Model for Determining Fracture Porosity and Permeability in the Conasauga Group, Oak Ridge National Laboratory, Tennessee*. ORNL/TM-7695

Solomon, D.K., G.K. Moore, L.E. Toran, R.B. Dreier, and W.M. McMaster. 1992. *Status Report: A Hydrologic Framework for the Oak Ridge Reservation,* ORNL/TM-12026.

Southworth, G.R., Loar, J.M., Ryon, M.G., Smith, J.G., Stewart, A.J., and Burris, J.A. 1992. *Ecological Effects of Contaminants and Remedial Actions in Bear Creek*. ORNL/TM-11977.

Stover, C.W. and Coffman, J.L. 1993. Seismicity of the United States 1568 – 1989 (Revised). USGS Prof. Paper 1527.

Tang, G., Watson, D.B., Parker, J.C., Jardine, P.M., and Brooks, S.C. 2010. "Long-Term Nitrate Migration and Attenuation in a Saprolite/Shale Pathway from a Former Waste Disposal Site." Abstract published in *Geochinica et Cosmochimica Acta*, vol. 27, no. 12, Supplement 1 A1118 for Goldschmidt 2010 Conference.

TDEC (Tennessee Department of Environment and Conservation), 2012. Environmental Monitoring Report January through December 2011.

TDEC, 2008. *Tennessee Natural Heritage Program Rare Plant List*.

USGS 2000. *The Severity of an Earthquake*. Unnumbered USGS general interest publication accessed at http://pubs.usgs.gov/gip/earthq4/severitygip.html on October 22, 2013.

USGS 2013a. Earthquake Probability Map for Magnitude 5 and 7 within 1000 years for Oak Ridge, Tennessee. Map developed at https://geohazards.usgs.gov/eqprob/2009/index.php on October 18, 2013.

USGS 2013b. Probable Seismic Hazard Deaggregation on NEHRP BC rock EMDF (latitude 35.970 N, longitude 84.283 W). Calculated at http://eqint.cr.usgs.gov/deaggint/2008/index.php on October 22, 2013.

USGS 2013c. October 18, 2013.Design Maps Detailed Report, 2009 NEHRP Recommended Seismic Provisions (Latitude 35.970 N, Longitude 84.283 W). Map developed at http://geohazards.usgs.gov/designmaps/us/application.php on October 18, 2013.

Van der Kamp, G., 2001. "Methods for determining the in situ hydraulic conductivity of shallow aquitards – an overview". *Hydrogeology Journal*, vol. 9, no. 1, pp. 5 – 16.

Vaughn, J. D., Obermeier, S. F., Hatcher, R. D., Howard, C. D., Mills, H. H., and Whisner, S. C. (2010). "Evidence for One or More Major Late-Quaternary Earthquakes and Surface Faulting in the East Tennessee Seismic Zone," *Seismological Research Letters*, 81(2), 323, March/April.

Walker, B.A. and Saylor, R.E. (eds.) 1988. *Data Package for the Low Level Waste Disposal Development and Demonstration Program Environmental Impact Statement*. ORNL/TM-10939/V1 & V2 (two volumes). September 1988.

Webster, D.A., 1996. *Results of Ground-Water Tracer Tests Using Tritiated Water at Oak Ridge National Laboratory, Tennessee*. U.S. Geological Survey Water-Resources Investigations Report 95-4182.

White, W.B. and White, E.L., 2001. "Conduit fragmentation, cave patterns, and the localization of karst ground water basin: the Appalachians as a test case", *Theoretical and Applied Karstology*, Vol. 13-14, pp. 9-24.

White, W.B. and White, E.L., 2003. "Conduit fragmentation, cave patterns, and the localization of karst ground water basins: the Appalachians as a test case". *Speleogenesis and Evolution of Karst Aquifers*, vol. 1, no. 2.

White, W.B. and White, E.L., 2005. "Ground water flux distribution between matrix, fractures, and conduits: constraints on modeling," *Speleogenesis and Evolution of Karst Aquifers*, vol. 3, no. 2.

Wilcox, B.P., Taucer, P.I., Munster, C.L., Owens, M.K., Mohanty, B. P., Sorenson, J.R., and Bazan, R. 2008. "Subsurface stormflow in important in semiarid karst shrublands", in *Geophysical Research Letters*, vol. 35, L10403. 6 p.

Worthington, S.R.H., 1991. *Karst Hydrology of the Canadian Rocky Mountains*. McMaster University: PhD dissertation accessed at *Open Access Dissertations and Theses,* Paper 3542, http://digitalcommons.mcmaster.ca/opendissertations/3542.

Worthington, S.R.H., 1999. "A comprehensive strategy for understanding flow in carbonate aquifers", in Palmer, A.N., Palmer, M.V., and Sasowsky, I.D. (eds.), *Karst Modeling: Special Publication 5.* Charles Town, WV: The Karst Waters Institute, pp. 30-37.

Worthington, S.R.H. and Ford D.C. 2009. "Self-Organized Permeability in Carbonate Aquifers", *Ground Water*, Vol. 47, no. 3, pp. 326–336.

# APPENDIX E – ATTACHMENT A:
# PHASE I CHARACTERIZATION REPORT
# OF THE ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY
# SITE IN EAST BEAR CREEK VALLEY

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... viii
1. INTRODUCTION ..... 1
1.1 DRIVERS ..... 1
1.2 OBJECTIVES ..... 2
1.3 REPORT ORGANIZATION ..... 2
1.4 BACKGROUND SITE AND CONCEPTUAL LANDFILL DESIGN INFORMATION ..... 2
1.5 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS ..... 3
1.6 KEY SITE FEATURES ..... 3
2. SITE PREPARATIONS AND PROCUREMENT ..... 7
3. PROJECT PLANS, FIELD SCHEDULE, AND SCOPE CHANGES ..... 7
4. PHASE I SCOPE SUMMARY AND FIELD METHODS ..... 8
4.1 MONITORING WELLS ..... 9
4.1.1 Contaminant Field Screening ..... 9
4.1.2 Drilling Methods, Sequencing, and Borehole Water Table Assessment ..... 10
4.1.3 Shallow Interval Drilling, Sampling, and Logging ..... 10
4.1.3.1 Disturbed Soil Sampling ..... 11
4.1.3.2 Undisturbed Shelby Tube Sampling and Testing ..... 11
4.1.3.3 Field Logging ..... 12
4.1.4 Intermediate Interval Well Drilling, Sampling, and Logging ..... 12
4.1.5 Rock coring Methodology, Logging, and Photography ..... 13
4.1.6 Borehole and Well Testing ..... 13
4.1.6.1 Borehole Geophysical Logging ..... 14
4.1.6.2 Packer Tests ..... 14
4.1.6.3 Slug Tests ..... 16
4.1.7 Well Construction and Development ..... 16
4.1.7.1 Shallow Well (Water Table Interval) Construction ..... 16
4.1.7.2 Deep Well (Intermediate Ground Water Interval) Construction ..... 18
4.1.7.3 Well Surface Completions ..... 19
4.1.7.4 Well Development ..... 19
4.2 SURFACE WATER AND GROUND WATER MONITORING ..... 20
4.2.1 Surface Water Monitoring ..... 21
4.2.1.1 Stream Gage Design, Installation, Instrumentation, and Monitoring ..... 21
4.2.1.2 Surface Water Observational Monitoring ..... 26
4.2.2 Ground Water Monitoring ..... 28

4.3 SURVEYING ..... 29
4.4 WASTE MANAGEMENT ..... 31
5. PREVIOUS INVESTIGATIONS RELEVANT TO PHASE I ..... 31
6. EMDF HYDROGEOLOGICAL SITE CONCEPTUAL MODEL ..... 34
7. PHASE I RESULTS ..... 39
7.1 SURFACE WATER HYDROLOGY ..... 39
7.1.1 Local Climate and Recent Precipitation ..... 39
7.1.2 Rainfall Runoff Relationships ..... 42
7.1.4 Surface Water Observational Monitoring Results ..... 51
7.1.4.1 Weekly Observational Monitoring Flow Data ..... 52
7.1.5 Surface Water Quality ..... 53
7.1.5.1 Surface Water Temperatures ..... 54
7.1.5.2 Specific Conductivity and pH ..... 54
7.2 HYDROGEOLOGY ..... 57
7.2.1 Stratigraphic Section ..... 57
7.2.2 Typical Subsurface Hydrogeological Profile ..... 59
7.2.3 Ground Water ..... 62
7.2.3.1 Phase I Ground Water Level Data ..... 62
7.2.3.2 Potentiometric Surface Contour Maps ..... 67
7.2.3.3 Horizontal and Vertical Ground Water Gradients ..... 71
7.2.3.4 Ground Water Quality Parameter Data ..... 74
7.2.3.5 Phase I Hydraulic Conductivity Tests ..... 79
7.2.3.6 Phase I Heat Pulse Flowmeter Tests ..... 84
7.2.4 Regolith Hydrogeology at the EMDF Site ..... 84
7.2.4.1 Phase I Results of Geotechnical Laboratory Tests ..... 89
7.2.4.2 Results of Geotechnical Laboratory Tests from Adjacent Sites ..... 89
7.2.5 Bedrock Hydrogeology at the EMDF Site ..... 91
7.2.5.1 Bedrock Structures ..... 91
7.2.5.2 Phase I EMDF Rock Core Data ..... 91
7.2.5.3 Overview of Phase I EMDF Borehole Geophysical Logging ..... 92
7.2.5.4 Correlations Between Phase I Rock Core Data and Borehole Geophysical Logs ..... 94
7.2.5.5 Other bedrock data in Bear Creek Valley relevant to the EMDF site ..... 96
7.2.5.6 Rome Formation Bedrock Hydrogeology ..... 98
7.2.5.7 Pumpkin Valley Shale Bedrock Hydrogeology ..... 99
7.2.5.8 Rutledge Limestone (Friendship Formation) Bedrock Hydrogeology ..... 106
7.2.5.9 Rogersville Shale Bedrock Hydrogeology ..... 111
7.2.5.10 Maryville Limestone (Dismal Gap Formation) Bedrock Hydrogeology ..... 114

7.2.5.11 Nolichucky Shale Bedrock Hydrogeology ..... 119
8. CONCLUSIONS AND RECOMMENDATIONS ..... 119
8.1 PHASE I CONCLUSIONS ..... 120
8.1.1 Surface Water Hydrology and Water Quality ..... 120
8.1.1.1 Surface Hydrology ..... 120
8.1.1.2 Surface Water Quality ..... 120
8.1.2 Hydrogeology ..... 121
8.1.2.1 Ground Water ..... 121
8.1.2.2 Regolith Hydrogeology ..... 123
8.1.2.3 Bedrock Hydrogeology ..... 123
8.2 PHASE I RESULTS RELATED TO CONCEPTUAL DESIGN AND SITE SUITABILITY ..... 124
8.3 RECOMMENDATIONS ..... 125
9. REFERENCES ..... 128

This page intentionally left blank.

# FIGURES

Figure 1. Phase I Monitoring Locations at the Proposed EMDF Site ..... 5
Figure 2. View toward the Southwest of the Proposed EMDF Site on September 3, 2014 ..... 6
Figure 3. Cutthroat Flume Dimensions for Flume at EMDNT3-SWG2 ..... 22
Figure 4. Cutthroat Flume Dimensions for Flumes at EMDNT3-SWG1 and EMDNT3-SWG3 ..... 23
Figure 5. One of the Three Continuous Stream Monitoring Systems Installed on the Main Tributary of NT-3 at the EMDNT3-SWG1 Location ..... 23
Figure 6. Photos of Two of the Six Observational Monitoring Locations at Springs EMDNT3-SP1 and at EMDNT3-SP2 ..... 27
Figure 7. Locations from Previous Investigations in Bear Creek Valley at and Near the Proposed EMDF Site ..... 33
Figure 8. Hydrogeological Site Conceptual Model for the Shallow Water Table Interval at the EMDF Site ..... 36
Figure 9. Hydrogeological Site Conceptual Model Illustrating Conceptualized Fracture Flow Paths in the Lower Water Table and Intermediate Ground Water Zones ..... 37
Figure 10. Hydrogeological Site Conceptual Model for Generalized Flow Paths in Shallow and Intermediate Ground Flow at and Downgradient of the EMDF Site ..... 38
Figure 11. Monthly Climate Normals (1981–2010) – Oak Ridge Area, Tennessee ..... 40
Figure 12 Location Map for Meterological Stations ..... 40
Figure 13. Cumulative Monthly Precipitation Records for NWS Station KOQT and the West Tower Meteorological Station at Y-12 (Y12 West) ..... 41
Figure 14. Summary of Observed Total Precipitation, Average Precipitation Intensity, and Maximum Hourly Intensity for each of 15 Rainfall Events Exceeding 0.1 in. Total ..... 42
Figure 15. Phase I Monitoring Locations and Approximate NT-3 Subcatchment Areas and Runoff Pathways for Flumes SWG-1, SWG-2, and SWG-3 ..... 43
Figure 16. Streamflow Hydrographs for the Three SWG Stations in the NT-3 Watershed ..... 45
Figure 17. December 2014–February 2015 Streamflow Hydrographs for the Three Phase I SWG Locations and Precipitation Data from the Y-12W Meteorological Station ..... 46
Figure 18. Estimated Event-total Runoff Plotted Against Storm Total Precipitation ..... 47
Figure 19. Event-total Runoff as a Percentage of Precipitation for Nine Runoff Events ..... 47
Figure 20. Peak Flow Rates Plotted Against Storm-total Precipitation for the Nine Runoff Events ..... 49
Figure 21. Phase I Surface Water Temperature Data ..... 55
Figure 22. Summary of Weekly Surface Water Quality Measurements Collected at the Six Observational Monitoring Sites ..... 56
Figure 23. Example of Reliable Water Quality Data at three SWG Stations ..... 58
Figure 24. Typical Subsurface Profile in Relation to the Conceptual Hydrogeological Model for Upland Areas at the EMDF Site ..... 59

Figure 25. Typical Subsurface Profile Anticipated Across the Valley of NT-3 near the Center of the EMDF Site ..... 60
Figure 26. Diagram Illustrating Relationships between Alluvium/Colluvium, Residuum, Saprolite, Bedrock, and Topography Anticipated at the EMDF Site ..... 61
Figure 27. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs ..... 63
Figure 28. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs ..... 64
Figure 29. Contour Map of the Potentiometric Surface for the Shallow Water Table Interval – December 25, 2014 ..... 69
Figure 30. Contour Map of the Potentiometric Surface for the Shallow Water Table Interval – Model-predicted Post Construction Steady State Ground Water Flow Conditions ..... 70
Figure 31. Ground Water Temperatures Observations during the December 2014 through February 2015 Reporting Period ..... 75
Figure 32. Average, Minimum, and Maximum Ground Water Temperatures Observed during the December 2014 through February 2015 Reporting Period ..... 76
Figure 33. Average Ground Water pH vs SpC Values observed during the December 2014 through February 2015 Reporting Period ..... 78
Figure 34. Schmidt Plot of Interpreted Structure Log Features in GW-968(I) Bedrock – Pumpkin Valley Shale ..... 101
Figure 35. Schmidt Plot of Interpreted Structure Log Features in GW-970(I) Bedrock – Pumpkin Valley Shale ..... 103
Figure 36. Portion of GW-970(I) Combination Log Showing High Angle Fracture Features from ~34–43 ft bgs ..... 104
Figure 37. Portion of GW-970(I) Combination Log Showing Potential Fracture Features Discordant to Bedding ..... 105
Figure 38. Schmidt Plot of Interpreted Structure Log Features in GW-972(I) Bedrock – Rutledge Limestone ..... 109
Figure 39. Schmidt Plot of Interpreted Structure Log Features in GW-974(I) Bedrock – Rogersville Shale ..... 112
Figure 40. Schmidt Plot of Interpreted Structure Log Features in GW-976(I) Bedrock – Maryville Limestone ..... 117

# TABLES

Table 1. Boring/Monitoring Well Construction Data ..... 17
Table 2. Well Development Summary ..... 20
Table 3. Measurable Flow Ranges for Phase I Flumes Installed at the EMDF ..... 25
Table 4. Final Monitoring Instrument Placement in Phase I Wells (as of March 9, 2015) ..... 29
Table 5. Elevation Data for Phase I Surface Water Monitoring Locations ..... 30
Table 6. Peak Flow Rates Estimated for the SWG-1 Subcatchment ..... 50
Table 7. Peak flow Rates at Stream Gages for Current Phase I Monitoring Period ..... 51
Table 8. Flow Statistics for NT-3 Tributary Locations between Headwater Springs/seeps and SWG Locations ..... 53
Table 9. Highest and Lowest Water Level (Potentiometric Surface) Elevations in Phase I Wells ..... 65
Table 10. Relationships between Water Level Depths and Depths to the Regolith/bedrock Interface ..... 67
Table 11. Vertical Gradients and Related Data ..... 72
Table 12. Slug Test Hydraulic Conductivity Results and Relevant Test Data for Shallow Wells - EMDF Phase I ..... 81
Table 13. Laboratory Test Results for Hydraulic Conductivity (K) from Phase I Shelby Tube Samples ..... 83
Table 14. Hydraulic Conductivity Data from Packer Tests ..... 85
Table 15. Summary of Heat Pulse Flowmeter Tests ..... 86
Table 16. Summary of EMDF Regolith Materials Based on Phase I Results ..... 87
Table 17. Summary Results from Geotechnical Laboratory Analysis of Phase I EMDF Shelby Tube Samples ..... 90
Table 18. Borehole Deviation Results from Geophysical Logs Run in Deeper Intermediate Zone Wells ..... 94
Table 19. Statistics for Natural Gamma Ray Logs run in Phase I Deep Borehholes ..... 96
Table 20. Descriptions of Geologic Formations Used for Comparison with Phase I Results ..... 97

# EXHIBITS

Exhibit A.1. TDEC Trip Report – July 2014 Alternative Proposed Location for GW-968(I)/GW-969(S)
Exhibit A.2. Documentation for Radiological Screening
Exhibit A.3. Laboratory Results of Shelby Tube Samples
Exhibit A.4. Phase I Boring Logs
Exhibit A.5. Photographs of Split-tube Samples
Exhibit A-6. Well Drilling and Construction Activity/Progree Reports
Exhibit A-7. Rock Core Photographs
Exhibit A.8. URS Borehole Geophysical Logging Report
Exhibit A.9. Packer Test Documentation
Exhibit A.10. Slug Test Documentations
Exhibit A.11. Monitoring Well Contruction Diagrams and Well Material Specification Cut Sheets
Exhibit A.12. Well Development Logs
Exhibit A.13. Cutthroat Flume Discharge Rating Tables and Long-Term Runoff Hydrographs
Exhibit A.14. Weekly Documentation for Continuous Surface Water and Ground Water Monitoring
Exhibit A.15. Documentation for Weekly Surface Water Obervation Monitoring
Exhibit A.16. BWSC Phase I Surveying Data
Exhibit A.17. Phase I Waste Disposal Documentation
Exhibit A.18. Representative Water Level Hydrographs and Vertical Gradients for EMWMF Monitoring Wells
Exhibit A.19. Summary Descriptions and Geotechnical Laboratory Test Results for Ogden Sites B and C and the EMWMF

# PLATES

Plate 1. Site-specific Hydrogeological Conceptual Model for the EMDF Site
Plate 2. Phase I Composite Boring, Borehole Geophysical, and Well Construction Logs
Plate 3. North-South Cross Section through Phase I EMDF Well Clusters
Plate 4. East-West Cross Section through Phase I EMDF Well Clusters

# ACRONYMS

| | |
|---|---|
| Alliant | Alliant Corporation |
| API | Antecedent Precipitation Index |
| ARAP | Aquatic Resources Alteration Permit |
| ASTM | American Society of Testing and Materials |
| ATV | accoustic televiewer |
| BCV | Bear Creek Valley |
| BWSC | Barge, Waggoner, Sumner, and Cannon, Inc. |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act of 1980 |
| DOE | U.S. Department of Energy |
| D | Draft |
| DQO | Data Quality Objective |
| EM | Office of Environmental Management |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| FFA | Federal Facility Agreement |
| FY | Fiscal Year |
| HPF | heat pulse flow |
| HSA | hollow-stem auger |
| K | hydraulic conductivity |
| LLLDDD | Low Level Waste Disposal, Development, and Demonstration |
| M&W | M&W Drilling, LLC |
| NGR | Natural Gamma Ray |
| NNSA | National Nuclear Security Administration |
| NT | Northern Tributary |
| NWP | Nationwide Permits |
| NWS | National Weather Service |
| ORAU | Oak Ridge Associated Universities |
| ORP | oxidation/reduction potential |
| ORR | Oak Ridge Reservation |
| OTV | optical televiewer |
| Pro2Serve | Professional Project Services, Inc. |
| PVC | polyvinyl chloride |
| RI/FS | Remedial Investigation/Feasibility Study |
| RQD | rock quality designation |

| | |
|---|---|
| SP | spontaneous potential |
| SpC | specific conductivity |
| SOP | standard operating procedure |
| SWG | surface water gaging |
| SWL | static water level |
| TDEC | Tennessee Department of Environment and Conservation |
| TDS | total dissolved solids |
| TOC | top of casing |
| U.S. | United States |
| UPF | Uranium Processing Facility |
| USACE | U.S. Army Corps of Engineers |
| USCS | Unified Soil Classification System |
| USGS | U.S. Geological Survey |
| VOC | volatile organic compound |
| WBCV | West Bear Creek Valley |
| Y-12 | Y-12 National Security Complex |

# 1. INTRODUCTION

This report documents the results of a limited Phase I site characterization at the proposed Environmental Management Disposal Facility (EMDF) site on the Oak Ridge Reservation (ORR). The report is provided as Attachment A to Appendix E of the current Draft (D3) version of the Remedial Investigation/Feasibility Study (RI/FS) Report for the EMDF. The Phase I site characterization activities were conducted in response to concerns voiced by the local United States (U.S.) Department of Energy (DOE) Oversight Office of the Tennessee Department of Environment and Conservation (TDEC) about site suitability. The TDEC comments were presented to DOE in response to the Draft (D2) RI/FS Report (DOE 2013a) and relate in part to concerns regarding springs, seeps, and the shallow water table at and near the footprint of the proposed EMDF.

The overriding objective of the limited Phase I site characterization activities was to provide data to demonstrate the suitability of the site as a viable on-site Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) disposal facility, similar to the existing adjacent Environmental Management Waste Management Facility (EMWMF). As the primary parties in the Federal Facilities Agreement for CERCLA activities on the ORR, TDEC and the U.S. Environmental Protection Agency (EPA) must concur with DOE on the suitability of the EMDF. Limiting the Phase I site characterization scope was viewed by DOE as a prudent step to avoid investing heavily in extensive site characterization until the site is deemed suitable and approved by TDEC and EPA. If the proposed EMDF site *is* approved by TDEC and EPA, then the DOE would proceed with a much more detailed Phase II site characterization program to thoroughly characterize the site and provide the extensive data required for development of a complete and rigorous engineering design for the proposed landfill. If TDEC and EPA reject the proposed EMDF site then DOE would not have invested unwisely in extensive site characterization.

The conceptual design for the EMDF includes the installation of underdrain systems beneath the landfill to ensure surface water and ground water diversion, drainage, and lowering of the water table below the waste cells. The results of the Phase I site characterization are presented in relation to the existing site topography and proposed conceptual design for the landfill and underdrain system. The results support the concept that the water table can be effectively managed and lowered during and after construction to ensure that the water table does not encroach on the geologic buffer or waste materials placed above the buffer and liner systems.

## 1.1 DRIVERS

The proposed site is undeveloped and lacks site-specific characterization information, although there is abundant data on geology and hydrogeology from adjacent areas. The lack of site-specific characterization data was raised as a concern by TDEC representatives at a workshop held in Oak Ridge on August 14, 2013. TDEC also offered several comments on the D2 RI/FS regarding site suitability and the lack of site characterization data for the selected site, noting that the agency would not approve the site unless site characterization was conducted. The cost and schedule for full site characterization, including a full year of monitoring, which is intended to support final design, monitoring and performance assessments, could not be justified by DOE unless the site was approved by the Federal Facility Agreement (FFA) parties (i.e., TDEC and EPA) as the preferred disposal site. Discussions between senior DOE Oak Ridge Office of Environmental Management (EM) managers and senior TDEC managers on September 13, 2013, produced an informal agreement that a limited Phase I site characterization, resulting in satisfactory findings, would be adequate to support a preferred site approval decision. DOE acknowledged that TDEC and EPA can disapprove the site or the action at several points after the RI/FS is approved if subsequent more detailed characterization data, or protectiveness evaluations, warrant disapproval. DOE subsequently prepared a work plan entitled *Limited Phase I Site Characterization Plan for the Proposed Environmental Management Disposal Facility Site as Requested by the Tennessee*

*Department of Environment and Conservation* (DOE 2013b) to document the original proposed scope of work. TDEC reviewed the work plan and provided comments. Based on TDEC comments, DOE made slight revisions to the work plan and proceeded with plans for the Phase I effort. EPA did not provide formal comments on the work plan.

## 1.2 OBJECTIVES

As noted above, the primary goal of the limited Phase I site characterization was to provide initial data on surface water and ground water conditions at the proposed EMDF site. These data will allow for a more informed decision on landfill site suitability so the project could move forward with a more complete Phase II characterization to follow upon approval. Secondary goals were to acquire initial data and make observations on seasonal changes in ground water level fluctuations, stream flow, springs, and seeps at the site in order to assess ground water/surface water interactions and to demonstrate that the conceptual design will be adequate to handle hydrological conditions at the proposed EMDF site.

## 1.3 REPORT ORGANIZATION

Sections 2 through 4 review the scope and detailed field methodologies of the Phase I investigation, as these have not been previously documented. Section 5 summarizes previous investigations near and along strike with the EMDF with references to documents and important data relevant to the EMDF. Section 6 presents a site-specific hydrogeological conceptual model for the EMDF. Section 7 presents the Phase I results under the general headings of surface water hydrology and hydrogeology (subsurface hydrology). Section 8 provides conclusions and recommendations based on the Phase I results addressing site suitability and general recommendations for follow on Phase II investigations. Section 9 lists all references cited. Plates with detailed large scale site drawings and cross sections are provided as attachments. Supporting documentation for the Phase I investigation (completed field forms, boring and geophysical logs, test results, calculations, monitoring data, etc.) are provided in various attached Exhibits.

## 1.4 BACKGROUND SITE AND CONCEPTUAL LANDFILL DESIGN INFORMATION

Numerous investigations have been completed for existing and planned waste sites within Bear Creek Valley (BCV) and across the ORR. Reports from these investigations provide a considerable amount of detailed surface and subsurface information dating back from the 1970s to the present. Much of the information is available from sites directly adjacent to the proposed EMDF providing a unique resource and opportunity for planning investigations at the EMDF. Relevant data from adjacent sites is briefly summarized in Section 5.0 and elsewhere in conjunction with the Phase I results as appropriate. Background information is also summarized in Appendix E of the current RI/FS report (D3 Version, On-site Disposal Alternative Site Description). A review of Appendix E and source documents referenced in the current Phase I report is encouraged and important in providing a more complete context for the results of this Phase I report.

Section 6 of the current RI/FS Report (D3) presents a review of the proposed engineering conceptual design for the EMDF. The conceptual design includes descriptions and drawings of the proposed underdrain system, geologic buffer and compacted engineered fill, the landfill liner/leachate system, waste and overlying cap/cover system and stormflow drainage/diversion systems for the landfill. These design elements and their relationships with the existing surface and ground water flow systems are critical to understanding and acceptance of the site as a suitable location for waste disposal and warrant review along with the Phase I site characterization results. Cross sections presented in Plates 2 through 4 accurately present Phase I results in relation to key design elements such as the underdrains, geobuffer, and liners.

## 1.5 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

It was recognized that the proposed Phase I characterization efforts would make minimal impacts to waters of the State; and certain permitting, including U.S. Army Corps of Engineers (USACE) pre-construction notices and Tennessee Aquatic Resources Alternation Permit (ARAP) requirements, might be relevant and appropriate. However, because this is a CERCLA action, only the substantive requirements of permits must be met.

A summary of the 2012 Nationwide Permits (NWP) of the USACE Nashville District Regulatory Branch, indicates that the Phase I characterization field activities would fall under NWP #5 (Scientific Measurement Devices) under statutory authority 10/404, with limits of 25 $yd^3$ for weirs and flumes. The 2012 NWP added meteorological stations, current gauges, and biological observation devices to the list of examples and added a requirement that devices and any associated structures or fills be removed upon completion of use and restored to pre-construction elevations to maximum extent practicable [http://www.usace.army.mil/Portals/2/docs/civilworks/nwp/2012/NWP2012__sumtable_15feb_2012.pdf]. According to these statutes, a Pre-Construction Notification would not be required for the scope of the Phase I investigation. Flow monitoring is not included in the actions requiring a TDEC ARAP.

CERCLA documentation meets the substantive requirements of the National Environmental Policy Act of 1969. The proposed Phase I field work is therefore covered under DOE's categorical exclusion B3.1, applicable to site characterization, monitoring, and general research. Specific activities included in this categorical exclusion that apply to the Phase I scope of work include:

- Geological, geophysical, geochemical, and engineering surveys and mapping, and the establishment of survey marks.
- Installation and operation of field instruments (such as stream-gauging stations or flow-measuring devices).
- Drilling of wells for sampling or monitoring of ground water or the vadose (unsaturated) zone, well logging, and installation of water-level recording devices in wells.
- Aquifer and underground reservoir response testing.

This Phase I site characterization is performed in partial fulfillment of the requirements of 40 CFR 264.97(a)(1) to determine background water quality. The results of this work will also be used to fulfill requirements for Site Evaluation and Low-Level Waste Disposal Facility Design given in DOE O 435.1A, as defined in DOE G 435.1, Chapter IV.

## 1.6 KEY SITE FEATURES

No hazardous or radioactive contamination was expected or found at the site through field screening activities. Review of available historical topographic maps and air photos indicated that the site had probably not been used for agricultural or industrial purposes since before World War II. Existing ground water contaminant plumes from the S-3 Ponds and former Bone Yard/Burn Yard and Oil Landfarm are all hydraulically downgradient of the EMDF.

A downburst (tornado-like wind) that occurred during a storm on May 19, 2013, toppled trees across much of the proposed EMDF site, as well as on the north side of Pine Ridge. Timber recovery started in the EMDF area in mid November, 2014, and was completed by mid July 2014. Figure 1 illustrates key site features in relation to the EMDF footprint. Features include Phase I monitoring locations, topographic contours, Northern Tributary (NT) drainage paths, approximate geologic formation outcrop boundaries, and the approximate layout of roads constructed to access drilling locations. A large portion of the footprint area has now been cleared of timber as shown in the aerial photo in Figure 2 taken on

September 3, 2014. The logging and road construction work have modified the original forested conditions and natural drainage features in some areas of the site. Potential influences on surface water and stormflow zone ground water flow conditions are discussed elsewhere in this report.

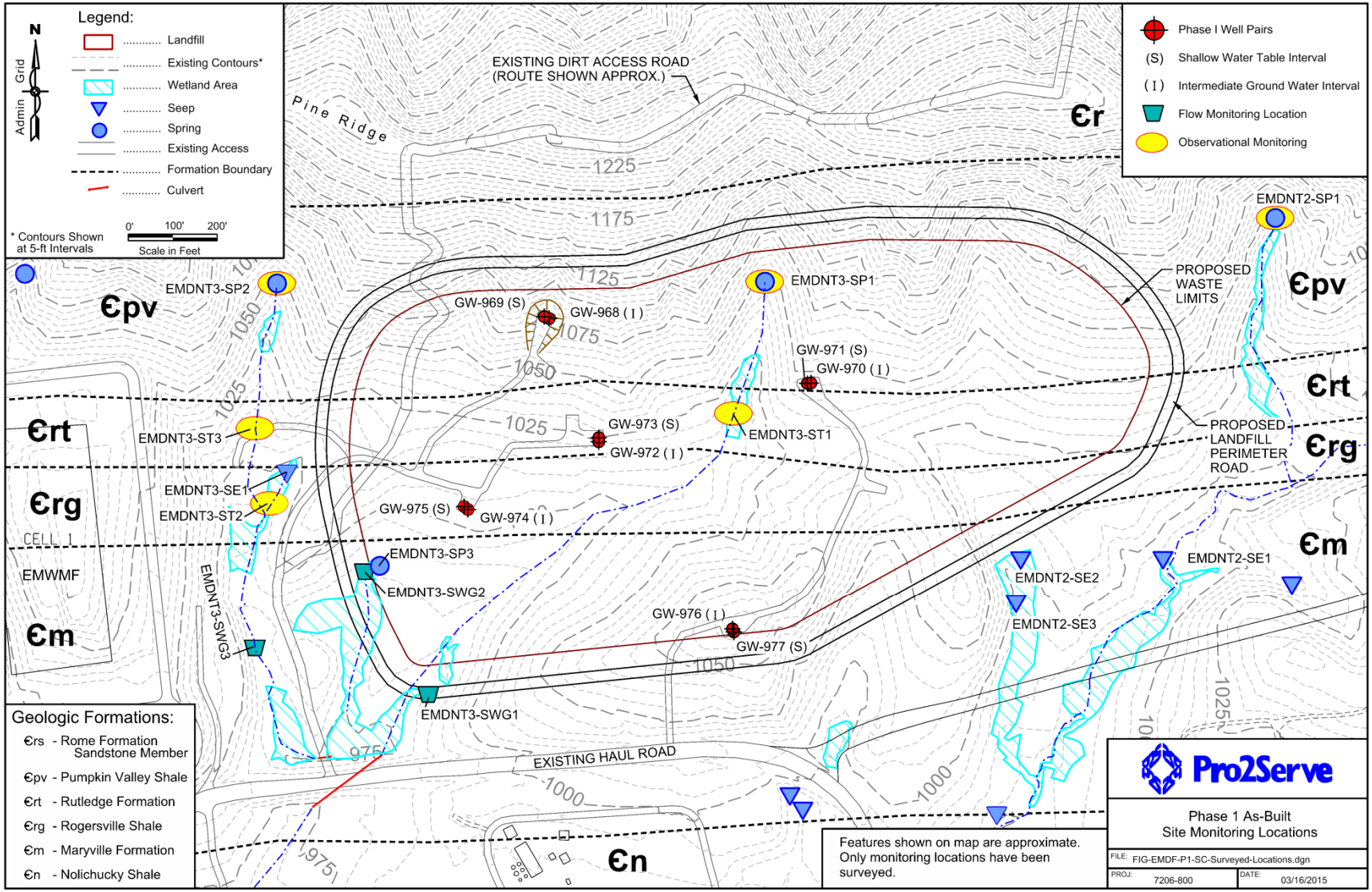
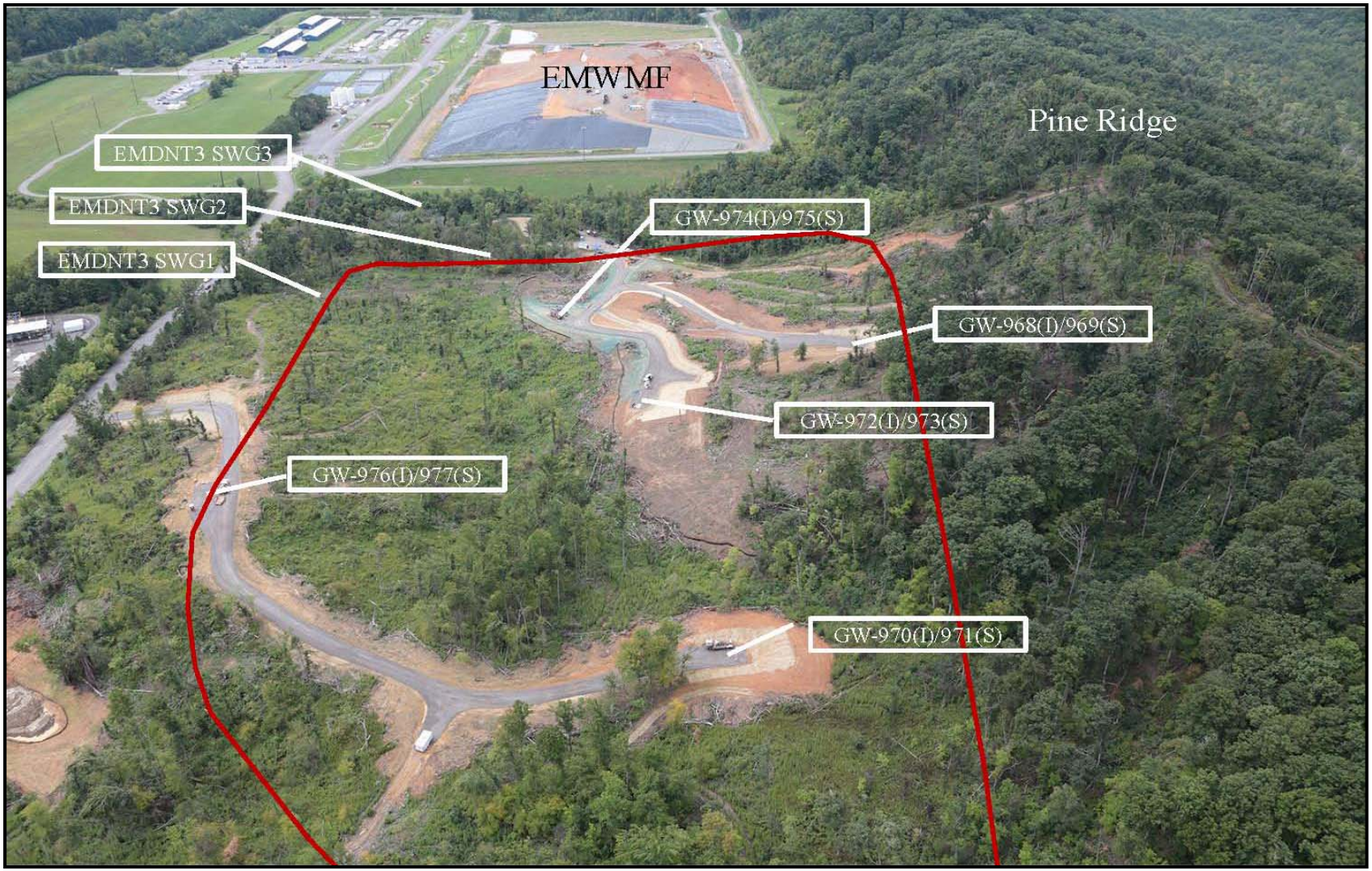



**Figure 1. Phase I Monitoring Locations at the Proposed EMDF Site**




Note: Trees removed from blowdown areas, Phase I well pair/flume locations; red line indicates approximate outline of waste limits.

**Figure 2. View toward the Southwest of the Proposed EMDF Site on September 3, 2014**

# 2. SITE PREPARATIONS AND PROCUREMENT

Because the proposed EMDF site covers areas inside and outside of the Y-12 National Security Complex (Y-12) 229 perimeter fence, a memorandum of understanding was developed between DOE EM and the National Nuclear Security Administration (NNSA) to facilitate site activities and effective coordination between DOE EM staff, NNSA staff, adjacent EMWMF staff (URS | CH2M Oak Ridge LLC), and other contractors working at and near the EMDF site. Excavation/penetration permits (including utility clearances) were required prior to road construction, drilling, and placement of flumes at stream gaging stations, and were obtained through the Y-12 permitting process.

In preparation for the Phase I field work, DOE employed an existing contract with ES&H, Inc., to construct road access to each of the proposed monitoring well locations. The road construction began on July 21, 2014, and was completed during the first week of September 2014. The construction included storm water routing and erosion control measures to prevent soil erosion into the neighboring NT tributaries at and beyond the site. Of note the road construction resulted in a reconfiguration of the former natural surface water drainage patterns (wet weather conveyances) in the vicinity of the roads leading to the three well clusters on the northwest side of NT-3. A portion of the intermittent surface runoff that had formerly followed natural drainage paths and been more evenly absorbed across the surface is now focused during significant precipitation/runoff events downhill toward and into the middle tributary of NT-3. The potential impacts of this reconfiguration in surface water runoff are discussed in Section 7.1 below.

Implementation of the Phase I field work was completed by DOE via procurement through existing DOE Blanket Purchase Agreement contracts for environmental work. DOE prepared a statement of work reflecting the scope and requirements of the approved Phase I work plan and a contract was awarded in late Spring of 2014 to Alliant Corporation (Alliant) to complete the Phase I field work and provide results to DOE. Alliant subcontractor team members included: M&W Drilling, LLC (M&W) for drilling, soil sampling, rock coring, packer testing, and well completions; Oak Ridge Associated Universities (ORAU) for radiological control/health physics support; URS Corporation for geophysical logging and packer test support; and Barge, Waggoner, Sumner, and Cannon, Inc. (BWSC) for site surveying. The interim results were provided to DOE for separate report preparation and integration with the current revised RI/FS report and to facilitate the FFA regulatory approval process for the site.

DOE conducted the procurement and managed the contract for the Phase I effort with intermittent technical oversight from Professional Project Services, Inc. (Pro2Serve) Portions of the Phase I results were provided as interim deliverables to support decision making during the fieldwork, and to provide data for the current Phase I Report. The results of continued Phase I surface and ground water monitoring through the end of Fiscal Year (FY) 2015, will be provided to DOE by Alliant over the coming months.

# 3. PROJECT PLANS, FIELD SCHEDULE, AND SCOPE CHANGES

Alliant developed a set of detailed project-specific work plans, standard operating procedures (SOPs), and other plans to address waste management and environmental, safety, and health requirements for completing the Phase I field work. The project plans were reviewed, revised, resubmitted, and approved by DOE before commencement of the field work. Because the limited Phase I field program was not formally recognized by the FFA parties as a primary or secondary FFA document, the Alliant work plans did not undergo regulatory review and approval by EPA or TDEC.

The final project plans were submitted on August 21, 2014, and field mobilization and drilling began on August 26. Drilling, soil sampling, rock coring, geophysical logging, packer testing, monitoring well installations, slug testing, and the installation of three stream flow monitoring stations were conducted from September through November 2014. Continuous monitoring equipment was installed in each of the

ten monitoring wells and at the three stream flow monitoring stations in late November 2014. Continuous monitoring and weekly equipment inspections, data downloads, and observational monitoring of springs and seeps began around December 1, 2014. Interim data were provided to DOE and Pro2Serve for the preparation of this Phase I report. The monitoring data included in this Phase I report includes the approximately three-month period from late November 2014 through February 26, 2015. Alliant will continue stream and ground water monitoring activities through the end of September 2015, with weekly checks and data downloads to ensure significant breaks in data are avoided. Monitoring may continue beyond the end of FY 2015 if DOE receives regulatory approval of the EMDF site, and if funding is available. Results from the continued monitoring will be shared with the FFA parties in concert with regularly scheduled project team meetings where EMDF progress is reviewed.

# 4. PHASE I SCOPE SUMMARY AND FIELD METHODS

The limited Phase I site characterization plan (DOE 2013b) did not include detailed descriptions of field methods, typically provided in RI/FS work plans, sampling and analysis plans, and quality assurance/quality control plans prepared for remedial investigations under CERCLA. Section 4, therefore, provides a summary of actual field methods, standards, and requirements employed by Alliant for the Phase I site characterization based on DOE contractual requirements and the project-specific Alliant work plans, SOPs, etc., noted above.

The limited Phase I scope of work included the following major field tasks in their general sequence of implementation:

- Monitoring well drilling, logging, sampling, testing, and well completions
- Construction of stream flow monitoring stations
- Monitoring of ground water and surface water

Details of field methods for implementing these three primary tasks are reviewed below. Phase I results with interpretations are presented in subsequent sections.

The following noteworthy scope changes were made from the original Limited Phase I Site Characterization Plan (DOE 2013b):

1) **Additional Well Pair:** One additional monitoring well pair was added to intercept and monitor ground water conditions within the outcrop belt of the Rutledge Limestone bringing the total number of well pairs from the originally proposed four well pairs to five (ten total wells).
2) **Deletion of Fourth Surface Water Gaging Station and Addition of Limited Observational Spring/seep Monitoring:** The originally proposed continuous stream gaging station to be located below the haul road culvert on NT-3 was removed from the scope because of the constricting plate welded onto the upstream side of the culvert. This plate significantly constrains natural flows resulting in unnatural flow conditions downstream of the culvert. Weekly "observational" monitoring of selected spring and stream locations was added to the scope.
3) **Rock Coring:** Continuous rock coring was added for two of the deeper wells located in the outcrop belt of the Rutledge Limestone (GW-972[I]) and Maryville Limestone (GW-976[I]) to obtain more direct data on the physical characteristics of these formations that are reported to include limestone interbedded with shales that might include dissolution features with higher hydraulic conductivity.
4) **Revised Location of the Upgradient Well Pair:** The upgradient well pair (GW-968[I]/GW-969[S]) originally located on top of Pine Ridge within the outcrop belt of the Rome Formation was moved downslope to a much lower position within the outcrop belt of the Pumpkin Valley Shale. This change was required because of the difficulties and expense associated with the construction of an access road up the very steep slopes of Pine Ridge. The

revised location was coordinated with and approved by TDEC staff with the understanding that TDEC would want future monitoring wells higher up slope within the Rome Formation if and when the EMDF site were approved for more detailed Phase II site characterization (see attached TDEC trip report dated July 29, 2014, in Exhibit A.1).

## 4.1 MONITORING WELLS

Five shallow/deep well pairs were installed at the locations shown in Figure 1. Each shallow well was drilled to auger refusal depth. Each deep well was drilled initially to auger refusal for placement of isolation casing and then drilled to a total depth of 100 ft below ground surface (bgs). The shallow well total depths range from 10–25 ft bgs, and the five deep wells were each completed at the nominal 100 ft depth. Each of the ten wells was assigned a unique number according to protocols established for subsurface data compiled and maintained by the Y-12 Environmental Compliance Department (per email correspondence from Steve Jones). The well locations were placed to intercept each of the four geologic formations that underlie the EMDF conceptual design footprint (i.e., Pumpkin Valley, Rutledge, Rogersville, and Maryville formations).

Originally an upgradient well pair was to be located along the top of Pine Ridge within the Rome Formation. As noted above, however, the location was moved downslope within the outcrop belt of the Pumpkin Valley Shale. The wells were numbered sequentially from north to south with the odd number in each well pair designating completion in the water table (or shallow - S) interval of the saturated zone and the even number in each pair designating completion in the intermediate interval (I) of the saturated zone. These designations are consistent with those described in the hydrologic framework for the ORR (see Solomon et al, 1992), and in the hydrogeological site conceptual model applied to the EMDF (see Appendix E and Section 6.0 below) and other sites on the ORR. The “deep interval” described by Solomon et al (1992) and applied to the EMDF, refers to a much deeper ground water interval occurring below depths of around 328 ft bgs, well below the 100 ft maximum depths of the deeper Phase I wells. Methodologies and standards for the drilling, sampling, logging, testing, completion, and development of the wells are reviewed in the subsections below.

### 4.1.1 Contaminant Field Screening

As previously noted, the EMDF site was anticipated to be uncontaminated; however, precautions were taken by Alliant to screen for any potential contaminants during the Phase I field work. The drilling pads and all subsurface materials (soil and rock cuttings/cores and water) were screened for radiological contaminants using alpha, beta, and gamma detection instruments, and for volatile organic contaminants using a photo-ionization detector.

The radiological screening equipment used by ORAU included:

- Ludlum Model 44-9 (otherwise known as a GM pancake probe) - Beta, Alpha, Gamma. This was paired with a Ludlum Model 12 Ratemeter.
- Ludlum Model 26 Integrated Pancake Frisker - Beta and Alpha. This unit is a self-contained detector/ratemeter.
- Ludlum Model 43-92 ZnS(Ag) scintillator - Alpha. This detector was paired with a Ludlum Model 12 Ratemeter.
- Ludlum Model 44-10 NaI wide-energy - Gamma. This detector was paired with a Ludlum Model 2221 Ratemeter.

Alliant used two instruments for field screening:

- Horiba Model U52 Multi Water Quality Checker (U-50 Series)
- RAE Systems MultiRAE PLUS, Model RAE-20 Photoionization Detector

Field screening indicated no evidence of contamination in any environmental media (i.e., surface or subsurface soils, ground water, or surface water). The rock core boxes stored on site were all green tagged. Drilling rigs, drill rods, and downhole geophysical instruments were all scanned before and after use to ensure contaminants were not introduced to or removed from the site and to ensure no human health exposure hazards. Personnel, soil and rock samples/cuttings, and all downhole field equipment were screened to ensure rapid detection and response for any anomalous conditions. Alliant documentation for radiological screening and equipment/core green tagging is provided in Exhibit A.2. Screening data for volatile organic compounds (VOCs) during drilling and sampling were recorded on boring logs.

### 4.1.2 Drilling Methods, Sequencing, and Borehole Water Table Assessment

Two drilling rigs were used for the Phase I subsurface investigation. A Diedrich D120, hollow-stem auger (HSA) drilling rig was used for the initial drilling through unconsolidated overburden materials down to auger refusal at each of the five deeper well locations. A second rig (Schramm T40W air rotary rig) followed behind the HSA rig to expand the initial borehole diameter and set shallow isolation casing required for each of the deeper wells. The HSA rig was also used for rock coring of bedrock at two of the five deeper well locations (GW-972[I] and GW-976[I]) and for drilling and installation of the five shallow monitoring wells. The air rotary rig was also used to drill through bedrock at three of the deeper well locations (GW-968[I], GW-970[I], and GW-974[I]) with no rock coring, and for widening (reaming) the borehole diameter at the rock cored locations prior to geophysical logging and packer testing.

The nature and sequencing of the drilling allowed for a better assessment of water table conditions prior to installation of shallow well casing and screen. After the initial overburden drilling at each of the five well pair locations, the auger flights were removed from the borehole allowing natural ground water levels to recharge and equilibrate in the open borehole. Observations and measurements of the depth to standing water were made after at least an overnight period, and the open boreholes were temporarily covered to prevent rainfall from entering the boreholes. The water level data in the open boreholes were then used to identify appropriate target depths for Shelby Tube sampling and appropriate depths and screen lengths for the shallow monitoring wells. Water level measurements were made (with consistent reference to the ground surface) after the drilling process upon reaching total depth using an electronic water level indicator to ensure that a sufficient saturated zone was encountered before well installation.

Topsoil materials (i.e, root zone) were removed at each of the drill locations during site grading for access road construction. Except for the GW-976/977 location where topsoil removal was minimal, all of the other drilling pad locations were cleared and graded down in excess of two or more feet below the original ground surface. Organic rich topsoil material was therefore not identified in the Phase I boring logs even though topsoils and a greater thickness of underlying clayey residuum were originally present at the well locations before road grading and well pad leveling. Pre-drilling elevation surveys were not completed to quantify differences between pre and post ground surface elevations. However, pre-drilling elevations were estimated based on the current topographical map for the east end of BCV, including the EMDF site.

### 4.1.3 Shallow Interval Drilling, Sampling, and Logging

Overburden soil and weathered bedrock (saprolite) samples were collected and logged to auger refusal during the initial HSA drilling at each deeper well pair location. Because of the close proximity of each well pair, no soil samples (except for single Shelby tube samples) were collected during the drilling at each adjacent shallow well location. After bedrock drilling was completed at each of the deeper well locations, the HSA rig was used for drilling and placement of an adjacent 4 in. diameter shallow well within the saturated zone of the unconsolidated overburden materials. The shallow wells were each bored to auger refusal at the top of competent unweathered or less weathered bedrock. Because of the nature and

sequence of the drilling, sufficient time was allowed for natural recharge of the borehole and water level monitoring of the recharge rate to ensure that the saturated conditions encountered were reasonably close to equilibrium (i.e., at least for an overnight period and typically greater than 24 hours before drilling and placement of the isolation casing for the deeper wells).

#### 4.1.3.1 Disturbed Soil Sampling

Soil samples in the initial boreholes (drilled for placement of the 10 in. diameter overburden isolation casing) were collected and logged at 5 ft intervals to auger refusal. Starting at the ground surface and at subsequent 5ft intervals thereafter (e.g., 0–2 ft, 5–7 ft, 10–12 ft, 15–17 ft, etc.), the samples were collected using an automatic hammer and split-barrel sampling of soils according to standard penetration testing per American Society for Testing and Materials (ASTM) D 1586 *Penetration Test and Split-Barrel Sampling of Soils*, with the exception that the split-spoon sampler was driven a total distance of 24 in. (four 6 in. increments), instead of 18 in. (three 6 in. increments) as required by ASTM D 1586 [at some locations Alliant collected 18 in. split-spoons rather than 24 in. split-spoon samples). The split-barrel sampling devices have a nominal outside diameter of 2 in. and were 6 in. longer than the sample interval to lessen the potential for over-compacting the sample in the split-barrel. Blow counts per 6 in. increments were recorded on field logs and N values were determined using the sum of the blow counts from the second and third 6 in. intervals. Soil consistency (i.e., stiffness and hardness) was found to increase with depth at each location as indicated by increasing blow counts with depth moving from shallow clayey residuum to increasingly less weathered saprolite with depth to auger refusal atop more competent bedrock. Because the shallow /deep well pairs were drilled in close proximity, (i.e., about 10–15 ft apart), split tube sampling was not conducted in the adjacent augered borehole drilled for shallow well installation.

#### 4.1.3.2 Undisturbed Shelby Tube Sampling and Testing

The scope of work prescribed that one undisturbed Shelby tube sample be collected within the saturated interval at each shallow well location. As noted above, the water level measurements in the open boreholes were used to determine appropriate depths for Shelby tube sample collection. The recovery of suitable Shelby tube samples is often limited by the hardness and stiffness of site soils (i.e., residuum and saprolite) which at the EMDF site naturally increase with depth. The depths selected for the Shelby tube samples were therefore made at depths only slightly below the water level depths measured in the open boreholes before isolation casing was installed. Shelby tube samples were collected, preserved, and transported according to ASTM methods D 1587 *Thin-Walled Tube Sampling of Soils*, and D 4220 *Preserving and Transporting Soil Samples*.

The Shelby tube samples were collected during the drilling of the boreholes for shallow wells at each location based on the results of split tube sampling and logging of the soils and saprolite and water levels in the initial boreholes drilled for the deeper well pairs. The Shelby tube samples from each shallow well were laboratory tested according to the latest version of the following ASTM Methods:

- D 422 – *Standard Test Method for Particle Size Analysis of Soils*
- D 5084 – *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*
- D 2487 – *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*
- D 854 – *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer*
- D 4318 – *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*

Geo/Environmental Associates, Inc., of Knoxville, Tennessee, conducted the laboratory analyses. Results of the laboratory analysis are presented in Section 7.2.4.1. Laboratory data sheets are provided in Exhibit A.3.

#### 4.1.3.3 Field Logging

Soils were classified and logged in the field according to: (1) ASTM method D 2488 *Description and Identification of Soils (Visual-Manual Procedure)*, and (2) Section III of the USACE Geology Section Field Manual (Nashville Engineer District). ASTM Method D 2487 (*Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System*) was also used in concert with D 2488 for field classification of soils (and for laboratory classification purposes of Shelby tube samples). These standards were incorporated into an Alliant SOP to identify consistent and detailed field logging protocols for the Phase I subsurface investigation. Subsurface materials, water level and drilling conditions, and other drilling and field logging activities were logged on a standardized field form (ENG Form 1836) for each well. This field form is specifically designed for use in geotechnical drilling applications suitable for landfill hydrogeological investigations. Munsell color charts were used to accurately and consistently define soil (and rock) colors. Sequential photographs were taken of each split-barrel sample and representative auger/air rotary cuttings to facilitate documentation of subsurface conditions. Completed boring logs for overburden materials are provided in Exhibit A.4, based on logging of the deeper well pair borehole at each of the five well pair locations. Field photographs of split tube soil samples are provided in Exhibit A.5.

In addition to the boring logs, the on-site field geologist recorded the progress of drilling, testing, and well completion activities using a field logbook and a well drilling and construction activity/progress report obtained from the Y-12 Environmental Compliance Department. The logbook and field forms were used to document the sequential progress of drilling, logging, testing, and well installation activities (e.g., mobilization/setup, initial and changing drilling conditions, subsurface water conditions, sounding of depths during well installation, cuttings/drill fluid disposition, demobilization, etc.). The form was also used to supplement information on the boring log where space was limited. Copies of the completed well activity/progress reports are provided in Exhibit A.6.

In as much as possible, augered cuttings before the first split barrel sample and between additional split barrel samples were evaluated and characterized on field logs. Logging of soils/rock was conducted by a professional geologist registered in Tennessee with experience and familiarity with: drilling and well installation, scientific/industry accepted logging methods, and ASTM methods for subsurface characterization.

### 4.1.4 Intermediate Interval Well Drilling, Sampling, and Logging

For each of the five deeper intermediate interval wells, 10 in. diameter polyvinyl chloride (PVC) casing was first placed across the shallow unconsolidated regolith to isolate the water table interval from deeper ground water zones occurring within fractures of more competent bedrock. Two of the five deeper intermediate zone well pairs (GW-972[I] and GW-976[I]) located within the outcrop belt of the Rutledge Limestone and Maryville Limestone, respectively, were continuously cored through the bedrock interval from auger refusal to depths of 100 ft bgs. Based on boring logs and geological descriptions from other sites in West Bear Creek Valley (WBCV), these formations were reported to include interbeds of limestone and shale. The intent of the continuous rock coring was to obtain more detailed information on the characteristics of these formations, particularly any evidence of dissolution of the limestone beds that might suggest larger aperture fractures or conduits with relatively higher hydraulic conductivity.

The remaining three deeper well pairs (GW-968[I], GW-970[I], and GW-974[I]) located within the outcrop belt of predominantly clastic formations (Pumpkin Valley Shale and Rogersville Shale) were each drilled in bedrock using an air rotary rig from near the auger refusal depth to a total depth of 100 ft bgs. During this air rotary drilling, cuttings were directed to the side of the drilling rig and very generalized logging by the field geologist was recorded on a boring log. Depth occurrences and general rates of ground water production in bedrock were also recorded during drilling, where observed. After removal of the drill string, water levels were monitored periodically within the open bedrock boreholes to

assess recharge, relationships to water levels in adjacent shallow wells, and to ensure saturated conditions were suitable for well installation. Because of the nature and sequencing of the drilling operations, the deeper open uncased boreholes were left open for a period of days until borehole geophysical logging and packer testing were completed.

### 4.1.5 Rock coring Methodology, Logging, and Photography

A double-tube HQ (2.5 in. inner diameter) core size barrel was used to continuously core bedrock at GW-972 and GW-976 after isolation casing was set across the overburden section of each hole. Core drilling, sampling, and logging was conducted according to the following ASTM standard methods: (1) D 2113 *Standard practice for Rock Core Drilling and Sampling of Rock for Site Investigations*, (2) D 5079 *Standard practices for Preserving and Transporting Rock Core Samples*, (3) D 5434 *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*, and (4) D 6032 Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core. The rig geologist followed the requirements for core logging, RQD, core boxing, and other relevant standards defined in Sections III, VII, VIII, IX, and XII of the ASACE Geology Section Field Manual (Nashville Engineer District), and the Alliant SOPs: Regolith and Bedrock Drilling Procedure (AC-4301-001-RBD) and Description of Geologic Materials (AC-4301-001-DGM). Munsell color charts were used to accurately and consistently define rock colors. Dilute hydrochloric acid (10% HCl) was used in the field to confirm and document individual beds of limestone or dolomite in each core run to distinguish between clastic and carbonate beds/lamina.

Core pulls (individual segments of cored intervals) were commonly 5ft in length, but depending on the drilling conditions and the discretion of the driller, shorter intervals were sometimes retrieved. Sturdy wooden core boxes were used for storage of rock cores. Core boxes were labeled and pull blocks were placed between each core run to clearly define each pull, depths, loss, gain, etc. After filling and marking, each core box was digitally photographed with photos of the entire box and additional sequential overlapping close-up photos suitable for a photographic assessment of key core features. Each photo includes a tape measure consistently located adjacent to the length of the box for reference and scale. Higher resolution photographs of the rock core boxes were made using a digital SLR camera. The photographs were made in sequence from top to bottom in overlapping one foot increments under natural light, with closeup photos of selected lithologic/structural features. The high resolution photos were compressed and the lower resolution photos were stitched together to represent each core box for purposes of the Phase I report. However, the high resolution photos are available from DOE upon request.

The core boxes were green tagged and temporarily stored at a climate controlled storage locker to allow for more detailed evaluation and lithologic description. The core boxes were subsequently returned to the proposed EMDF site in late October 2014, placed on wooden pallets, and covered with plastic sheeting. They are currently located near the GW-972(I)/973(S) well pair at the EMDF. The rock cores were made available to TDEC and EPA for their independent evaluation. TDEC/EPA representatives reviewed the cores on October 22, 2014. TDEC representatives also reviewed the cores on February 11, 2015. Photographs of the rock cores with notes and depth indicators highlighting key aspects of the cores are provided in Exhibit A.7. Boring logs based on the rock cores are provided in Exhibit A.4.

### 4.1.6 Borehole and Well Testing

The following additional characterization activities were completed at each well pair location:

- Borehole geophysical logging: conducted in the five deeper bedrock open boreholes to characterize subsurface lithologic, stratigraphic, and hydrogeologic conditions.

- Slug tests to determine hydraulic conductivity (K) of the saturated screened interval in the shallow monitoring wells.
- Packer tests to determine K values for depth discrete bedrock intervals in the deeper boreholes.

Details of the methodologies for these field tests are summarized in the following subsections.

#### 4.1.6.1 Borehole Geophysical Logging

Borehole geophysical logs were run in the uncased open bedrock boreholes at each of the deeper well locations (GW-968, GW-970, GW-972, GW-974, GW-976). The borehole logs included:

- 3-Arm Caliper
- Natural Gamma Ray (NGR)
- Spontaneous Potential (SP)
- Fluid Temperature/Delta Temperature
- Fluid resistivity
- Acoustic televiewer (ATV)/Deviation
- Optical televiewer (OTV)/Deviation
- Heat pulse flowmeter

Within the limitations inherent to borehole geophysical methods, the suite of logs were chosen with the following objectives: (a) identify subsurface stratigraphy/lithology and contacts, (b) identify the nature and density of fractures/fracture zones/intervals, bedding planes, joints, conduits, (c) identify approximate ground water flow intervals, and (d) identify the orientation of fractures/joints/bedding planes/conduits (strike, dip, relative to true/magnetic north).

The geophysical work was subcontracted by Alliant to a geophysicist with URS Corporation with previous experience on the ORR. The results and additional details of the geophysical logging, equipment, etc., are presented below in Section 7.2.5. A separate report of the geophysical logging prepared by URS is provided in Exhibit A.8.

#### 4.1.6.2 Packer Tests

Packer testing was performed within the open uncased boreholes in each of the deeper well pairs (GW-968[I], GW-970[I], GW-972[I], GW-974[I], GW-976[I]) to determine K values within selected bedrock intervals. Rock cores, synoptic water level measurements in the shallow wells and deep boreholes, and results from the borehole geophysical logs were used to identify discrete intervals for packer testing. The Phase I budget was limited to a total of nine tests, and the packer testing interval was set at 10 ft (i.e. the distance between the bottom of the upper packer and the top of the lower packer). In the three borings without rock core data, the intervals were selected based strictly on geophysical features suggesting fractures or other anomalous features that might be indicative of higher permeability. In the two borings with rock core data (GW-972 and GW-976), the intervals were selected based on both rock core and geophysical features. The testing intervals were focused on determining K values for potential fractured zones and not on determining K values for unfractured intervals likely to have very low K values.

Packer tests were performed in accordance with a testing methodology, field forms, protocols, and equipment prescribed in an Alliant SOP (AC-4301-001-SPT – Straddle Packer with Transducers Testing Procedure), and DOE-contract requirements, as part of the Phase I project-specific work plans. This methodology was based on the following standards for packer testing: (a) ASTM D 4630 *Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ*

*Measurements Using the Constant Head Injection Test*, (b) the USACE RTH 381-80 *Suggested Method for In Situ Determination of Rock Mass Permeability Using Water Pressure Tests*, and (c) packer testing methods described in the U. S. Bureau of Reclamation *Earth Manual* (1974). Just before the field testing, the SOP methodology, field forms, and Microsoft Excel™ algorithms were modified slightly to address the use of pressure transducers above, within, and below the isolated packer test interval.

The general testing process for packer testing included the following steps: (1) lowering of the packer testing equipment down to the selected depth interval within the open borehole; (2) inflating the packers to seal off the test interval from intervals above and below the test zone; (3) introducing potable water into the test interval under a constant pressure and measuring the rate of water flow (logging injection flow rates and pressure readings over time). For each test interval, the testing was normally conducted under at least three different increasing test pressures (e.g.,10 lb per square in. [psi], 20 psi, 30 psi), below a maximum calculated injection pressure designed to prevent hydraulic fracturing. During each test, pressure data were recorded electronically using transducers (In-situ® TROLL devices) connected to a laptop computer with In-situ® software, while flow data were recorded manually using field forms/logbooks. Four transducers were employed: one within the packer test interval, one each above and below the upper and lower packers, and one at the surface to measure surface barometric pressures. A Moyno™ pump on the drilling rig was used to inject potable water under controlled flow rates to the isolated packer interval. A conventional in line flow meter with flow rates measured in gallons per minute (gpm) was used to visually monitor and record flow rates. The in line flow meter was incapable of accurate measurements below approximately 0.5 gpm over the typical time scale of the tests. This limited the ability of the packer tests to measure order of magnitude K values at and below $10^{-6}$ centimeters per second (cm/sec). The piping system also included a visible analog pressure gage (in psi) for assessing flow line pressures against pressures measured by the downhole transducers. Field data were entered into Excel™ spreadsheets to calculate K values for each test interval.

The maximum injection pressure (not to be exceeded during packer testing) for each deep well was calculated as the sum of pressures above and below the potentiometric surface; assuming 1 psi/ft of depth from the ground surface to the potentiometric surface depth, plus 0.57 psi/ft of depth from the potentiometric surface to the midpoint of the packer test interval depth (e.g., for a packer test interval from 25 to 35 ft bgs and a potentiometric surface at 10 ft bgs the maximum injection pressure would be 21.4 psi).

The equation used for determining K based on the packer test field data is:

$$\mathbf{K = Q/2\pi LH^{*}\ ln(L/r)\ *\ 0.06797}$$

where:

K = hydraulic conductivity in cm/sec

Q = constant rate of flow into the borehole in gpm

L = length of test section (10 ft in all the EMDF packer tests)

H = total head (in ft) on the test section – based on pressure transducer reading located within packer test interval

ln = natural logarithm

r = radius of borehole (4 in.; 0.33 ft), and

0.06797 is a conversion factor translating field measured units to cm/sec

This equation is applied where $L \geq 10r$. Results of the packer tests are reviewed below in Section 7.2.3.5. Complete documentation for the packer tests is provided in Exhibit A.9.

#### 4.1.6.3 Slug Tests

Slug tests were conducted in each of the shallow wells (except for GW-977[S], which is dry) to determine K values after well installation and development, and after water levels had stabilized to local equilibrium. The tests were conducted by Alliant over a three day period from October 28 to 30, 2014. The test methodology was documented in an Alliant SOP (AC-4301-001-STP – Slug Testing Procedure) as part of the Phase I project-specific work plans. The slug tests were conducted using commercially available pressure transducers (In-situ® TROLL devices; non-vented, using separate barometric TROLL devices) and data loggers with field laptop computer data storage and retrieval capabilities, and recording of rapid water level fluctuations and recovery periods. Alliant used a large diameter solid plastic slug for the tests to induce a rapid and instantaneous water level change up or down for the tests. The pressure transducer sits below the slug during the tests and records the rate of change in the water level in seconds

Determinations of K were made using the commercially available AQTESOLV software (developed by RockWare™) which provides a systematic and consistent process for data plotting, interpretations, and calculation of K values. K values were determined using the method of Bouwer and Rice (1976) and Bouwer (1989). Results of the slug testing are presented in Section 7.2.3.5 below. Slug test data plots, interpretations, calculations, and references are provided in Exhibit A.10.

### 4.1.7 Well Construction and Development

Because all monitoring wells were located within the proposed EMDF footprint, the wells were all completed with PVC casing/screen to facilitate ultimate plugging and abandonment (as opposed to steel commonly used for long-term permanent installations and sampling). The only exception was for stainless steel casing near and above surface at GW-968(I) as described below. Details related to shallow and deep well construction and well development in the shallow wells are reviewed in the following subsections. Table 1 summarizes key boring/monitoring well construction data for the ten Phase I wells. Monitoring well construction diagrams illustrating as-built components for each of the ten Phase I monitoring wells are provided in Exhibit A.11, along with material specification cut sheets used in well construction.

#### 4.1.7.1 Shallow Well (Water Table Interval) Construction

All shallow wells were drilled to and completed at auger refusal depths and constructed of nominal 4 in. diameter ASTM Schedule 40 PVC flush-joint casing and slotted screen (0.010 in. slots). Screen intervals were 10 ft in length, except for two wells (GW-969[S] and GW-975[S]) where depth to auger refusal was so shallow that a shorter 5 ft screen length was required. Shallow wells were completed through the HSA casing with placement of screen and riser followed by careful removal of auger flights as annular materials were placed. The depths of key completed features (i.e., hole bottom, filter pack bottom and top, bentonite seal, and grout depths) were tagged using a weighted tape to ensure accurate depth placement. Measurements were recorded on field forms and in field logbooks to document field quality control.

Artesian ground water flow overflowing the top of the well casing at GW-969(S) was first observed on December 31, 2015. DOE was immediately notified of the need to extend the existing riser pipe and the top of casing (TOC) to contain the overflow in order to provide accurate continuous water level data using the downhole instruments (In-situ® TROLL devices). Continuous water level monitoring data subsequently provided by Alliant, indicated that GW-969(S) had begun overflowing the TOC elevation (1,072.98 ft) on December 24, 2014. Alliant/M&W installed an additional 10 ft of PVC riser pipe to the existing TOC on February 11, 2015, extending the new TOC elevation to 1,082.98 ft (extending the original stick up of 2.31 ft above the ground surface to12.31ft). The PVC casing was installed in 2.5 ft sections such that upper sections could be removed as appropriate, depending on the most likely seasonal maximum water levels.

**Table 1. Boring/Monitoring Well Construction Data**

| Well Number | Geologic Formation | Estimated Natural Pre-Ph I Surface Elevation[1] | Surveyed Elevation TOC[2] | Surveyed Elevation Top Concrete Well Pad | Surveyed Elevation Top of Ground Surface | Well Casing Stickup | Estimated Topsoil Removed | Auger Refusal Depth (ft bgs) | Bedrock Isolation casing depth [see note for GW-974] (ft bgs)[3] | Difference between isolation Casing and AR Depths | Length Rock Cored Bedrock Interval (ft) | Maximum Total Drilling Depth (ft bgs) | Latest Final Total Depth Measurement in Deep Open Holes | Length of Borehole Bottom Collapse (ft) | Screened or Open Hole Interval (ft bgs) | | Screen or Open Hole Length (ft) | Filter Pack Interval (ft bgs) | | Filter Pack Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Top | Bottom | | Top | Bottom | |
| GW-968(I) | Cpv | 1077.4 | 1082.56 | 1070.39 | 1070.21 | 12.35 | 7.19 | 10.0 | 10.0 | 0.0 | No rock coring - air rotary drilling in BR | 100.0 | 92.6 | 7.4 | 12.7 | 82.7 | 70.0 | 9.0 | 92.7 | 83.7 |
| GW-969(S) | Cpv | 1075.1 | 1082.98 | 1070.67 | 1070.45 | 12.53 | 4.65 | 13.5 | NA | NA | NA | 13.5 | NA | NA | 8.4 | 13.4 | 5.0 | 5.5 | 13.5 | 8.0 |
| GW-970(I) | Cpv | 1045.3 | 1043.17 | 1041.20 | 1040.93 | 2.24 | 4.37 | 25.6 | 34.1 | 8.5 | No rock coring - air rotary drilling in BR | 101.0 | 97.4 | 3.6 | 34.1 | 97.4 | 63.3 | NA | NA | NA |
| GW-971(S) | Cpv | 1045 | 1043.11 | 1040.81 | 1040.69 | 2.42 | 4.31 | 23.8 | NA | NA | NA | 23.8 | NA | NA | 13.2 | 23.2 | 10.0 | 11.9 | 23.8 | 11.9 |
| GW-972(I) | Crt | 1022.4 | 1026.20 | 1023.75 | 1023.55 | 2.65 | -1.15 | 24.2 | 23.8 | -0.4 | 75.9 | 101.0 | 99.6 | 1.4 | 23.8 | 99.6 | 75.9 | NA | NA | NA |
| GW-973(S) | Crt | 1025 | 1026.96 | 1024.68 | 1024.46 | 2.50 | 0.54 | 23.0 | NA | NA | NA | 23.0 | NA | NA | 12.9 | 22.9 | 10.0 | 10.3 | 23.0 | 12.7 |
| GW-974(I) | Crg | 1003.1 | 1005.38 | 1003.19 | 1002.80 | 2.58 | 0.3 | 12.5 | 10" csg @ 0-12.5'; 8" csg @ 0-15.0' | 2.5 | No rock coring - air rotary drilling in BR | 101.0 | 97.9 | 3.1 | 15.0 | 97.9 | 82.9 | NA | NA | NA |
| GW-975(S) | Crg | 1003.3 | 1005.16 | 1003.01 | 1002.52 | 2.64 | 0.78 | 10.0 | NA | NA | NA | 10.0 | NA | NA | 4.9 | 9.9 | 5.0 | 3.9 | 10 | 6.1 |
| GW-976(I) | Cm | 1067.5 | 1068.41 | 1066.15 | 1065.84 | 2.57 | 1.66 | 24.4 | 27.8 | 3.4 | 71.8 | 101.0 | 100.3 | 0.7 | 27.8 | 100.3 | 72.6 | NA | NA | NA |
| GW-977(S) | Cm | 1067.5 | 1068.17 | 1065.84 | 1065.63 | 2.54 | 1.87 | 25.1 | NA | NA | NA | 25.1 | NA | NA | 15.0 | 25.0 | 10.0 | 12.1 | 25.1 | 13.0 |

Notes and Abbreviations:

[1] Estimated natural pre-Phase I surface elevations are based on the BWSC surveyed well locations and the current surface topographic contour map for the EMDF site utilized in AutoCad for the conceptual design (5ft contour intervals).

[2] Artesian flow in wells GW-968(I) and GW-969(S) resulted in extensions to the original TOC elevations. The original professionally surveyed TOC Elevation at GW-968(I) was 1072.52; a 5ft SS 4 in. diameter casing extension was added on 12/23/14 making the new TOC elevation 1077.52; an additional 5.04 ft SS casing extension was added on 2/9/15 making the final TOC elevation 1082.56.

[2] The original professionally surveyed TOC Elevation at GW-969(S) was 1072.98; a 10ft 4 in. diameter PVC casing extension was added on 2/11/15 making the new TOC elevation 1082.98

[3] Original 10 in. PVC isolation casing at GW-974 was retrofitted with 8 in. diameter PVC casing grouted inside the 10 in. casing after driller broke shallow portion of 10 in. surface casing.

- All deep boreholes drilled w/ air rotary 8" diam hole (for GW-972/976 after rock cores acquired).
- GW-974(I) - specific total depth of 10 in. PVC isolation casing apparently not recorded - assumed to be at 12.5 ft bgs.
- Isolation casing was set in three of the five deep wells at auger refusal depth.

| | | | |
|---|---|---|---|
| AR | auger refusal | NA | not applicable |
| bgs | below ground surface | PVC | polyvinyl chloride |
| BR | bedrock | SS | stainless steel |
| Csg | casing | TOC | top of casing (inner casing of riser pipe) |
| ft | feet | | |

This page intentionally left blank.

#### 4.1.7.2 Deep Well (Intermediate Ground Water Interval) Construction

Except for GW-968(I), each of the deep wells was completed as an open hole from the depth of the 10 in. diameter PVC isolation casing to the approximately 100 ft total depth of each deep well (natural borehole collapse in each of the five deep boreholes ranged from 0.7–7.4 ft bgs, see Table 1). 10 in. diameter Schedule 40 PVC casing was placed from the ground surface to depths at or near auger refusal in each of the five deep wells. This isolation casing was seated and sealed with pressure grouting methods to variable depths in each well ranging between 0 and 8 ft into the top of bedrock. The objective of this casing is to isolate the shallow ground water associated with the water table interval within the relatively unconsolidated surficial materials (regolith), from the deeper intermediate interval of the saturated zone located within fractured, less weathered or unweathered bedrock.

An exception to the 10 in. diameter isolation casing exists at GW-974(I) where an 8 in. diameter casing was seated just below and grouted inside of the original 10 in. diameter casing. A skid steer accident resulted in a break in the upper part of the 10 in. PVC isolation casing. This warranted the placement of an inner 8 in. isolation casing before drilling of the deep open borehole section of bedrock. The DOE contract for the Phase I work included an option for completing the deep wells with screen and casing over discrete intervals. However, the results from the limited number of packer tests and geophysical logs were insufficient to clearly identify depth discrete intervals yielding ground water to the deeper open boreholes within wells GW-972(I) and GW-974 (I). The relatively rapid response of water levels in the shallow/deep well pairs at these two locations with respect to a heavy rainfall event in mid October 2014, indicated that ground water was recharging the bedrock interval over a fairly short timeframe. Completing these open holes by isolating a particular screen interval of 10–20 ft might result in inadvertent isolation of fractures yielding water to these deep wells. Therefore, the decision was made to leave the deep wells with open hole (uncased) intervals so that further testing could be made during a Phase II effort if desired (an exception was made for GW-968[I] as described below). With additional testing to clearly identify water producing depth intervals, the deep open hole wells could be completed within relatively common depth intervals relative to the water table intervals at each well pair. Consideration could also be given to completing the open holes as nested piezometers to evaluate permeability differences, vertical gradients, and variations in pressure heads between the depth discrete, vertically separated, completed intervals.

Rationale for completing GW-968(I) with conventional well screen and riser pipe was provided to DOE by Alliant/M&W and was primarily based on concerns relating to the potential for artesian water flow to freeze and break PVC casing near and above the ground surface during cold winter months. To prevent this occurrence, Alliant/M&W proposed completing the open hole interval with 4 in. diameter PVC well screen and riser pipe extending up through the 10 in. isolation casing, and topped with stainless steel casing near the surface where freezing might occur. The completion also included conventional filter pack sand around the screen interval with a bentonite plug and overlying grout to a depth near ground surface.

At GW-968(I), 70 ft of 4 in. diameter PVC slotted screen (0.01 in. slot size) was set from 12.7–82.7 ft bgs within the open hole interval and surrounded with filter pack sand from 9–92.7 ft bgs (a total of 83.7 ft of filter pack). Between drilling the original 100 ft deep borehole on September 10, 2014, and the time of this final well completion on November 3, 2014, the lower 7.4 ft of the borehole had collapsed so that the bottom of the casing was placed at 92.7 ft bgs. Centralizers were used in GW-968 (at depths of 27.5, 57.5, and 87.5 ft bgs to maintain the screen and riser in the center of the borehole.

The 10 in. diameter isolation casing for GW-968(I) was grouted in place at 10.0 ft bgs (at auger refusal) on September 8, 2014. The stickup on the 10 in. casing at that time was about 0.41 ft above ground surface. The bedrock interval was subsequently drilled from 10 to 100 ft bgs on September 10, 2014. On September 22, 2014, ground water was observed overflowing the top of the 10 in. diameter isolation casing. Subsequent intermittent water level measurements made at GW-968(I) during October and November 2014 indicated that ground water was either very close to or overflowing the top of the

casing.In late November 2014, after the completion of GW-968(I) with screen and riser pipe and a surface stick up, ground water was observed overflowing the top of the 4 in. inner casing (at 2.31 ft above ground surface). DOE was notified of the need to extend the surface casing to capture the static water level (SWL), and on December 23, 2014, an additional 5ft extension of stainless steel riser pipe was added by M&W to the original stick up, extending the overall top of the inner casing to a height of 7.31 ft above ground surface (based on the surveyed ground surface elevation and TOC elevations made by BWSC). Continuous monitoring at the EMDF began officially on December 1, 2014. After the extension of the casing to the 7.31 ft height continuous monitoring data indicated water levels rising to within a few inches of the new TOC elevation at 1,077.52 ft. DOE subsequently directed Alliant to extend the casing even higher to avoid potential future overflows. Alliant added 5.04 ft of additional stainless steel casing on February 9, 2015, extending the new final TOC height to 12.35 ft above ground surface (1,082.56 ft elevation).

#### 4.1.7.3 Well Surface Completions

Each of the shallow and deep wells were completed at the surface with a 4 ft × 4 ft concrete pad sloped to drain and a metal outer protective surface casing with locking cover. The outer protective casing was cemented into the concrete pad with approximately 3 ft of stickup above the ground surface and 2 ft embedded in the ground. A 1/8 in. to 1/4 in. weep hole was drilled into the annulus of the protective casing just above the level of concrete inside the casing. A vented cap was installed on the riser pipe inside the protective casing. Keyed alike locks were placed on each well with keys provided to DOE. The well clusters are all located within the DOE/Y-12 property protected fence (229 fence) with restricted public access. Each well is located within the landfill footprint but would be ultimately plugged and abandoned before landfill construction. Therefore no bollards were installed. Each well was marked with an identification number using a printed metal tag screwed into to the side of the outer metal protective casing, with an equivalent metal tag on top of the well cap/cover.

#### 4.1.7.4 Well Development

Each of the shallow wells and GW-968(I) were developed by surging, bailing, and/or pumping to settle the filter pack and remove fine materials prior to slug testing and installation of continuous monitors. A 4 in. diameter bailer was used to surge the well and a mini-purger Whale® pump was used to remove surged water. Turbidity and other water quality parameters were monitored and documented on well development logs. A minimum of 3–5 well volumes were removed. The development procedures were repeated until sediment-free low turbidity water was produced. In instances where relatively clear water could not be produced conditions were documented with rationale for ceasing development. A summary of development for the Phase I wells is provided in Table 2. Detailed well development logs are provided in Exhibit A.12.

Because the wells are located in historically undisturbed non industrial areas and far upgradient of any subsurface source areas and ground water contaminant plumes, soil and water were assumed to be uncontaminated. In addition, soils were screened in the field for radiological and VOC contamination. Equipment and materials that came in contact with site soils were field screened and smear samples were collected and submitted to ORAU for detection of radiological contamination. No radiological activity in site soils or on equipment and materials used in site activities at the EMDF was detected above background by field screening or laboratory testing. Nevertheless, the water was screened for contamination as done for subsurface soils. Because the screening did not detect any radiological contamination, the well development water was assumed to be uncontaminated (as was water used for cleaning drilling rigs, equipment, etc.). The well development water was contained and solids were allowed to settle out before release to the environment. Clear settled waters were discharged on site.

**Table 2. Well Development Summary**

| Well | Development Dates | Total Volume Removed (gallons) | Max Water Level Drawdown (ft BTOC) | Total Depth of Well BTOC | TOC Elevation (at that time) | Max Water Level Drawdown Elevation |
|---|---|---|---|---|---|---|
| GW-968(I) | 11/5/2014 | 370 | 84.7 | 95.2 | 1072.52 | 987.82 |
| GW-969(S) | 9/30/2014; 10/1/14; 10/7/14 | 34; from three separate days | Pumped dry each event | 13.5 | 1072.98 | 1059.48 |
| GW-971(S) | 9/22/2014; 9/29/14; 9/30/14 | 35.5; from three separate days | Pumped dry each event | 23.3 | 1043.11 | 1019.81 |
| GW-973(S) | 9/30/2014; 10/1/14; 10/2/14 | 63; from three separate days | Pumped dry each event | 23 | 1026.96 | 1003.96 |
| GW-975(S) | 11/5/2014 | 5.5; from three separate days | Pumped/bailed dry each event | 12.32 | 1005.16 | 992.84 |
| GW-977(S) | 9/30/2014; 10/2/14; 10/6/14 | DRY | NA | 27.42 | 1068.17 | NA |

Notes and abbreviations:

- GW-968(I) is the only deep (intermediate ground water level) boring that was completed with screen/riser pipe within the bedrock interval; all other "deep" wells were completed as open holes and were therefore not developed.
- GW-977(S) is dry; water table is roughly 20 ft or more below the elevation of the bottom of the well at 1,040.75; it is unlikely that this well will ever penetrate the saturated zone.

BTOC below top of casing
TOC top of casing

## 4.2 SURFACE WATER AND GROUND WATER MONITORING

One of the primary objectives of the limited Phase I characterization was to monitor variations in stream, spring, and seep flow, ground water level fluctuations, and basic water quality parameters at the proposed EMDF site over a period of one year or more. The data would be used to assess seasonal/temporal variations and to correlate those data with meteorological data collected at the adjacent EMWMF and the Y-12 west tower meteorological station. The data would provide baseline environmental data needed for landfill design and satisfy regulatory requirements and guidance.

Instrumentation and data loggers were placed in each of the ten monitoring wells and at three surface water stream gage locations to provide continuous data for evaluating temporal and spatial relationships between stream discharge rates, ground water level fluctuations, precipitation, and key elements of the proposed conceptual design (e.g., the physical relationships between surface and ground water level fluctuations and key elements of the conceptual design such as the base of the geologic buffer and underdrain system). Although the Phase I data currently includes only about three months of data, DOE currently plans to continue the Phase I monitoring program through at least the end of FY 2015. The monitoring period could be extended for a longer timeframe if the TDEC and EPA concur with the selection of the proposed EMDF site for CERCLA waste disposal.

The Phase I surface and ground water monitoring provides initial baseline data for assessing spatial and temporal relationships between surface water runoff, relatively rapid shallow subsurface stormflow zone discharge to streams, and relatively slower ground water discharge to surface streams, springs, and seeps.

Surface water data from previous investigations (USGS 1994a and b, and BJC 1999) and recent field observations along the NT tributaries at and near the EMDF indicate that baseflow along the NT streams varies considerably between the wetter and colder Winter/Spring nongrowing season, and the drier and warmer growing season of late Spring, Summer, and early Fall. During the wetter, cooler, nongrowing season, base flow along the NT streams is typically continuous downstream from headwater springs and flow rates are much higher than during the drier, warmer, growing season when flow is much lower and may be intermittent during the late Summer and early Fall when rainfall is often minimal.

The Phase I monitoring will more accurately define these seasonal changes in stream baseflow and the range of variations for peak flow and baseflow. Depending on seasonal conditions, sections of the NT-2 and NT-3 tributaries may be gaining baseflow from ground water discharge, or losing surface water to the shallow water table. The Phase I monitoring data also provides baseline data for ground water conditions at the EMDF site. Ground water and stream flow conditions are fundamentally important to the design of the proposed underdrain system for the EMDF, and to a design that ensures waste materials remain sufficiently elevated above the water table over the long-term time span of the proposed disposal facility. If the EMDF site is approved, additional characterization would be performed in a Phase II field investigation with data quality objectives to support detailed landfill design.

### 4.2.1 Surface Water Monitoring

The Phase I surface water monitoring program included two main components: (1) continuous surface water monitoring at three stream gage locations along tributaries of NT-3, and (2) weekly monitoring of six locations upstream from the stream gage locations (see the nine surface water monitoring locations in Figure 1). The weekly monitoring locations included the three headwater spring locations where the NT-2 and NT-3 tributary stream flows originate, and three stream flow monitoring stations at locations between the headwater springs and the stream gage locations. Details of the monitoring program are reviewed in the following subsections.

#### 4.2.1.1 Stream Gage Design, Installation, Instrumentation, and Monitoring

During November 2014, Alliant installed three flume gage monitoring stations to characterize tributary flows draining the uppermost reaches of the NT-3 watershed, including roughly two thirds of the EMDF footprint. The three locations are identified as: EMDNT3-SWG1 (East Branch NT-3), EMDNT3-SWG2 (Middle Branch NT-3), and EMDNT3-SWG3 (West Branch NT-3).

The basic specifications for each stream gage monitoring location included:

- A cutthroat flume with built-in stilling well for continuous water level monitoring (for conversion to flow rate/discharge).
- A staff gage with graduated markings in 0.1 ft increments.
- A separate stilling well for continuous monitoring of temperature, pH, specific conductivity, and oxidation/reduction potential (ORP).

Details of the flume design, installation, instrumentation, and monitoring are addressed in the following subsections.

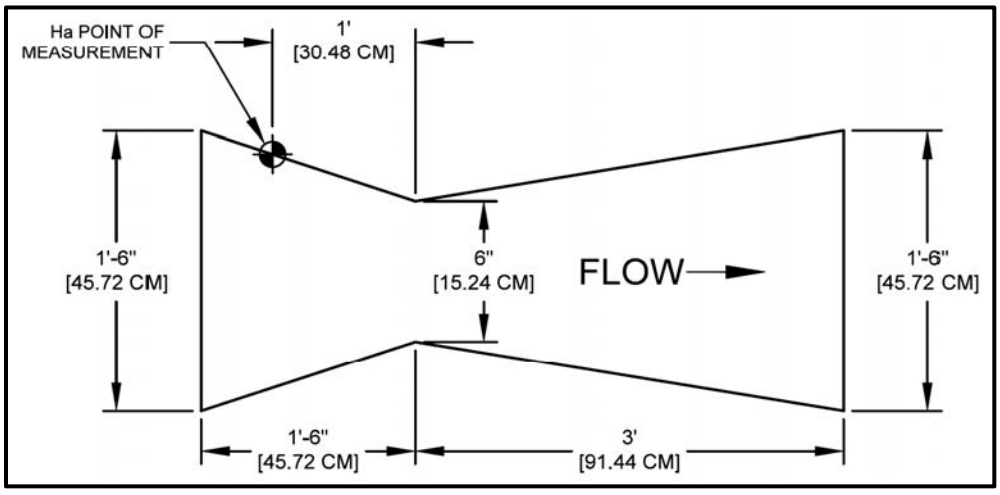
**Flume Design and Installation**

The intent of surface water flow monitoring is to provide data to support design of the EMDF underdrain and surface water control systems. Measurements of the upper flow ranges (peak flows) were deemed more critical to design, and the flumes were sized accordingly. The cutthroat flumes were designed based in part upon precipitation and streamflow data collected from a number of locations along the middle to upper reaches of NT-4 and one location along NT-3 near the center of the EMDF footprint (BJC 1999,

Appendix G). These data were collected over a one year period prior to the construction of the EMWMF, although instrument failure limited the data at some gaging locations. Alliant purchased the flumes from a commercial vendor (OpenChannelFlow®) from a range of available sizes. Based on the smaller channel width and estimated watershed for the middle NT-3 tributary, a smaller flume was selected for the EMDNT3-SWG2 location (see Figure 3) relative to the other two monitoring stations. The larger channel widths and estimated watershed areas for the NT-3 east and west tributaries warranted the use of a larger flume to capture anticipated peak flow discharge at the EMDNT3-SWG1 and EMDNT3-SWG3 locations (see Figure 4). The flumes are rectangular (not trapezoidal) in cross section with flat bottoms placed perfectly level within the existing stream channels along relatively straight stream segments with relatively low natural gradients.

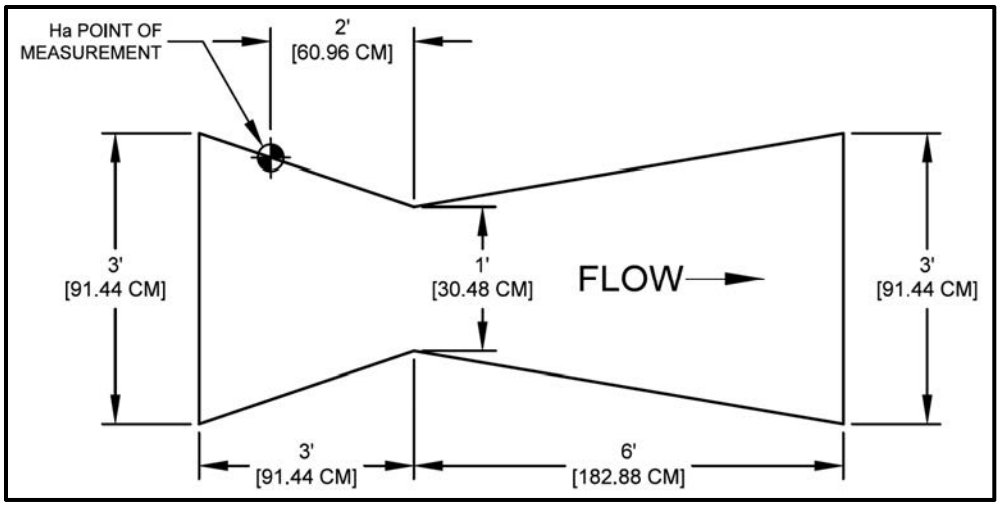
The flumes are constructed of fiberglass with a built-in stilling well that extends about 3 in. below the base of the flume. The stilling well is a cylindrical sump located along the side wall of the flume connected at its base to the water in the flume channel. The stilling well provided the measurement point where a pressure transducer was placed to continuously record water level data. A separate stilling well constructed of 4 in. diameter perforated PVC pipe was placed vertically within the upstream pool at each flume to provide a stable location for continuous recording of water quality data via a separate instrument probe. The photographs in Figure 5 show the typical stream gage monitoring system at the EMDNT3-SWG1 location along the largest main tributary of NT-3 crossing the EMDF site (see location in Figure 1).

A flat staff gage with graduations in tenths of feet was installed on the inner face of the flume wall adjacent to the built-in stilling well for weekly visual monitoring, recordkeeping, and calibration of observed measured water levels to those measured electronically. Measurement point locations were professionally surveyed at each flume to relate water levels/flow rates to topographical elevations. Locations were surveyed to the nearest 0.1 ft horizontally and 0.01 ft vertically. Additional requirements and guidelines for the proper installation of the flumes were defined in the Alliant SOP Flume and Weir Installation Procedure (AC-4301-001-FIP).




(Height is 1.5 ft)

**Figure 3. Cutthroat Flume Dimensions for Flume at EMDNT3-SWG2**




(Height is 3.0 ft)

**Figure 4. Cutthroat Flume Dimensions for Flumes at EMDNT3-SWG1 and EMDNT3-SWG3**

The water level data measured continuously by the data loggers are converted to discharge values in cubic ft per second (cfs) or gpm using discharge rating tables and equations provided in Exhibit A.13. The manufacturer recommendations were followed for the proper placement and orientation of the flume within existing channels, and the maintenance and monitoring of the flumes after installation.

(See Figure 1 for location)

**Figure 5. One of the Three Continuous Stream Monitoring Systems Installed on the Main Tributary of NT-3 at the EMDNT3-SWG1 Location**

Wing walls constructed of several concrete bags anchored with rebar were placed along the upstream sides of the flumes to prevent the bypass of water around the outside of the flumes during high intensity/duration runoff events. It should be noted that the height of the wing walls dictates the maximum flow of water through the flume and therefore the maximum value of peak flow that can be calculated based on discharge rating tables. The lowest approximate levels along or upstream beyond the wing walls

where high water could wrap around or overflow low points along the wing walls at each flume were estimated by Pro2Serve using a hand held Leica laser Disto™ D3. The lowest points were leveled back to the staff gage on the flume at the stilling well. The minimum and maximum measurable discharge levels and flow rates at each flume are shown in Table 3.

**Instrumentation**

Each surface water monitoring station was equipped with two instruments: (1) a multi-parameter data logging instrument for water quality parameters (YSI® 600XLM – 1.7 OD × 18 in.), and (2) a data logger for monitoring of water levels (In-Situ® Level TROLL 700) and temperature. The TROLL device was placed in the stilling well in the flume body, and the YSI® device was placed in a separate stilling well just upstream of the flume. Data were recorded and stored automatically at 20 minute intervals. The stilling wells located upstream of each flume were constructed of 4 in. diameter PVC with pre-drilled holes along an approximately 4 in. vertical spacing. The open bottom of the stilling well was placed about 8–10 in. below the base of the stream channel on top of a thin layer of gravel fill so that stream channel water infiltrates through the base of the stilling well in addition to entering through the vertically spaced holes. The YSI sonde was placed at the base of the stilling well to ensure the water quality probes remained submerged.

**Monitoring**

The weekly monitoring practices at the gaging stations include: (1) data download to a laptop computer with subsequent conversions of water level data to discharge rates; (2) physical inspections and cleaning of the flume and nearby stream channels to monitor and amend any anomalous conditions that would negatively impact the consistency and completeness of monitoring data; (3) instrument inspections, cleaning, and calibration checks, and (4) field log form/logbook and photo documentation. Monitoring results were documented in field forms completed by field technicians for each weekly visit with notes on general daily activities documented in a bound field logbook. Calibration checks made concurrent with the weekly measurements were documented on a separate calibration log.

Systematic instrument calibrations for the YSI water quality instruments were made every four weeks. These monthly calibration events included the removal of the YSI sonde and immersion of the sonde in calibration fluid standards for each water quality parameter. The calibration process was conducted according to YSI protocols using a hand-held unit and YSI calibration software that determines whether or not sensors are within appropriate calibration ranges. Sensors failing the calibration tests were replaced with new sensors and the sonde was replaced at its former location in the stilling well, or in the case of the monitoring wells, at the previous depth within the well. The field forms include notes on any significant changes or anomalous conditions observed during each weekly visit. Photographs were also taken during the weekly events from a marked surveyed location for consistency. Additional details of monitoring practices were defined in the Alliant SOP *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM). Practices and procedures for stream discharge measurements for the flumes were defined in the Alliant SOP *Stream Discharge Measurement Methods* (AC-4301-001-SDM), and subsequent updated discharge rating tables for the larger flumes installed at the EMDNT3-SWG1 and EMDNT3-SWG3 locations.

Alliant documentation of weekly data downloads, equipment checks, cleaning, and periodic calibration events for the continuous monitoring is provided in Exhibit A.14. This documentation includes weekly monitoring equipment status/data sheets and checklists, but does not include the raw or processed data files from the continuous monitoring equipment. The processed data are presented in subsequent sections of this report as plots of flow and water quality data over the initial three month Phase I monitoring period. The raw instrument and processed data files are extensive and therefore are not included as attachments to the Phase I report.

**Table 3. Measurable Flow Ranges for Phase I Flumes Installed at the EMDF**

| Flume ID/Location | Cutthroat Flume Size | Lowest Measurable Discharge Rate (Based on Discharge Rating Table) | | | Highest Measurable Discharge Rate (Based on Lowest Point Along Upstream Wing Wall or Ground Surface at each Flume) | | | Discharge Formula |
|---|---|---|---|---|---|---|---|---|
| | | Water Height above Flume Base (ft) | CFS | GPM | Water Height above Flume Base (ft)* | CFS | GPM | |
| EMDNT3-SWG1 | 108 in. L × 12 in. W | 0.10 | 0.0964 | 43.26 | 1.73 | 8.230 | 3694 | $CFS = 3.50\ H_{ft}^{1.56}$ |
| EMDNT3-SWG2 | 54 in. L × 6 in. W | 0.10 | 0.0373 | 16.76 | 0.54 | 0.6792 | 304.8 | $CFS = 1.96\ H_{ft}^{1.72}$ |
| EMDNT3-SWG3 | 108 in. L × 12 in. W | 0.10 | 0.0964 | 43.26 | 1.96 | 10.00 | 4488 | $CFS = 3.50\ H_{ft}^{1.56}$ |

Notes and Abbreviations:

* Height of wing walls were not professionally surveyed but estimated based on using a hand held Laser Disto D3 instrument as a level tool; heights are therefore estimated to be ± 0.1-0.3 ft.

- OpenChannelFlow™ discharge rating tables for the installed flumes indicate that water level discharge rates between 0.01 and 0.10 ft above flume base cannot be accurately determined because of "excessive error due to fluid-flow properties and boundary conditions."

CFS cubic feet per second
ft feet
GPM gallons per minute
H height of water in flume above base level in feet
ID identification number

#### 4.2.1.2 Surface Water Observational Monitoring

In addition to the three stream gaging stations, six other surface water locations within and near the EMDF footprint were monitored on a weekly basis without dedicated instrumentation. The weekly observational monitoring locations included:

- EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2: Three springs each located at the head of separate NT-2 and NT-3 tributaries represent the most upstream locations of seasonal stream flow. Each spring is located near the base of ravines that cut into the steep lower south facing slopes of Pine Ridge.
- EMDNT3-ST1, EMDNT3-ST2, and EMDNT3-ST3: These stream channel locations were selected to provide intermediate measurements of flow rates and water quality along the eastern (main) and western branches of NT-3.

The surveyed observational monitoring locations are shown on Figure 1 (Note the SP designation indicates spring locations and the ST designation indicates stream channel locations). The EMDNT3-ST1 location is just below a seepage/wetlands area centered about 150 ft downstream from the EMDNT3-SP1 headwater spring location. The EMDNT3-ST2 location is below a seepage area designated as EMDNT3-SE1 that coalesces into a channel that drains into the west channel of NT-3. The EMDNT3-ST2 location was placed about 10 feet upstream of the junction of the west NT-3 channel with the smaller channel draining from the EMDNT3-SE1 seepage area.

The EMDNT3-ST3 location was selected near the upstream end of a 12 in. diameter (HDPE) culvert below a gravel access road over the west NT-3 channel. The EMDNT3-ST3 location is approximately halfway between the EMDNT3-SWG3 flume location and the headwater spring at EMDNT3-SP2.

One foot tall staff gages attached to wooden stakes were placed at each of the observational monitoring locations and those locations were accurately surveyed by BWSC (see staff gages in photos of Figure 6 at two of the headwater springs for NT-3). The three headwater springs are small ground water discharge areas no more than 1–3 $ft^2$ in diameter. The absence of distinct stream channels above these spring locations suggest that ground water discharge and surface water flow generally does not occur above these points. The stream channels at the other three observational locations are relatively small with base level flows that are typically just a few inches deep and channels that are less than 1–2 ft wide.

The minimum requirements for the weekly observational monitoring at each of the six locations included:

- Estimate flow rates and measure representative water quality parameters (temperature, pH, conductivity, turbidity, and ORP) from a consistent, marked location.
- Record field observations and data.
- Photograph conditions during each site visit.

**Spring EMDNT3-SP1**

**Spring EMDNT3-SP2**

Surveyed staff gages mark the locations of each spring – white vertical bars in each photo.

**Figure 6. Photos of Two of the Six Observational Monitoring Locations at Springs EMDNT3-SP1 and at EMDNT3-SP2**

The water quality parameters noted above were measured weekly using a portable hand-held unit (Horiba U-50 multi-parameter water quality meter) and documented on a field form for consistency and completeness. Calibration checks made concurrent with the weekly measurements were documented on a separate calibration log. The field forms include notes on any significant changes or anomalous conditions observed during each weekly visit. The photographs were taken from a marked surveyed location for consistency. Additional details of monitoring practices were defined in the Alliant SOP *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM).

Concurrent with the weekly water quality measurements, surface water flow measurements were made at each observational monitoring location. Alliant used two possible methods for measuring stream flow depending on site conditions at the observational monitoring locations. One method involved using a Flo-mate electronic flow meter to determine an average velocity across a measured cross sectional area (where flow rate is calculated as the average velocity times the cross sectional area of the stream channel). A second method involved a simple measurement of the time required to fill a container of known volume. The field measurements and methodology employed were documented on standardized field forms. Additional details of practices and procedures for stream discharge measurements were defined in the Alliant SOP *Stream Discharge Measurement Methods* (AC-4301-001-SDM). Documentation of the weekly observational monitoring is provided in Exhibit A.15.

Near the onset of the Phase I field work, road construction began for the new Uranium Processing Facility (UPF) haul road that extends the existing haul road (located immediately south of the EMDF) further to the east into the Y-12 Plant. Former wetland areas along the southeast side of the EMDF footprint, that included seep, spring, and streamflow channels were destroyed and reworked during the UPF road construction and wetlands mitigation process. Seep, spring, and stream channel flow measurement locations in these areas that were previously identified by the U.S. Geological Survey (USGS) in 1994 were destroyed during the construction and wetland mitigation work (USGS locations 1090, 1095, 1100, 1110, 1125; see USGS 1995/1996). These low elevation areas along the southeast flank of the proposed EMDF footprint are significant in relation to shallow ground water discharge and segments of the proposed underdrain system. The underdrain system proposed for these tributary valleys that intersect the EMDF footprint would dewater the shallow subsurface water table interval and lower the water table in these areas. Phase II field investigations are recommended to further evaluate subsurface conditions

associated with these areas of natural ground water discharge and properly design underdrain systems there.

### 4.2.2 Ground Water Monitoring

Instrumentation and monitoring requirements for ground water levels and water quality parameters in each of the monitoring wells were identical to those for the Phase I surface water gaging stations, with the following exceptions. Turbidity was excluded as a measured water quality parameter in ground water. In the absence of well pumping (which may dramatically increase turbidity levels), the relatively slow fluctuations in water levels and the natural filtration effects of subsurface formations and filter packs typically result in ground water with very low turbidity. The other exception was GW-977(S) which does not intersect the water table. Each of the shallow wells was drilled through shallow soils and weathered bedrock (saprolite) to auger refusal, with screened intervals placed atop the auger refusal depth. GW-977(S) is the only shallow well that experienced dry conditions above the water table; therefore no instrumentation was installed (although weekly monitoring was conducted to evaluate the possible occurrence of any rise of the water table into the well).

The same In-Situ® Level TROLL 700 and YSI 600XLM multi-parameter data logging instruments used at the flumes were placed in each of the monitoring wells to document variations in ground water levels and water quality parameters at one hour increments. The requirements for weekly ground water monitoring and documentation were identical to those described above for the gaging stations, except that inspections and cleaning requirements were limited because of the protected and more stable conditions offered by the inner casing and protective casings. In addition, photo documentation was also not warranted. Additional details of the ground water monitoring practices were defined in the Alliant SOP *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM). Table 4 provides a summary of instrument depth placements in each well relative to ground surface and the regolith/bedrock interface. Table 4 reflects instrument depths as of March 4, 2015. Previous depth locations are summarized in the notes following the table. Adjustments were made periodically by Alliant to account for adjustments in surface casing stick ups and to ensure data quality.

Records of Alliant weekly downloads, equipment checks, and periodic calibration events for the continuous ground water monitoring are provided in Exhibit A.14. This documentation includes weekly monitoring equipment status/data sheets and checklists, but does not include the raw or processed data files from the continuous monitoring equipment. The processed data are presented in subsequent sections of this report as plots of water level fluctuations and ground water quality data over the initial three month Phase I monitoring period. The raw instrument and processed data files are extensive and therefore are not included as attachments to the Phase I report.

**Table 4. Final Monitoring Instrument Placement in Phase I Wells (as of March 9, 2015)**

| Well ID | Surveyed Elevation TOC | Surveyed Elevation Top of ground surface | Well casing stickup above ground surface | Auger Refusal Depth or Regolith Thickness (ft bgs) | Troll Depth (BTOC) | Troll Elevation | YSI Depth (BTOC) | YSI Elevation | Difference YSI to Troll Depths (ft) | Screen or Open Hole Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| GW-968(I) | 1082.56 | 1070.21 | 12.35 | 10.0 | 35.0 | 1047.6 | 30.0 | 1052.6 | 5.0 | 70.0 |
| GW-969(S) | 1082.98 | 1070.45 | 12.53 | 13.5 | 25.0 | 1058.0 | 25.0 | 1058.0 | 0.0 | 5.0 |
| | | | | | | | | | | |
| GW-970(I) | 1043.17 | 1040.93 | 2.24 | 25.6 | 55 | 988.2 | 40 | 1003.2 | 15.0 | 63.3 |
| GW-971(S) | 1043.11 | 1040.69 | 2.42 | 23.8 | 25.0 | 1018.1 | 25.0 | 1018.1 | 0.0 | 10.0 |
| | | | | | | | | | | |
| GW-972(I) | 1026.20 | 1023.55 | 2.65 | 24.2 | 32.3 | 993.9 | 29.8 | 996.4 | 2.5 | 75.9 |
| GW-973(S) | 1026.96 | 1024.46 | 2.50 | 23.0 | 24.5 | 1002.5 | 24.5 | 1002.5 | 0.0 | 10.0 |
| | | | | | | | | | | |
| GW-974(I) | 1005.38 | 1002.80 | 2.58 | 12.5 | 20.5 | 984.9 | 19.0 | 986.4 | 1.5 | 82.9 |
| GW-975(S) | 1005.16 | 1002.52 | 2.64 | 10.0 | 11.0 | 994.2 | 11.0 | 994.2 | 0.0 | 5.0 |
| | | | | | | | | | | |
| GW-976(I) | 1068.41 | 1065.84 | 2.57 | 24.4 | 55.0 | 1013.4 | 47.0 | 1021.4 | 18.0 | 72.6 |
| GW-977(S) | 1068.17 | 1065.63 | 2.54 | 25.1 | DRY | DRY | DRY | DRY | DRY | 10.0 |

Notes and Abbreviations:

- GW-968(I) - YSI sonde originally deployed at 20.1 ft BTOC until 12-23-14 when the 5 ft extension was installed. Troll originally deployed at 22.6 ft BTOC until 12-23-14 when the original 5 ft extension was installed.
- Elevations of the Troll and YSI sondes were not changed on 2-9-15 and 2-11-15 when additional casing extensions were added to the TOC at GW-968(I) and GW-969(S).
- GW-970(I) - Troll originally at 45 ft BTOC; lowered to 55 ft BTOC on 12-17-2014.
- GW-974(I) – YSI sonde originally at 18 ft BTOC; lowered to 19 ft BTOC on 1-26-2015.
- GW-976(I) - Troll originally at 45 ft BTOC; lowered to 65 ft BTOC on 12-17-2014.

BTOC below top of casing

## 4.3 SURVEYING

Professional surveying of all Phase I monitoring locations was completed during the first week of December 2014 by BWSC. The surveying was conducted to accurately define the coordinates and elevations for each well location and the nine Phase I surface water monitoring locations (continuous and observational). For each monitoring well, survey locations included the top of the inside casing (uncapped) as a reference benchmark for water level measurements, and the elevation of the top of concrete (approximate ground surface elevation) at the base of the protective surface casing. Other control points were surveyed such as spot ground surface elevations located adjacent to the concrete well pads, invert locations for some of the culverts installed during road construction, upper corners of the flumes, and intermediate control points.

For the surface water monitoring locations (see Figure 1) benchmarks were surveyed on the following features as shown in Table 5:

- The top and flume floor level at the stilling well location on the three flumes installed at EMDNT3-SWG1, EMDNT3-SWG2, and EMDNT3-SWG3.
- The top and bottom of wooden stakes placed at each of the six observational monitoring locations (the three headwater spring locations at EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2; and the three stream monitoring locations at EMDNT3-ST1, EMDNT3-ST2, and EMDNT3-ST3).

BWSC tied into existing Y-12 system benchmark locations and elevations at monuments 89-Y-116 and 89-Y-117. Surveying data were provided to Pro2Serve for integration into current site topographical survey maps for accurate presentation of key locations on maps and cross sections. The BWSC surveying data (coordinates and elevations) are provided in Exhibit A.16. The elevation data are also included in various report tables where key monitoring well and surface water monitoring data are presented.

**Table 5. Elevation Data for Phase I Surface Water Monitoring Locations**

| | Surface Water Monitoring Location | Top Staff Gage | | Ground Elevation in Channel Bottom at/near Staff Gage | Staff Gage Difference | Top Marking on Staff Gage = Top Staff Gage Elevation | Elevation at 0.00 ft on bottom of staff gage |
|---|---|---|---|---|---|---|---|
| Observational Monitoring Locations | EMDNT2-SP1 | 1059.33 | | 1057.81 | 1.52 | 1.06 | 1058.27 |
| | EMDNT3-SP1 | 1042.30 | | No Data | No Data | 1.06 | 1041.24 |
| | EMDNT3-SP2 | 1044.39 | | 1042.83 | 1.56 | 1.06 | 1043.33 |
| | EMDNT3-ST1 | 1011.03 | | 1009.79 | 1.24 | 1.06 | 1009.97 |
| | EMDNT3-ST2 | 994.00 | | 992.68 | 1.32 | 1.06 | 992.94 |
| | EMDNT3-ST3 | 1006.96 | | 1005.74 | 1.22 | 1.06 | 1005.90 |
| | **Surface Water Monitoring Location** | **Reference Elevation Datum** | **Top of Flume at Stilling Well** | **Bottom of Flume at Stilling Well** | **Flume Height at Stilling Well** | | |
| Flume Locations | EMDNT3-SWG1 | 975.06 | 978.05 | 975.06 | 3.0 | | |
| | EMDNT3-SWG2 | 981.66 | 983.17 | 981.66 | 1.5 | | |
| | EMDNT3-SWG3 | 979.68 | 982.67 | 979.68 | 3.0 | | |
| Other Surface Water Locations | EMDNT3-SE1 | Not surveyed and not part of Phase I monitoring | | | | | |
| | EMDNT3-SP3 | Not surveyed and not part of Phase I monitoring | | | | | |
| | EMDNT2-SE1 | Not surveyed and not part of Phase I monitoring | | | | | |
| | EMDNT2-SE2 | Not surveyed and not part of Phase I monitoring | | | | | |
| | EMDNT2-SE3 | Not surveyed and not part of Phase I monitoring | | | | | |

Abbreviations:

SE seep
SP spring
ST stream

### 4.4 WASTE MANAGEMENT

Surface and subsurface media (i.e., soil, rock cuttings, water, etc.) were expected to be uncontaminated because there is no evidence that the EMDF site has been impacted by industrial operations, waste disposal, or other contaminant releases. This was verified throughout the Phase I field work by pre-screening of drilling locations and by visual observation and active use of field instruments (radiation meters, photo-ionization detectors) to screen all media, equipment, and potentially exposed site personnel. Drill cuttings and fluids from soil borings and well drilling were contained on plastic sheeting near each drill site and screened for contamination. After field screening indicated no contamination, subsurface media were spread or discharged in the local areas near the drill sites so as not to negatively impact or influence existing site features or environmental conditions. Disposable personal protective equipment such as latex gloves and other uncontaminated disposable materials such as paper, packaging, plastic sheeting, etc., were bagged and disposed of at the ORR Y-12 Landfill as non-hazardous waste. Water produced during well development was temporarily stored in plastic containers, allowed to settle, and the relatively clear water was discharged to the ground surface near the well site. Documentation for Phase I waste disposal is provided in Exhibit A.17.

## 5. PREVIOUS INVESTIGATIONS RELEVANT TO PHASE I

Data from previous subsurface investigations along geologic strike with the EMDF in BCV provide a substantial amount of background information applicable to the proposed EMDF. The USGS completed an inventory and limited measurements of flow at spring, seep, and stream locations across the entire length of BCV in the mid 1990's that included NT-2 and NT-3 tributaries crossing the EMDF (Robinson and Johnson, 1995, and Robinson and Mitchell 1996). More accurate stream flow monitoring was completed in support of the EMWMF along upper portions of the NT-3, NT-4, and NT-5 tributaries during the late 1990's (BJC 1999). Subsurface investigations were completed by Ogden in 1992/1993 at sites on either side of and along geologic strike with the EMDF (Ogden 1993a and b). The Ogden investigations included 27 borings at Site B, adjacent to the EMDF on the northeast and 52 soil borings at Site C, now occupied by the EMWMF, adjacent to the EMDF to the southwest. The geotechnical and hydrogeological data from these investigations was extensive and relevant to the EMDF site. Pre-construction test pits and monitoring well drilling and installation were conducted at the EMWMF (circa late 1990s/early 2000s) also directly adjacent to and along strike with the EMDF (BJC 1999, CH2M Hill 2000). In addition, subsurface investigation results are available from monitoring well drilling just south of the EMDF and the Haul Road, and for portions of the Bear Creek Burial Grounds further to the southwest and along strike to the EMDF (Bechtel 1984). Results of multiple investigations for waste sites in BCV were synthesized in the multi-volume BCV RI report (DOE 1997). Figure 7 illustrates the locations of borings, monitoring wells, and surface water monitoring stations from previous investigations at and near the proposed EMDF site. A brief summary of the Ogden and EMWMF geotechnical and hydrogeological investigations with excerpts relevant to the EMDF is provided in Exhibit A.19. A careful review of the original reports (Ogden 1993a and b, CH2M Hill 2000) from these investigations and other design related investigations and testing at the EMWMF site is encouraged for planning a Phase II investigation at the EMDF site.

Not shown on Figure 7 but relevant to the EMDF investigation, extensive surface and subsurface investigations were completed in WBCV in the late 1980s and early 1990s within some of the Conasauga Group formations that are along geologic strike with the EMDF. These investigations were completed for the formerly proposed Low Level Waste Disposal, Development, and Demonstration (LLWDDD) Program, also known as the Class L-II Disposal Facility. This facility (never constructed) was located approximately 3.5 miles to the southwest of the EMDF. Field investigations included extensive and detailed hydrogeological site characterization. Multiple reports addressing the LLWDDD site included soils and bedrock characterization, over 8,000 ft of rock coring, numerous monitoring wells and piezometers, surface water and ground water characterization, aquifer testing, tracer testing, and ground

water modeling (Lee and Ketelle 1989; Golder Associates 1989; ORNL 1997). The collective results from these investigations and reports provide a valuable and unique source of detailed information that is useful for the interpretation of the Phase I results and for the design and interpretation of data that may be collected from future EMDF investigations.

This page intentionally left blank.

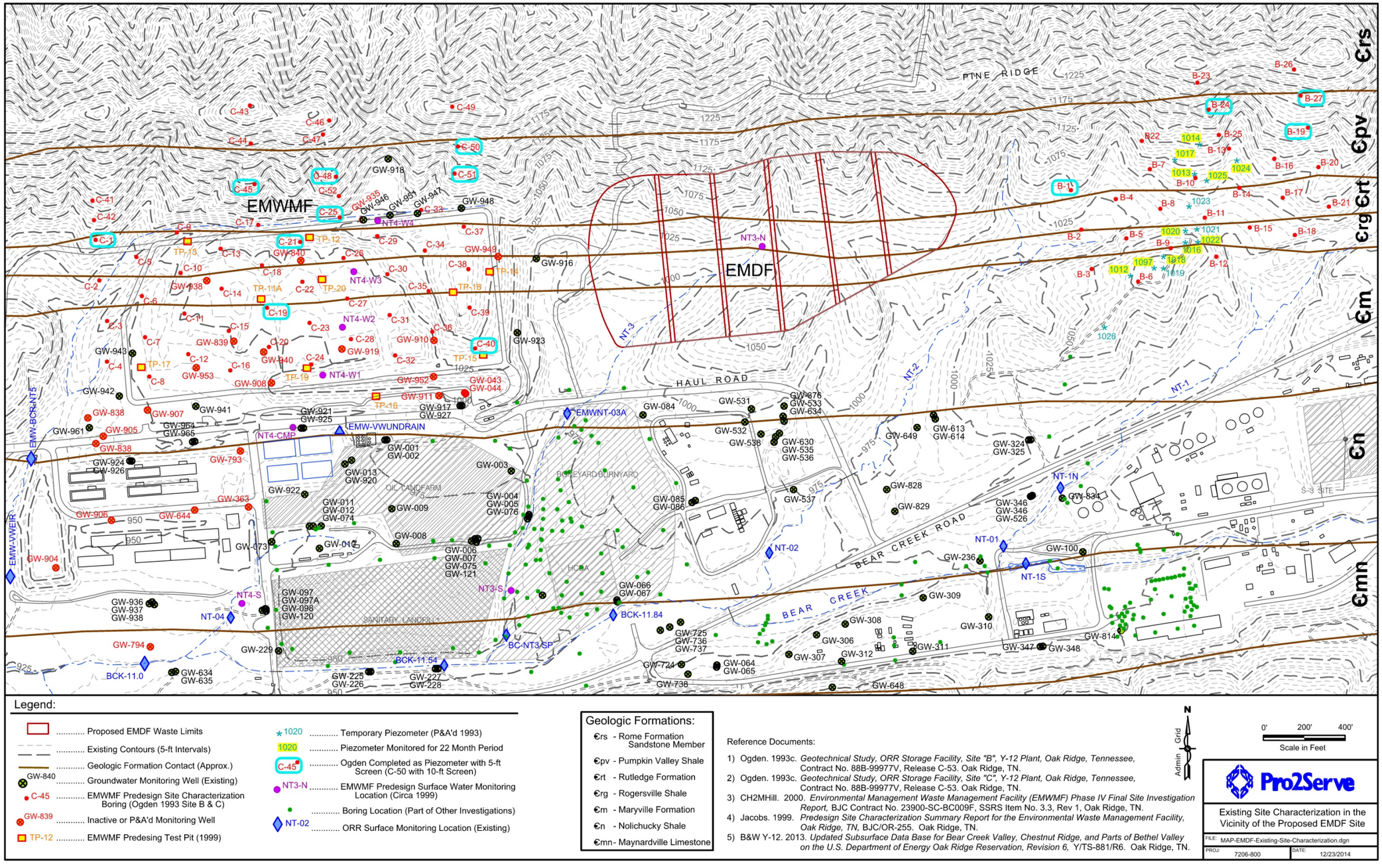



**Figure 7. Locations from Previous Investigations in Bear Creek Valley at and Near the Proposed EMDF Site**

This page intentionally left blank.

# 6. EMDF HYDROGEOLOGICAL SITE CONCEPTUAL MODEL

A site-specific hydrogeological conceptual model for the EMDF site is presented in Appendix E of the RI/FS Report. This conceptual model is supplemented herein for the Phase I in the attached Plate 1 and in Figures 8–10, and in the summary descriptions that follow. The illustrations and descriptions provided in the cross sectional view of Plate 1 summarizes the site-specific EMDF conceptual model. The cross section is drawn to scale near the center of the EMDF footprint and oriented from northwest to southeast perpendicular to geologic strike. Closeup inserts illustrate details of the hydrogeological model for upland areas and for lowland areas along the valley floor of NT-3 that are characteristic of the site. Intermediate elevation areas of the EMDF site which comprise much of the EMDF footprint are transitional between the upland and lowland areas. The relative positions of the stormflow zone, vadose zone, water table interval, and intermediate and deep ground water intervals are illustrated in cross sectional views. The closeup views also highlight the zone of water table fluctuation that commonly occurs within saprolite of the regolith and the upper portion of bedrock below auger refusal depths. The detailed vertical profile also illustrates the relative change from more porous and permeable regolith materials and shallow fractured bedrock downward into more competent and less fractured and unweathered bedrock at greater depths.

Figures 8–10 present three-dimensional perspective views at and downgradient of the EMDF that provide additional tools for visualizing the conceptual model for ground water flow patterns at the EMDF. The basic elements of the model are derived from the hydrologic framework for the ORR, modifications to that framework (Solomon et al, 1992; Clapp R. B. 1997 and 1998), and similar conceptual models presented for other sites within BCV (ORNL 1997), particularly that presented in the BCV Remedial Investigation Report (see Volume 4 of Appendix E of DOE, 1997). Those reports should be referenced for additional detailed descriptions reflected in the EMDF hydrogeological conceptual model illustrated in these figures. The EMDF conceptual site model refines earlier models by including a mechanism for transferring ground water across the structural-stratigraphic grain of BCV. This refined concept postulates strike-parallel flow towards tributary streams and underlying vertically-oriented fracture systems that have been enhanced by deep weathering. Ground water flow is then captured by the streams and underlying fractures and conveyed towards Bear Creek and Maynardville Limestone conduit systems.

The hydrogeological cross sections shown in Plates 1–4 show the relationships between the Phase I results and surface topography, surface water features (springs, seeps, and NT drainage paths), and key conceptual design elements. Hydrogeological features, including water level data from the Phase I monitoring wells, are accurately shown in relation to existing surface topography, and the positions of underdrain trench/blanket system, the geobuffer, liner system, and final landfill surface grades proposed in the engineering conceptual design for the EMDF. Research on the ORR has demonstrated that the majority of ground water flux occurs via two subsurface pathways: 1) within the stormflow zone associated with the surficial topsoil layer and 2) within the water table interval which commonly occurs within regolith saprolite and weathered bedrock near the zone of water table fluctuations. Solomon et al (1992) reported that >90% of the estimated water flux occurs through the stormflow zone, but subsequent studies reported by Clapp (1997/1998) have shown that the proportion of stormflow zone flux may be much less. The studies suggest that the proportions of shallow stormflow zone versus shallow ground water zone contributing to stream flow were 53% and 47%, respectively. However, there simulations were based on a seven year study period where mean annual precipitation was 25% below the average. The stormflow zone contribution was therefore thought to be closer to 70% during an average year. The overall conclusions of the study suggest that annual ground water recharge and contributions of the ground water zone to streamflow may be much higher than originally proposed by Solomon et al (1999) and closer to 30% on average rather than the 10% originally reported. The relative proportions of the water table, intermediate, and deep intervals of the ground water zone would remain similar to those presented by Solomon et al (1992), as illustrated on Plate 1, with most of the ground water flux still occurring from the water table interval.

As illustrated conceptually in Figures 8 and 10, ground water flow in the water table and intermediate intervals migrates from recharge zones in upland areas and converges toward and slowly discharges along valley floors supporting baseflow along the NT streams. Upwelling may occur from the lower water table and intermediate ground water intervals via fracture zones that intersect with valley floors. Flow along fracture paths is preferential along geologic strike toward the cross cutting NT tributary valleys as illustrated conceptually in Figure 9. Actual fracture flow paths are three dimensionally complex and cannot be accurately defined beyond the locations of individual monitoring wells. Ground water discharge through macropores of regolith materials and fractures within saprolite and bedrock is commonly expressed at seeps and springs along lower slopes of the NT tributaries and along upper reaches of the NT tributaries where abrupt slope transitions occur (see springs/seeps and wetland areas shown on Figures 1 and 9).

It is important to note that the natural conditions just described will be significantly altered during the construction and post-closure period of the proposed EMDF. As the landfill is constructed the area available for ground water recharge will be progressively reduced and restricted to a relatively narrow strip along the uppermost south facing slopes of Pine Ridge north of the EMDF footprint (roughly 10 acres in size). The waste footprint area is estimated to cover about 30 acres while the final cover system will occupy about 35 acres. The former natural recharge area contributing to current surface and ground water flow at the EMDF site would be reduced by roughly 75% after landfill construction. Topsoil materials will be removed and replaced with engineered fill and geobuffer clays. Alluvial and colluvial materials along the valley floors will be removed and replaced with the underdrain system and topped with fill, geobuffer, and liner system materials. The natural surface water and ground water flow regime will thus be dramatically altered and reduced. Ground water within undisturbed natural materials would continue to migrate slowly downgradient but the elimination of significant portions of the former natural recharge area will greatly reduce the overall ground water flux below the footprint. These changes are addressed in modeling simulations that include changes to recharge, surface and ground water flux, and contaminant transport (see Appendix H to the current RI/FS report). These changes are also reflected in the post construction water table configuration shown elsewhere in this Phase I report.

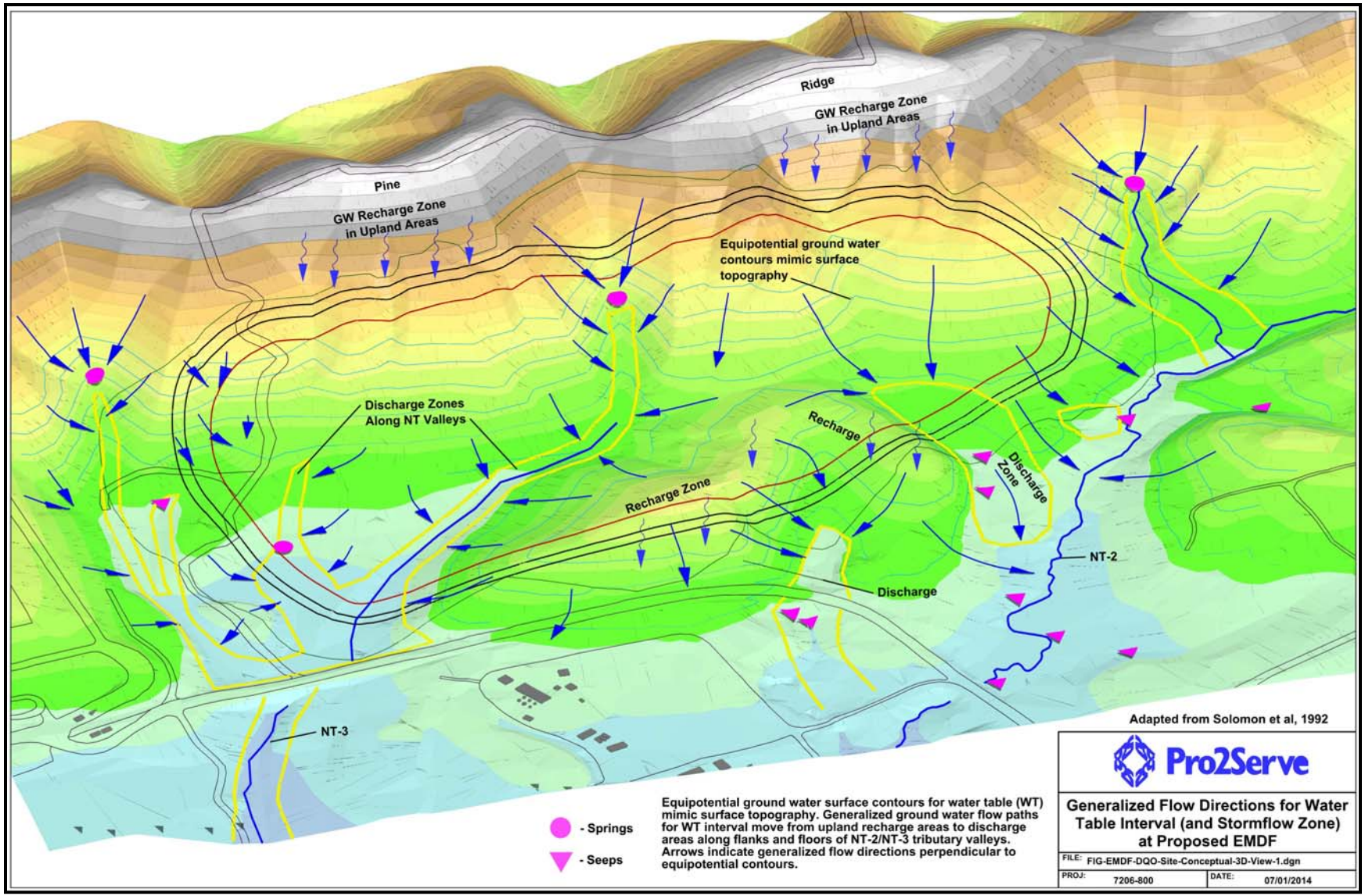



**Figure 8. Hydrogeological Site Conceptual Model for the Shallow Water Table Interval at the EMDF Site**

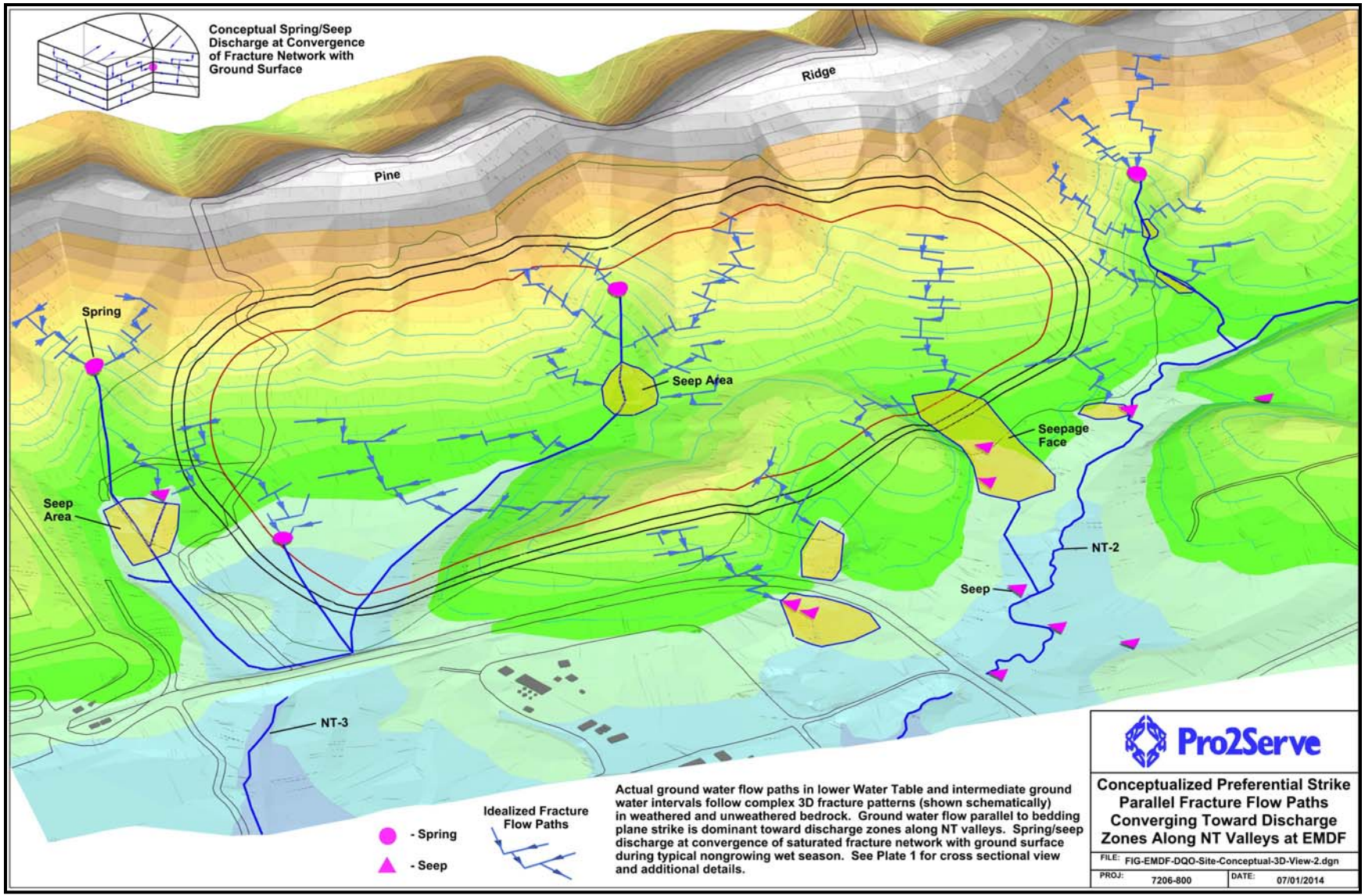



**Figure 9. Hydrogeological Site Conceptual Model Illustrating Conceptualized Fracture Flow Paths in the Lower Water Table and Intermediate Ground Water Zones**

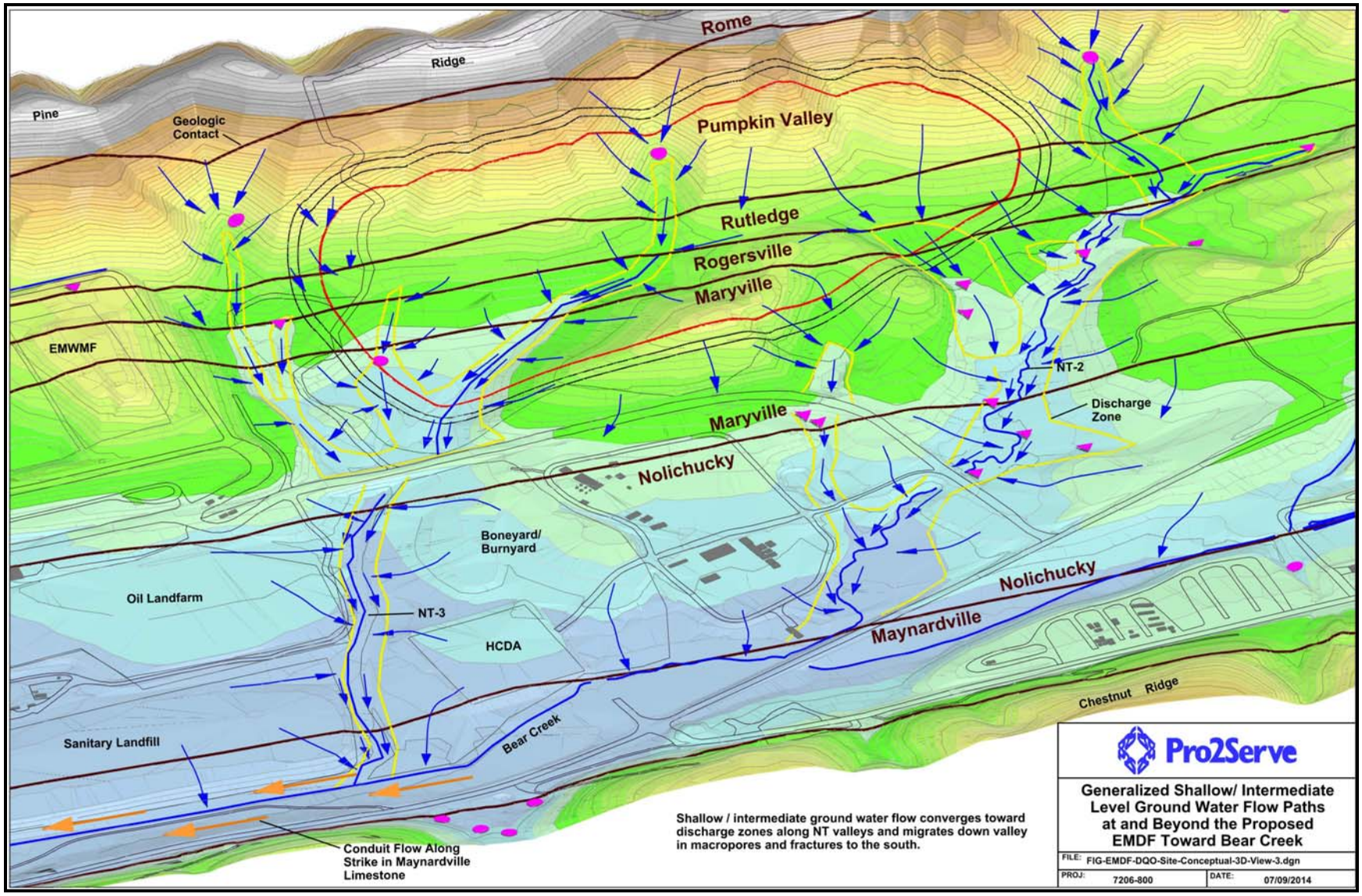



**Figure 10. Hydrogeological Site Conceptual Model for Generalized Flow Paths in Shallow and Intermediate Ground Flow at and Downgradient of the EMDF Site**

# 7. PHASE I RESULTS

The limited Phase I investigation results focus primarily on the hydrogeology of the shallow and intermediate ground water intervals, surface water features (springs, seeps, and stream flow), and the general relationships between ground water and surface water. The results are representative of the wet non-growing season when runoff and ground water levels are normally at their highest levels. Results from monitoring surface water flow and water quality parameters are reviewed in Section 7.1. The various subsections of Section 7.2 review Phase I water level monitoring, flow directions and gradients, ground water quality parameters, and results of Phase I hydraulic conductivity tests and heat pulse flow (HPF) meter tests. Additional Phase I findings from geotechnical laboratory tests of soil/saprolite and bedrock hydrogeological conditions based on collective interpretations of rock cores, geophysical logs, and hydraulic data are presented in Section 7.2.5. Where Phase I data are lacking, relevant results from previous investigations at sites similar and/or in close proximity to, and along geologic strike with the EMDF, are compared with the EMDF site. Longer term precipitation and runoff records from locations near the EMDF were also used for comparison with the short term Phase I data (Late November 2014 through late February 2015).

It is important to note that the Phase I investigation was not intended to provide a comprehensive characterization of the EMDF site. The Phase I results were intended to provide initial baseline data to demonstrate the suitability of site conditions in relation to the conceptual design for the disposal facility, and set the stage for further investigations. With EPA and TDEC approval of the EMDF site, a follow on Phase II investigation would be performed to provide much more extensive and detailed data in support of a detailed engineering design for the disposal facility. A Phase II investigation would also provide data to improve the accuracy of fate and transport modeling used for development of final waste acceptance criteria. For now, the Phase I investigation provides baseline site-specific data limited to that obtained from the five well pair locations, three surface water gaging stations, and six surface water weekly monitoring locations.

## 7.1 SURFACE WATER HYDROLOGY

The surface water and ground water hydrology at the EMDF site are addressed below in separate sections but interactions between surface and ground water are clearly significant at the EMDF site and throughout BCV, as shallow ground water supports seasonal baseflow to the uppermost tributaries of NT-2 and NT-3 and discharge to springs and seeps within and adjacent to the EMDF footprint. If the proposed EMDF site is approved, interactions between surface and ground water would presumably be further characterized during a Phase II investigation, particularly in support of a detailed engineering design for the proposed underdrain system.

### 7.1.1 Local Climate and Recent Precipitation

Current climate normal values (1981–2010) from the National Weather Service (NWS) for the Oak Ridge area are 50.91 in. for annual precipitation and 58.8° F for mean annual temperature. Precipitation is distributed uniformly through most of the year, with normal monthly precipitation for August through October averaging about 1 in. lower than during other months (see Figure 11). These three months of lower precipitation and high temperatures tend to comprise a seasonal dry period in which evapotranspiration losses are large relative to inputs of rainfall.

Cumulative monthly precipitation data since 1999 (NWS station KOQT in Oak Ridge) and corresponding recent records from the Y-12 West Tower meteorological station (Y-12W) located near the EMDF site (see Figure 12) suggest that precipitation amounts for the 2014-2015 winter wet season are close to averages observed over the last decade (see Figure 13). Hourly precipitation data for Y-12W are utilized in this report to represent rainfall at the EMDF site.

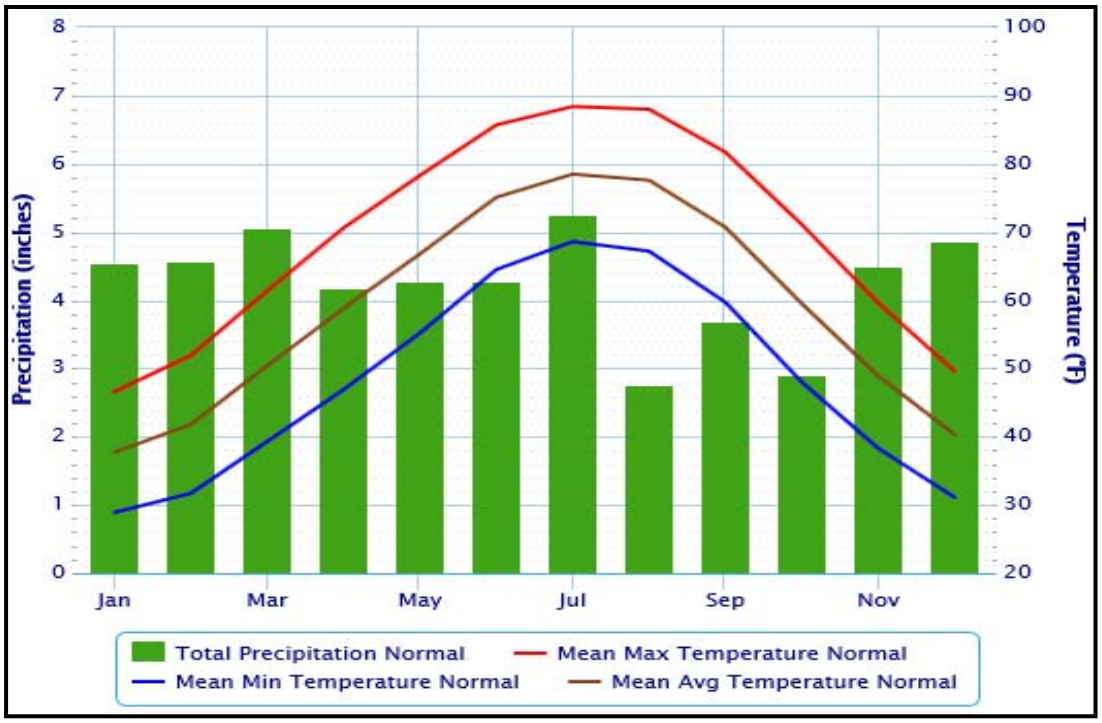



**Figure 11. Monthly Climate Normals (1981–2010) – Oak Ridge Area, Tennessee**

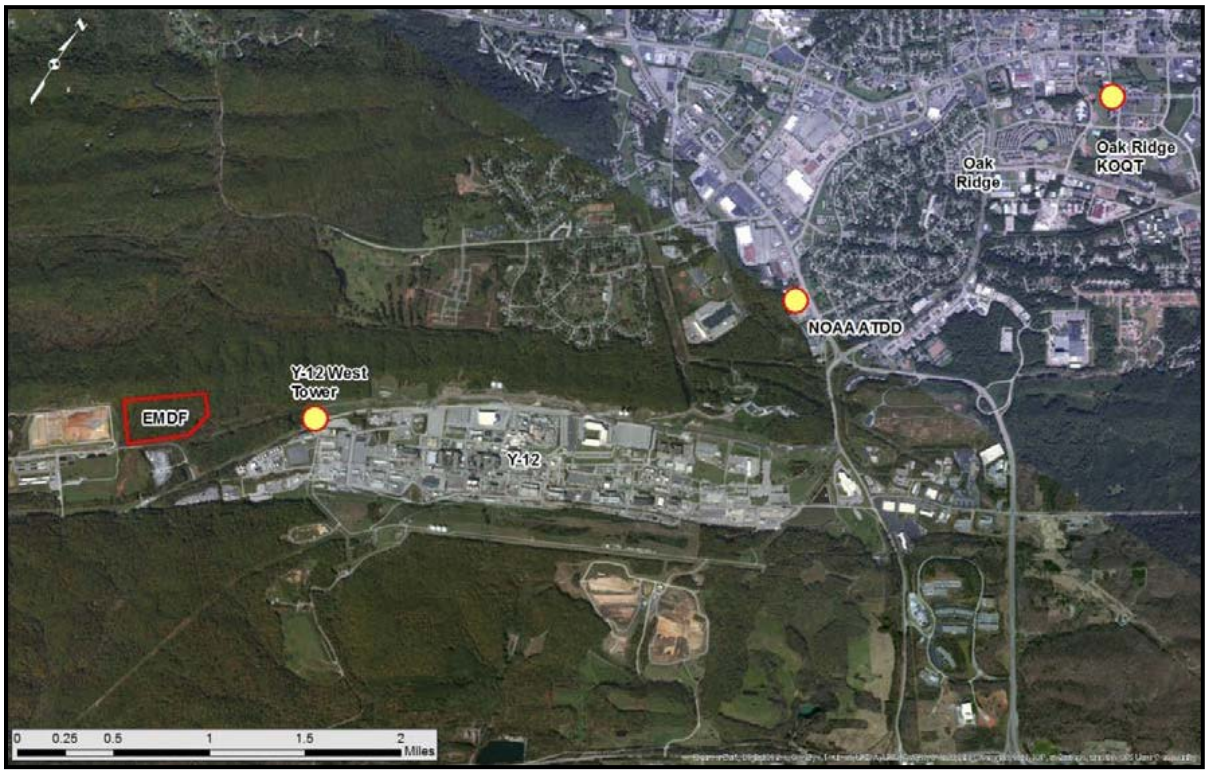
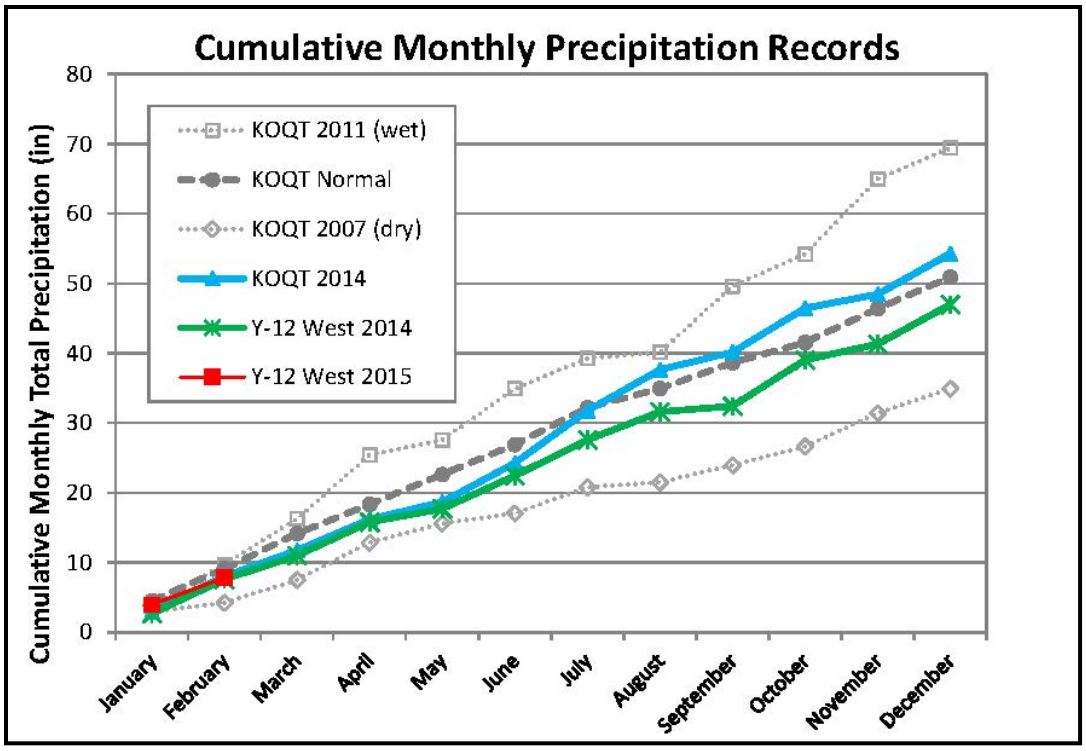



**Figure 12 Location Map for Meterological Stations**



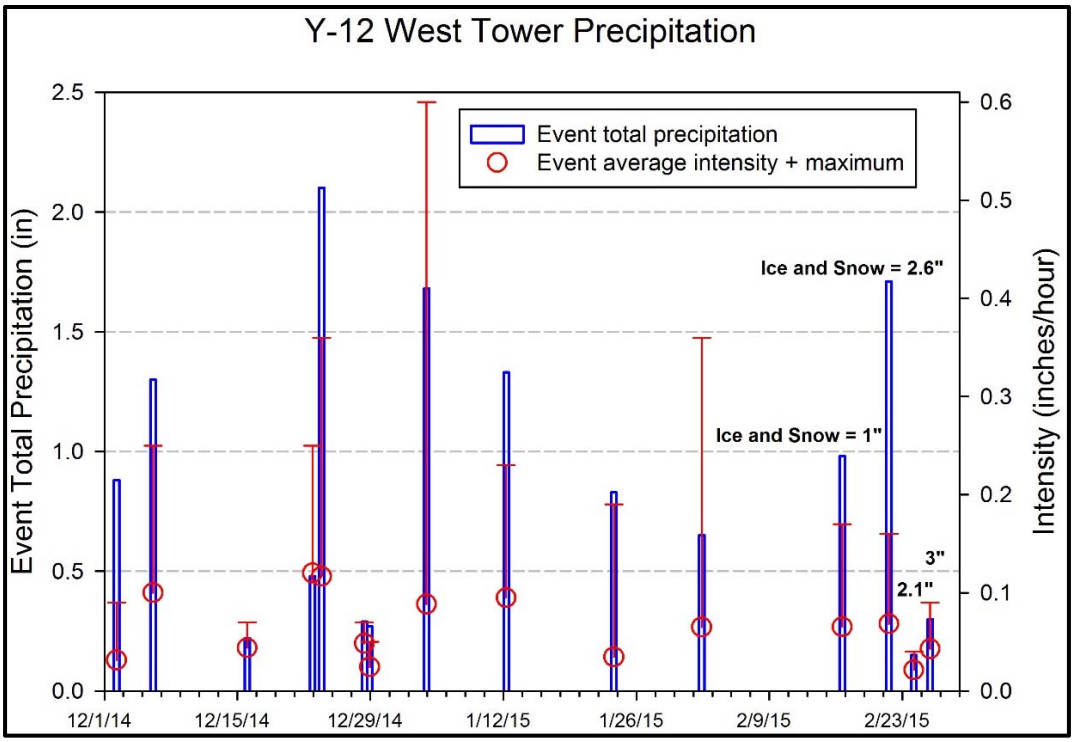

KOQT records for the year of highest (2011) and lowest (2007) total annual precipitation illustrate the observed range of variability since 1999. Refer to Figure 12 for locations of KOQT and Y-12W.

**Figure 13. Cumulative Monthly Precipitation Records for NWS Station KOQT and the West Tower Meteorological Station at Y-12 (Y12 West)**

For the period from December 1, 2014 through February 28, 2015, there were 15 precipitation events exceeding 0.1 in. at the Y12W tower (see Figure 14). Five of these events exceeded 1 in. total storm precipitation and one event exceeded 2 in. For the February 2 and earlier events, the type of precipitation was primarily rain, whereas the last four events (February 1626) included significant amounts of snow and ice as noted on Figure 14.

Average rainfall intensity for the four earlier events exceeding a 1 in. storm total was approximately 0.1 in. per hour, and maximum hourly intensities during these storms ranged from 0.23 to 0.6 in. per hour. To put the magnitude of these storm events in hydroclimatic context, the NWS point precipitation frequency estimate for hourly rainfall intensity at the National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Division station (within 4 miles of the EMDF site, see Figure 12) given a one year average recurrence interval is 1.14 in. per hour, almost twice the maximum observed hourly intensity for Y-12W precipitation during the three month reporting period. Hourly precipitation exceeding 0.6 in. was recorded at Y-12W 48 times during the five years from 2009 to 2014, over nine times per year, on average.

Similarly, for the three month reporting period, the Y-12W storm event with the highest average intensity (0.12 in. per hour over 4 hours on December 22, total rainfall = 0.48 in.), is small compared to the 1.58 in. over four hours (0.395 in./hour) NWS estimate for a one year average recurrence interval. Storms of equal or greater magnitude than the 15 observed events are likely to occur several times per year in the vicinity of Oak Ridge.



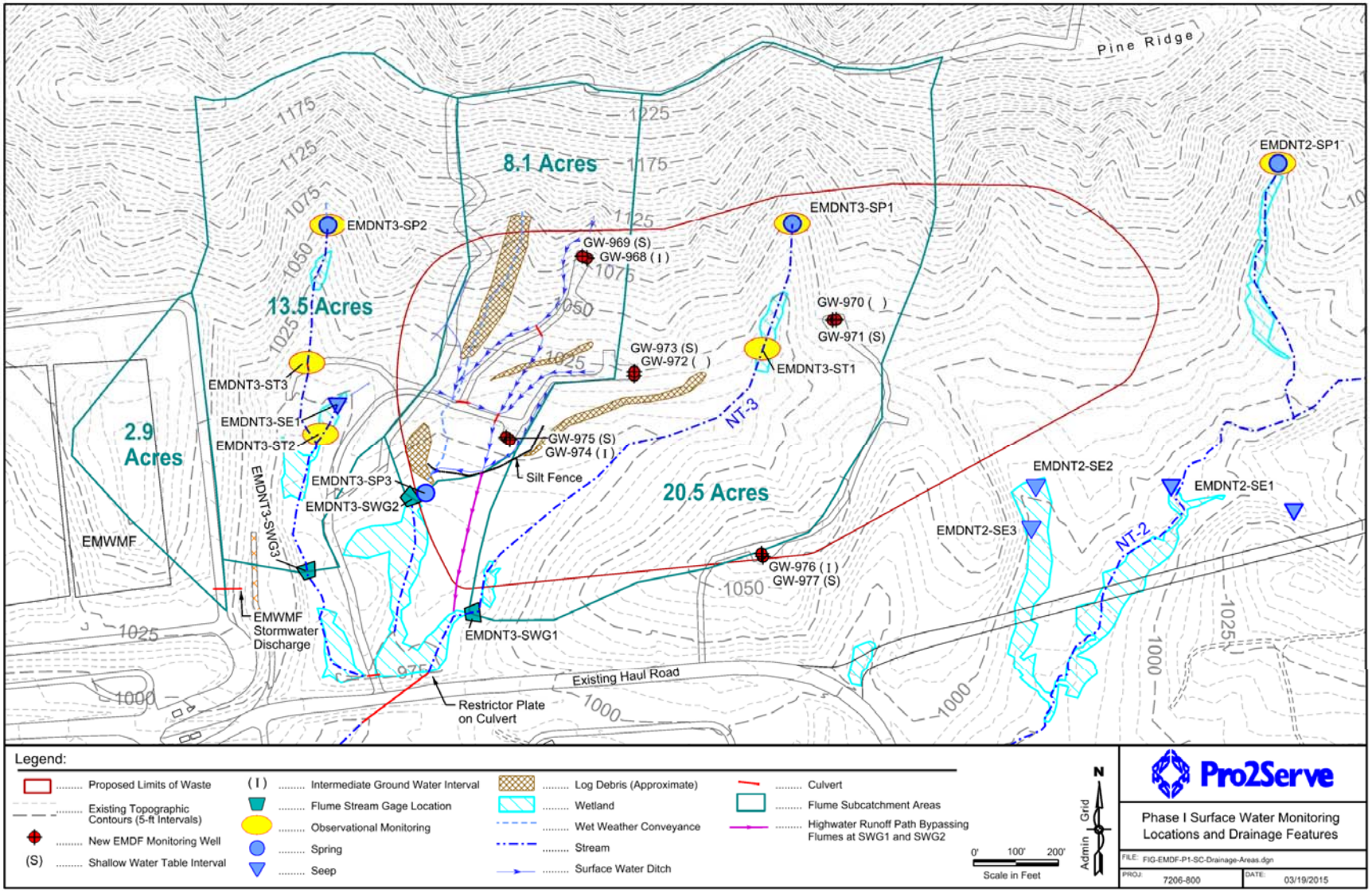

As Recorded at the Y-12W Station during December 2014 and January–February 2015

**Figure 14. Summary of Observed Total Precipitation, Average Precipitation Intensity, and Maximum Hourly Intensity for each of 15 Rainfall Events Exceeding 0.1 in. Total**

### 7.1.2 Rainfall Runoff Relationships

The portion of the NT-3 watershed upslope of the existing haul road along the base of Pine Ridge at the EMDF site has experienced several significant physical disturbances over the last two years. Following severe storm-damage to the forest cover that occurred in May 2013 (refer to Section 1.6 and Figure 2), salvage logging operations began in November 2014 and continued through July 2014. Heavy equipment used during this effort produced widespread disturbance of existing vegetation cover and soils on portions of of Pine Ridge within the proposed EMDF footprint (see Figure 2). Subsequent development of the site for well drilling operations including grading and road construction has altered the original drainage patterns and further disturbed the watershed. These physical and biological impacts will have altered the hydrologic response of the upper portion of the NT-3 catchment, likely resulting in increased runoff and higher peak flows compared to pre-disturbance conditions. The surface flow and water quality monitoring data collected during the three month period covered by this report document the current disturbed condition of the watershed, and may or may not be representative of future conditions, depending on the recovery of natural vegetation and drainage patterns and ongoing development of the site for EMDF construction.

Figure 15 illustrates the current approximate catchment areas for the three subwatersheds draining to each of the three Phase I surface water gaging (SWG) stations. The Phase I road construction has altered the natural runoff patterns primarily within the central catchment area associated with SWG-2. Eastern portions of the current catchment area for SWG-2 that previously flowed into the catchment for SWG-1 are now diverted toward runoff feeding into the SWG-2 flume. However, during periods of higher precipitation and runoff a high water overflow pathway breaches the existing silt fence (shown in Figure15) and flows southward bypassing both the SWG-1 and SWG-2 flumes. DOE plans to have this




New runoff patterns associated with Phase I road construction/culverts and the high flow bypass route are shown with blue and magenta arrow lines.

**Figure 15. Phase I Monitoring Locations and Approximate NT-3 Subcatchment Areas and Runoff Pathways for Flumes SWG-1, SWG-2, and SWG-3**

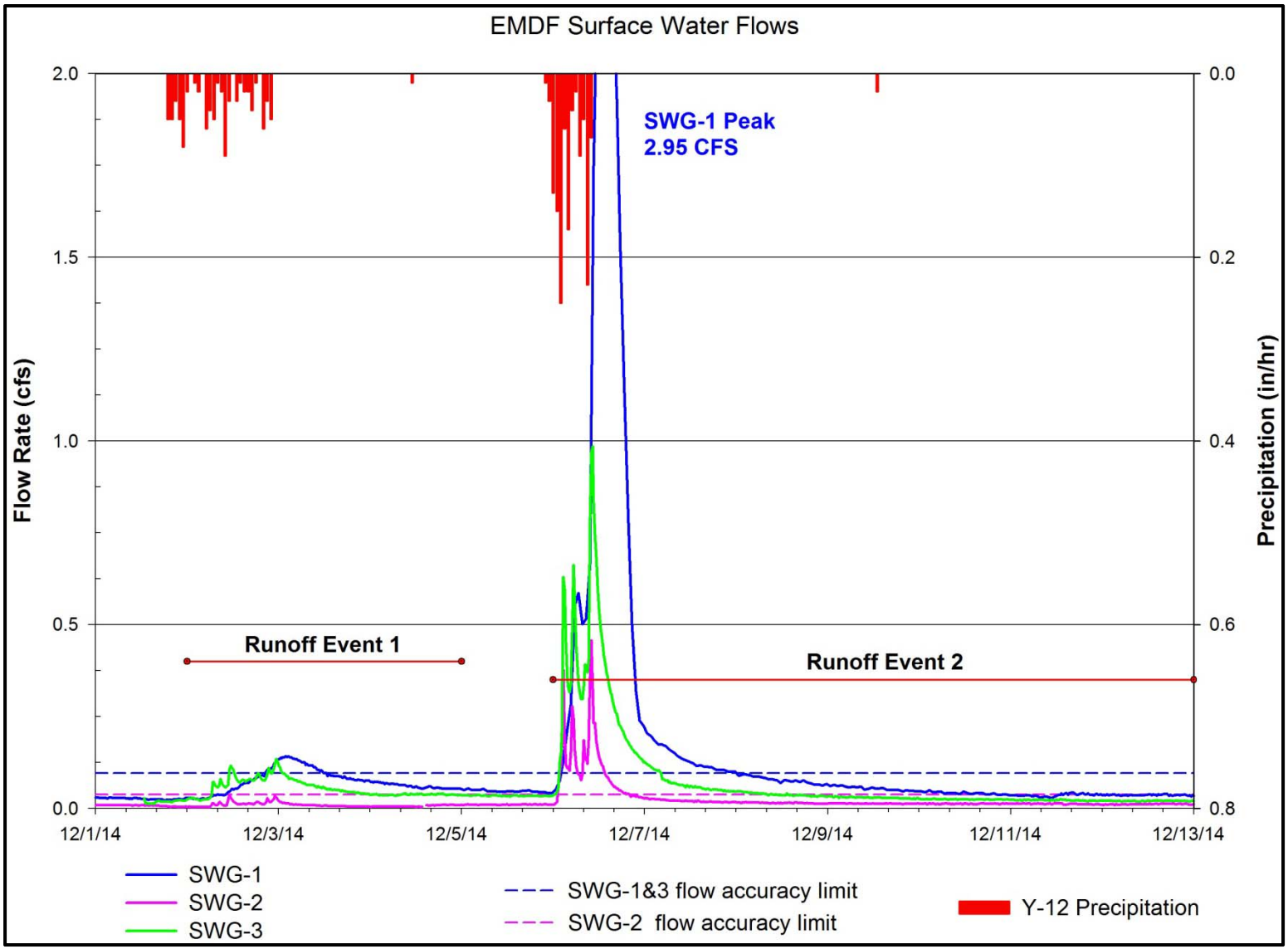
drainage pattern modified to direct runoff toward the west into the SWG-2 catchment area but runoff data for the current reporting period does not include this ungaged fraction of overland bypass flow.

Stream hydrographs recorded at the three SWG stations illustrate relatively rapid hydrologic response to rainfall, as expected for a small, fairly steep, recently disturbed watershed. An example of this response is illustrated in Figure 16). The streamflow data are consistent with precipitation inputs and appear to be generally reliable (see Figure17), although for flow depths less than 0.1 ft, the manufacturer's rating for the flumes is subject to uncertainty resulting from the site-specific geometry of the flume installation and flume entrance hydraulics. Flow rates corresponding to this lower flow accuracy limit for the larger (SWG-1 and SWG-3) and smaller (SWG-2) flumes are indicated by dashed horizontal lines on the hydrographs in Figures 16 and 17. Much of the runoff record lies below these lower flow accuracy limits, but the data are coherent in terms of responses to precipitation and the similarity of hydrographs for events of varying magnitude, suggesting that reliable flow ratings for depths less than 0.1 ft could be developed on a site-specific basis. For the analysis in this report all flows including those below the lower accuracy limit (less than 0.1 ft depth), have been estimated using the manufacturer's flume ratings. Given that the flume sizes were selected to ensure that peak flow rates are reliably estimated, the errors in estimating low flows are considered acceptable for the purposes of this Phase 1 site characterization.

An additional source of error in estimated flow rates is related to the accuracy and precision of flow depth measurements. The factory-calibrated pressure transducers are accurate to +/- 0.01 ft and uncertainty in precisely positioning transducers (datum control) is at maximum +/- 0.05 ft. Changes in estimated flows corresponding to datum shifts of this magnitude are evident in the SWG-2 flow record on some occasions when instruments were serviced and data downloaded. For the smaller flume at SWG-2, this flow depth uncertainty corresponds to relatively large proportional errors in flow estimates near the lower accuracy limit. As flow depth increases, the proportional error decreases rapidly in proportion to 1/depth. For the two larger flumes (SWG-1 and SWG-3), the proportional error due to depth uncertainty at the flow accuracy limit would be lower than for the smaller flume, and becomes negligible at higher flows. The uncertainties in low-flow estimates related to flow depth accuracy and precision are probably larger than the errors associated with utilizing the manufacturer's flume ratings to estimate flow at depths less than 0.1 ft.

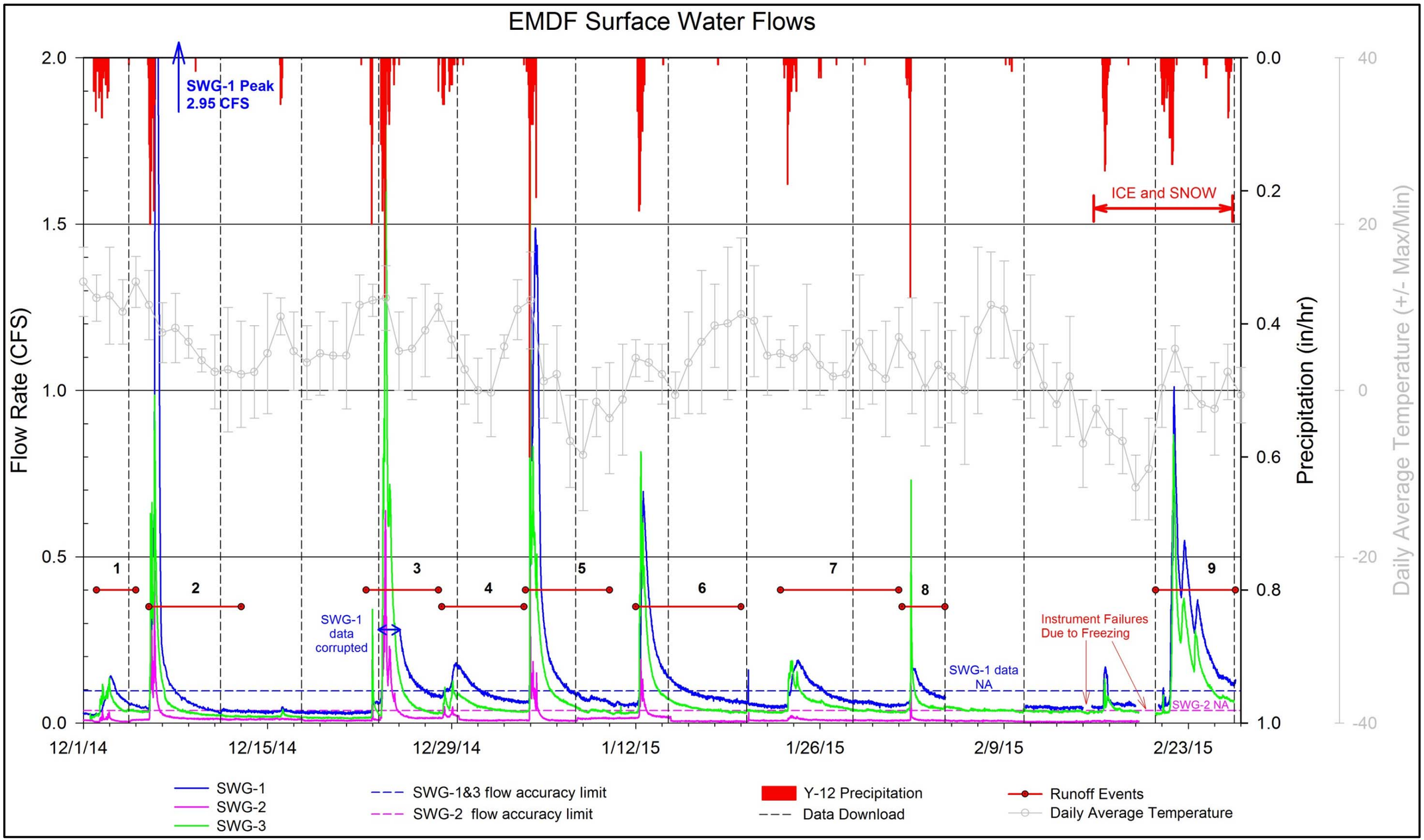
For purposes of comparing runoff to precipitation inputs, nine runoff events (discrete portions of the runoff record) were identified (see Figure 17) and event-total streamflow volume was calculated by integrating flow rates over time. These estimated volumes were scaled by the estimated area contributing runoff to each SWG (see Figure 15) to obtain a measure of total runoff per area (inches) suitable for direct comparison with precipitation (see Figure 18), and to facilitate direct comparisons among the three subcatchments. Figures 18 and 19 also include estimated runoff at the BC-NT3 gaging station on NT-3 downstream of the EMDF site and located about 100 ft above the confluence with Bear Creek (See location on Figure 7). The rainfall-runoff (mass-balance) analysis was performed as a rough data quality assessment only, and was not intended to quantify rainfall-runoff dynamics or the factors affecting these dynamics. Using this approach, the flow data for SWG-1 during event #3 (December 22–27) was found to correspond to 8 in. of runoff versus an estimated precipitation input of 2.6 in. This discrepancy was determined to be caused by a wooden pallet obstructing the flume entrance, leading to larger flow depths and overestimated flow rates.

In comparing estimated runoff to precipitation inputs, the selection of the time period over which streamflow is integrated will affect the results. For example during events #1 and #8, an increase of water storage in the SWG-1 and SWG-3 subcatchments is suggested by the difference in flow rates between the beginning and end of the integration period (see Figures 16, 17). This gain in storage is reflected in the low runoff as a proportion of precipitation input for events #1 and #8 relative to the other seven events (see Figure 19). In these two cases the selection of a longer flow integration period to more closely




Hourly Y-12W precipitation is also shown for reference.

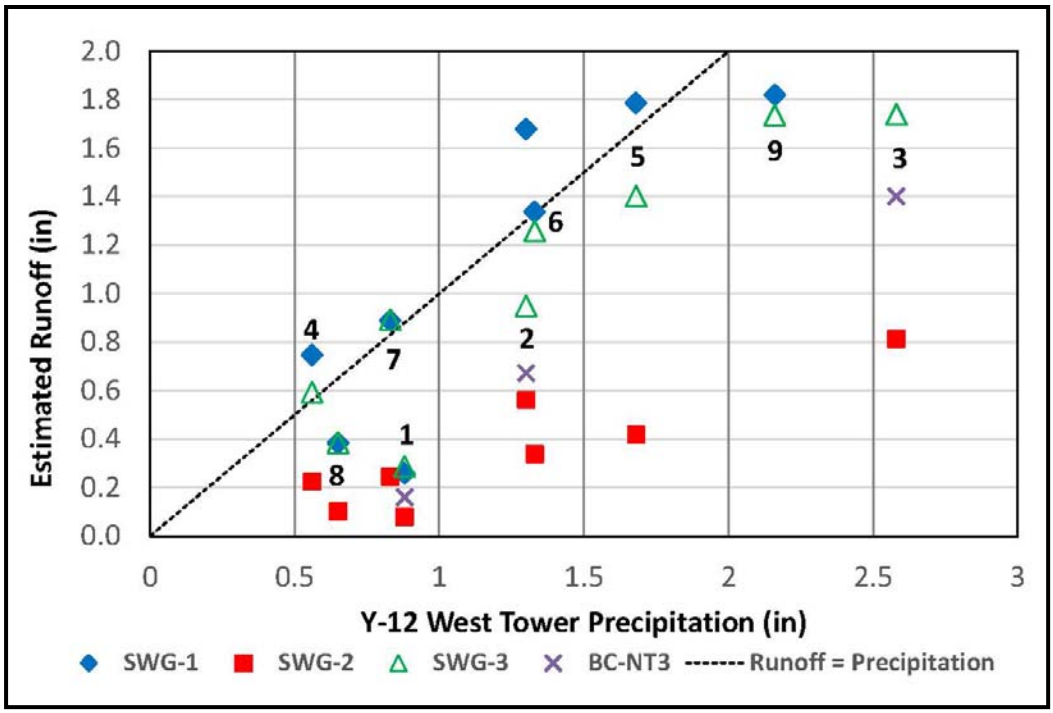
**Figure 16. Streamflow Hydrographs for the Three SWG Stations in the NT-3 Watershed**




Daily average, minimum, and maximum air temperatures for the Oak Ridge area are NWS data. Numbered horizontal lines delimit the runoff events identified for analysis.

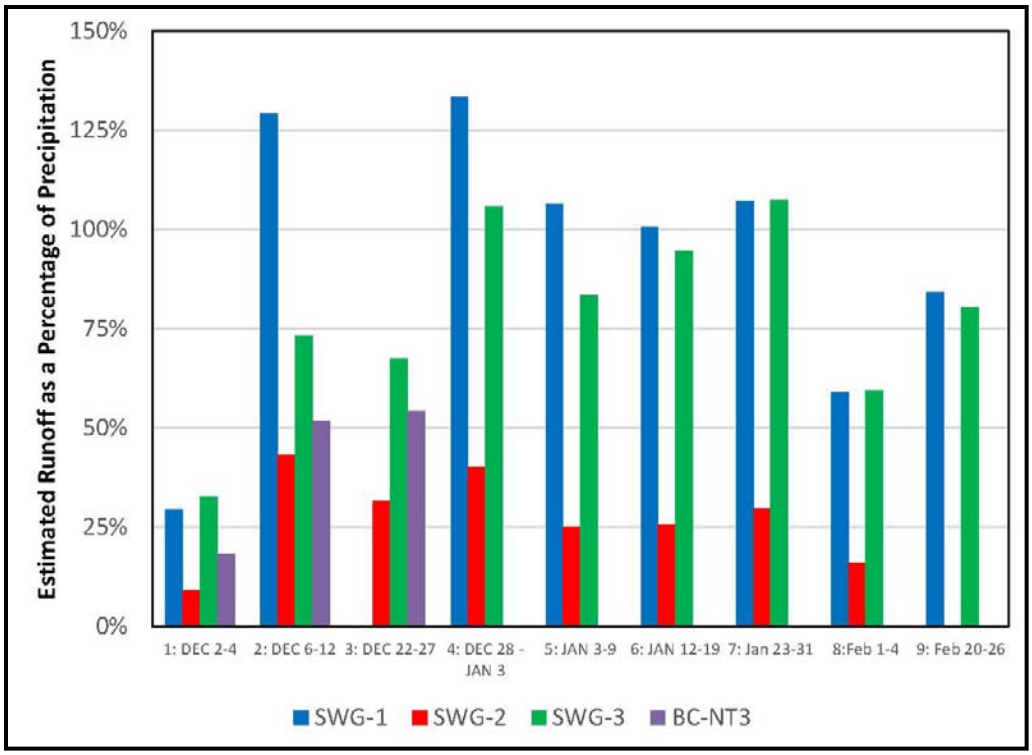
**Figure 17. December 2014–February 2015 Streamflow Hydrographs for the Three Phase I SWG Locations and Precipitation Data from the Y-12W Meteorological Station**

This page intentionally left blank.




Numbers on plot correspond to the nine runoff events identified in Figure 17.

**Figure 18. Estimated Event-total Runoff Plotted Against Storm Total Precipitation**




Data from Y-12 gaging station BC-NT3 downstream of the EMDF near the junction with Bear Creek shown for comparison.

**Figure 19. Event-total Runoff as a Percentage of Precipitation for Nine Runoff Events**

approximate zero change in storage is precluded by the occurrence of flow event #2 and the loss of SWG-1 water level data for February 4–10 due to equipment failure.

Runoff in relation to precipitation varied considerably among the three flumes and among flow events, reflecting differences among subcatchments and among precipitation events, as well as a number of data uncertainties. Estimated event-total runoff increased with observed storm-period precipitation, with SWG-2 having much lower runoff values than SWG-1 and SWG-3 (see Figure 18). Event-total runoff measured at SWG-2 was less than 44% of precipitation input for the first eight events (no SWG-2 data was collected during event #9 due to equipment failure). In contrast, runoff at SWG-1 and SWG-3 was greater than 50% of precipitation for all but the first event (December 2–4), and exceeded 100% on several occasions (see Figure 19). For the first event, relatively low runoff relative to precipitation for all three stations is consistent with the transition from drier conditions into the wet season, and reflects increasing ground water storage during the event (see Figure 16) and possibly higher interception and evapotranspiration losses than occurred during subsequent events. For event #8, well into the wet season, precipitation is less than for event #1, but event-total runoff is higher than for event #1 at all three stations (see Figure18), despite a net increase in water storage during the relatively short flow integration period (see Figure 17).

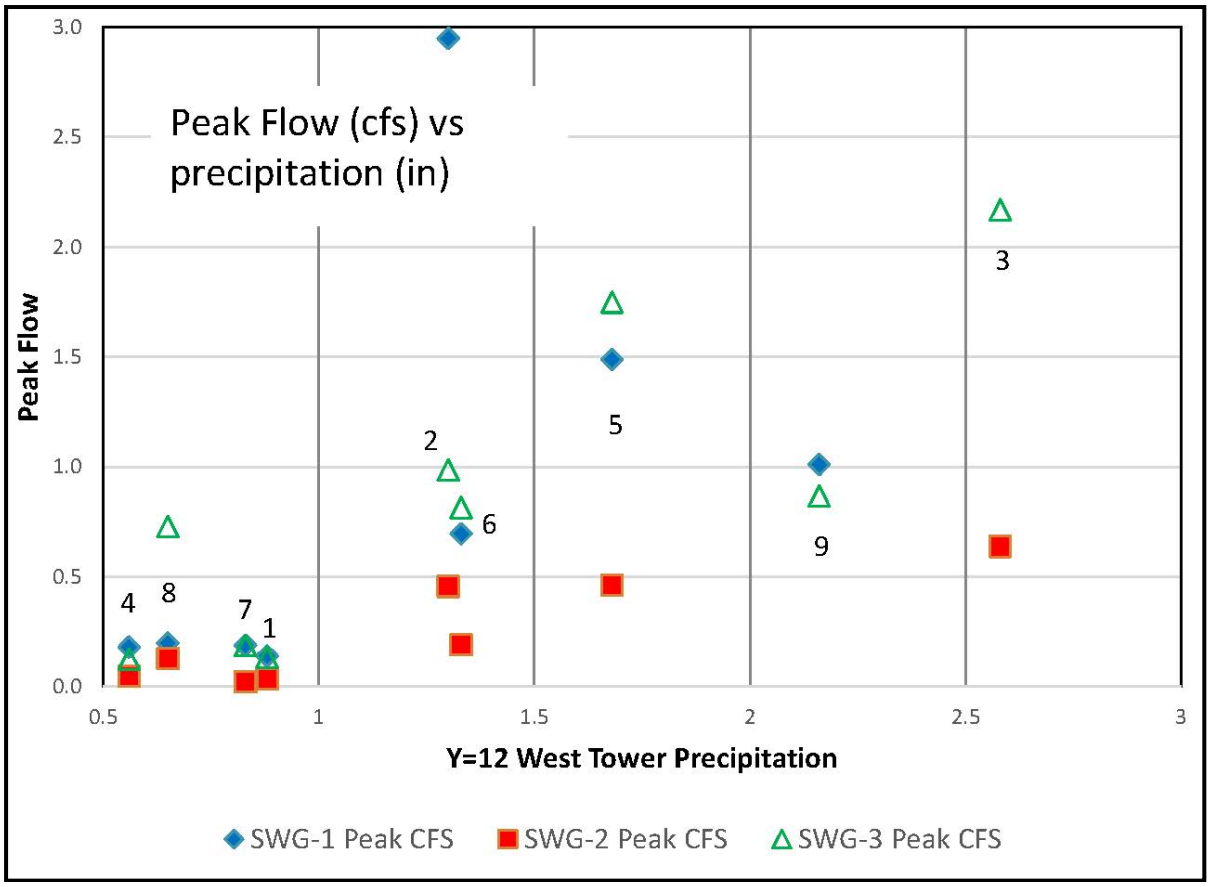
For events one through seven, for which SWG-1 and SWG-3 have consistently more runoff volume per catchment area than does SWG-2 (see Figure 17), there are several possible factors that may explain this difference. Because the SWG runoff estimates utilize the subcatchment contributing areas for scaling the storm-total flow volume, uncertainty in surface water drainage pathways and the location of subcatchment divides affects the magnitude of estimated runoff and differences among gaging sites. Owing to the physical disturbance of salvage logging and access road construction, drainage patterns in the lower portion of the SWG-2 subcatchment are complex and variable. The subcatchment areas identified in Figure 15 are based upon digital topographic data and field mapping of drainage pathways during the monitoring period, but do not reflect the potential for surface runoff originating upslope of the gaging sites to cross the assumed subcatchment boundaries or to bypass the flumes. Field observations indicate that during larger flow events (e.g., events #2, #3, #5, #6, and #9) a portion of surface runoff flowing toward the SWG-2 flume along a silt fence can overtop the fence and flow into NT-3 below the SWG-1 flume, leaving a portion of the runoff from the SWG-2 catchment ungaged (see Figure 15). This ungaged flow may account for the persistently low SWG-2 runoff (see Figures 18, 19).

Other environmental factors that can cause inter-site and inter-event differences in runoff include variations in total precipitation and the intensity and type of precipitation, which may account for some of the disparity between SWG-1 and SWG-3 for events #2, #4, and #5, where SWG-1 runoff is significantly greater than SWG-3 and exceeds 100% of assumed precipitation input (see Figure 19). Runoff totals exceeding 80% of precipitation inputs are not unreasonable for the wet season in a humid-temperate climate, while estimates exceeding 100% are not unexpected given spatial variations in precipitation and errors in precipitation measurements, uncertainty in flow rate estimates and contributing areas, and the potential for ungaged flows.

### 7.1.3 Stream Flow Response to Precipitation

Subcatchments SWG-2 and SWG-3 respond more quickly to precipitation than does SWG-1. SWG-2 and SWG-3 flows tend to peak earlier than SWG-1 (see Figure 16), and for runoff events #5 and #8 SWG-3 peak flow is higher than SWG-1 (see Figure 17). SWG-2 and SWG-3 also tend to exhibit several successive peaks in response to brief periods of high rainfall intensity, whereas SWG-1 exhibits a less flashy response. These differences reflect variation in drainage area and topography among the three subcatchments, with SWG-1 having longer hydrologic travel distances and travel times than SWG-2 and SWG-3.

Peak flows tend to scale with storm-total precipitation and subcatchment area (see Figure 20), and also depend on precipitation intensity and watershed characteristics. Runoff event #8, produced by a precipitation event (0.65 in. over 9 hours) with over half (0.36 in.) of the total rain falling in a single hour, exhibits very rapid flow increase at all three SWG locations and a much higher SWG-3 peak flow (0.73 cfs) than occurred at the other two gages (< 0.2 cfs). Event #2 is another unusual case in which the SWG-1 peak flow rate is much higher than at SWG-2 and SWG-3 (see Figure 16). The higher SWG-3 flow peak during runoff event #8 is probably related to catchment size and shape effects on hydrologic response time coupled with precipitation intensity, whereas the extremely high SWG-1 peak during runoff event #2 may reflect higher total precipitation input and higher rainfall intensity in the SWG-1 subcatchment than the rest of the NT-3 watershed.




See Figure 17 for duration and magnitude of nine events.

**Figure 20. Peak Flow Rates Plotted Against Storm-total Precipitation for the Nine Runoff Events**

During the late February 2015 period of ice and snow accumulation, event (#9) peak flows are small relative to total precipitation because snowmelt patterns controlled runoff (see Figure 20) and produced three distinct peaks following precipitation on February 21 (see Figure 17).

Longer-term stream flow data are available from a flume gaging station, BC-NT3, located on NT-3 at a location about 100 ft upstream of the junction with Bear Creek (see location on Figure 7). The BC-NT3 station is located approximately 1200 ft downstream of the NT-3 culvert at the Haul Road along the southwest corner of the EMDF site. A restrictor plate with a vertical slit was placed across the upstream

side of this culvert at the end of remedial actions completed at the Bone Yard/Burn Yard site in September 2002 (the culvert was plugged during construction activities between May and September 2002 while NT-3 stream flow was diverted to NT-2). Since September 2002, this restrictor plate has constrained the runoff rates from the upper NT-3 watersheds at the EMDF site and created artificial wetland areas immediately above and behind the Haul Road. Exhibit A.13 contains streamflow hydrographs illustrating the daily average flow rates from 2000 through 2014 at the BC-NT3 gaging station, along with more recent hourly BC-NT3 flows from October 1 through December 31, 2014. The recent hourly BC-NT3 flow data are shown along with the Phase I continuous streamflow monitoring records for the three EMDF surface water gaging stations to permit comparison during the first month of the Phase I reporting period (December 2014). For the relatively small flow events #1 and 4, peak BC-NT3 flow rates were much higher than peak flows at SWG-1 and 3, whereas during the larger event #2, peak flows at BC-NT3 and SWG-1 were of similar magnitude (1462 and 1324 gpm, respectively). Further analysis of the relationships between hydrologic response at the EMDF site and the downstream BC-NT3 gaging station are recommended as additional BC-NT3 records are issued on a quarterly basis and as additional Phase I stream flow data are produced [at least through the end of September 30, 2015 (FY 2015)]. Comparisons of future stream flow hydrographs between the three Phase I SWG stations and the BC-NT3 gaging station would allow for comparisons of flow rates and precipitation records over about a fifteen year historical period (bearing in mind the effects of the restrictor plate). Correlations between extreme rainfall events could be assessed for a decade or more of records from BC-NT3.

Given that the precipitation events recorded during the three month reporting period are relatively small magnitude, high frequency occurrences (refer to Section 7.1.1), peak flow rates higher than those reported here are almost certain to occur in an average year. The USGS Tennessee Water Science Center has developed a web-based application (http://water.usgs.gov/osw/streamstats/tennessee.html) for estimating peak flows for unregulated Tennessee streams (Law and Tasker, 2003, Ladd and Law, 2007). This statistical tool utilizes multivariate regression to predict peak flows of varying return period as a function of catchment size, stream channel slopes, and local climate factors. The empirical model was developed from data for catchments ranging in size from 2.5–2,560 square miles, and may not be accurate for catchment areas outside of this range. Peak flows for the SWG-1 subcatchment (0.3 square miles) predicted with this tool are likely to be underestimates because very small catchments are more likely to experience uniformly large and intense rainfall inputs. These SWG-1 estimates for 2-year, 5-year, and 10-year return period peak flows are presented here as a rough indication of possible high flow rates in the future, and should not be considered to be statistically robust predictions (see Table 6).

**Table 6. Peak Flow Rates Estimated for the SWG-1 Subcatchment**

| Return Period (years): | 2 | 5 | 10 |
|---|---|---|---|
| Annual Maximum Peak Flow Rate (cfs) | 9.77 | 16.8 | 22.5 |

Rates estimated using data obtained from Tennessee StreamStats using the regression model of Law and Tasker, 2003.

Peak runoff for the nine major precipitation events for the Phase I monitoring period to date are shown in Table 7. The peak flow ranges include:

- SWG-1: 0.14-9.63 cfs (62.84 – 4322 gpm)
- SWG-2: 0.02-0.64 cfs (8.98 – 287.3 gpm)
- SWG-3: 0.13-2.17 cfs (58.35 – 974 gpm)

**Table 7. Peak flow Rates at Stream Gages for Current Phase I Monitoring Period**

| Runoff Event | Dates | Peak Flow (cfs) | | | Peak Flow (gpm) | | |
|---|---|---|---|---|---|---|---|
| | | SWG-1 | SWG-2 | SWG-3 | SWG-1 | SWG-2 | SWG-3 |
| 1 | 12/4/2014 - 12/2/2014 | 0.14 | 0.04 | 0.13 | 63.6 | 16.2 | 60.5 |
| 2 | 12/6/2014 - 12/12/2014 | 2.95 | 0.46 | 0.99 | 1323.6 | 205.2 | 442.7 |
| 3 | 12/22/2014 - 12/27/2014 | * | 0.64 | 2.17 | * | 286.6 | 973.8 |
| 4 | 12/28/2014 - 1/3/2015 | 0.18 | 0.05 | 0.13 | 81.4 | 22.3 | 56.8 |
| 5 | 1/3/2015- 1/9/2015 | 1.49 | 0.46 | 1.75 | 668.0 | 207.7 | 785.0 |
| 6 | 1/12/2015- 1/19/2015 | 0.70 | 0.19 | 0.82 | 312.3 | 86.1 | 365.9 |
| 7 | 1/23/2015- 1/31/2015 | 0.19 | 0.02 | 0.19 | 84.9 | 10.0 | 84.0 |
| 8 | 2/1/2015- 2/4/2015 | 0.20 | 0.13 | 0.73 | 89.2 | 57.6 | 327.5 |
| 9 | 2/20/2015- 2/26/2015 | 1.01 | NA | 0.87 | 453.6 | NA | 389.4 |

* A peak flow value of 9.63 cfs (4321.4 gpm) was calculated for Event #3 at SWG-1 based on the hourly water level readings. Subsequent analysis indicated that this peak flow value was far too high relative to the total precipitation for this event. A check of Alliant field notes indicated that a wooden pallet had been swept into the upstream end of the flume during this runoff event. This was presumed to have distorted and erroneosuly magnified the water level readings, resulting in invalid peak flowsfor Event #3 at SWG-1.

The baseflow rates at the three Phase I stream gages are below the minimum quantifiable flows rated by the vendor (OpenChannelFlow™) for the two types of flumes installed:

- For SWG-1 and SWG-3 – 0.0964 cfs (43.26 gpm)
- For SWG-2 - 0.0373 cfs (16.76 gpm)

These limits are set by the vendor rating tables (see Exhibit A.13) where the water level in the flume is at 0.1 ft (for both flume sizes). The rating tables note "excessive error due to fluid-flow properties and boundary conditions" for flow rates where water levels fall below 0.1 ft.

### 7.1.4 Surface Water Observational Monitoring Results

The six Phase I quasi-weekly observational monitoring stations are highlighted on Figure 15 with yellow ovals. The locations include the three headwater springs originally identified by USGS surveys of BCV circa 1992, and three locations along the east and west upper tributaries of NT-3 at locations intermediate between the headwater springs and the SWG locations. Details of the monitoring activities are described above in Section 4.2.1.2. The results of weekly water quality parameter readings, photographs, and estimates of flow rates are provided in Exhibit A.15 along with spreadsheet compilations of data for the initial 12 weeks of monitoring (from December 10, 2014 through February 27, 2015).

Part of the rationale for weekly monitoring was to determine the nature of spring and stream flow along the upper most reaches of the NT tributaries at the EMDF site over the course of a full year. The weekly observational data would document whether or not the headwater springs and upper sections of the stream channels become dry or flow is intermittent during the late summer and fall growing season when evapotranspiration is highest and flow is typically at its lowest. Field traverses before the Phase I investigation indicated that each of the three springs mark the beginning of the stream channels with surface water runoff along the uppermost sections of the NT-2 and NT-3 tributaries. The three springs are relatively small features no more than 1–2 ft wide and only a few inches deep. The natural stream channels below the springs follow the primary NT tributary valley floors as shown by the dashed lines on Figure 15. The spring at EMDNT3-SP3 (not monitored during Phase I) located just above the middle flume location at EMDNT3-SWG2 marks the start of a relatively smaller and shorter stream channel between the two primary NT-3 tributaries crossing the middle and western parts of the EMDF site. No other springs or seeps have been identified along the other narrow ravines that drain the steep south facing slopes of Pine Ridge. The locations of other individual seeps and broad flat seepage areas indicated as wetlands are shown on Figure 15 within and adjacent to the proposed EMDF footprint. Each of these areas should be assessed during a Phase II investigation to ensure data are available for proper design of the underdrain system. Road construction for the new UPF haul road included reworking of the seepage/wetland areas along the southeast part of the EMDF footprint (see EMDNT2-SE1, -SE2, and SE3 locations on Figure 15). Outlets for the proposed underdrain systems would be located along these valleys as they represent discharge zones for shallow/intermediate ground water. Water within the newly constructed wetland mitigation pond near EMDNT2-SE2 is almost certainly maintained by shallow ground water discharge.

The results of the weekly surface water observational monitoring flow data are presented below. The results from the weekly observational water quality data are reviewed separately in Section 7.1.5 in conjunction with the water quality results from continuous monitoring at SWG-1, SWG-2, and SWG-3.

#### 7.1.4.1 Weekly Observational Monitoring Flow Data

The weekly Phase I data indicate that flows during the wetter winter/early spring season are continuous at and below the springs (see photographs and estimates of flow rates in Exhibit A.15 for details). Table 8 presents stream flow statistics for the three locations EMDNT3-ST1, -ST2, and -ST3, located between the SWG locations 1 and 3, and the two headwater springs EMDNT3-SP1 and –SP2, and the seep at EMDNT3-SE1. It should be noted that these flow measurement calculations are relatively inaccurate and based on simple measurements of flow rates and cross sectional areas of the stream channels (the flume data above the minimum 0.1 ft level are much more accurate and reliable than the observational data). Flows at EMDNT3-ST3 may be considered slightly more accurate in that measurements were made there using the culvert outfall to contain and time water flow. Baseflow averages in Table 8 were calculated based on the weekly measurements made during the flat sections of the flow recession curves shown in Figure 17. Flows were averaged for the four baseflow measurements made on December 17, 2014, and on January 21 and 29, and February 11, 2015. The data in Table 8 indicate baseflow rates ranging from 0.007 cfs (3.1 gpm) at EMDNT3-ST3 to 0.056 cfs (25 gpm) at EMDNT3-ST1 located on the primary branch of NT-3. EMDNT3-ST2 is located just downstream of a relatively broad wet season seepage area at EMDTN3-SE1 where ground water discharges near the base of a swale draining from Pine Ridge. The baseflow average at EMDNT3-ST2 is apparently slightly more than that at EMDNT3-ST3 which is located further upstream along the primary channel of the west tributary adjacent to the EMWMF. These data provide an indication of the very low baseflow rates that occur at the site during the wet winter months. Site reconnaissance during the warm growing summer/fall seasons indicate that these stream paths hold water in puddles along the channel but that the movement of base flow water is barely perceptible.

**Table 8. Flow Statistics for NT-3 Tributary Locations between Headwater Springs/seeps and SWG Locations**

| Weekly Surface Water Monitoring Location | Statistics | Flow (cfs) | Flow (gpm) |
|---|---|---|---|
| EMDNT3-ST1 | Average | 0.073 | 32.7 |
| | Maximum | 0.134 | 60.1 |
| | Minimum | 0.020 | 8.98 |
| | Baseflow Average | 0.056 | 25.0 |
| EMDNT3-ST2 | Average | 0.033 | 14.9 |
| | Maximum | 0.054 | 24.2 |
| | Minimum | 0.017 | 7.6 |
| | Baseflow Average | 0.034 | 15.1 |
| EMDNT3-ST3 | Average | 0.01 | 6.22 |
| | Maximum | 0.027 | 11.9 |
| | Minimum | 0.001 | 0.40 |
| | Baseflow Average | 0.007 | 3.1 |

Note:

Baseflow averages are based on observational monitoring data from December 17, 2014, January 21 and 29, 2015, and February 11, 2015. These four dates were selected based on the stream flow recession curves in Figure 17 as the lowest four runoff periods representative of baseflow conditions. See locations on Figure 15. At the NT3-ST2 location lower flows were measured at other times, skewing the overall average below the baseflow average – see detailed tables in Exhibit A.15 for details.

### 7.1.5 Surface Water Quality

Continuous monitoring of water temperature, pH, specific conductivity (SpC), and ORP at the three surface water gaging stations, along with weekly observational monitoring of these parameters at the locations described in Section 7.1.4 provide a general characterization of surface water quality at the EMDF site during the reporting period. The continuous collection (generally at a 20 min interval) of these data is potentially valuable for understanding water quality over the full range of flow conditions that may occur. During the three month reporting period, a variety of challenges including sensor malfunctions, calibration errors, cold weather impacts, and development of unrepresentative microenvironments in stagnant water surrounding sensors has limited the amount of data that is useful for site characterization purposes. Fortunately, the quasi-weekly field measurements at stream sites upstream of SWG-1 and SWG-3 are more consistent and can be used as a basis for assessing the reliability of the continuous monitoring data as accurate measures of water quality variations at the EMDF site.

In the following description, general observations on water quality variations are limited to the most reliable portions of the continuous monitoring records. Assessment of data reliability is based upon the similarity of parameter values to weekly independent field measurements and on the magnitude of unusual or unexplained variations in parameter values in relation to calibration uncertainties and the magnitude of responses to runoff events, and upon comparison among records for different parameters or sites over the same time period. Using these data quality criteria, very little of the continuous records of

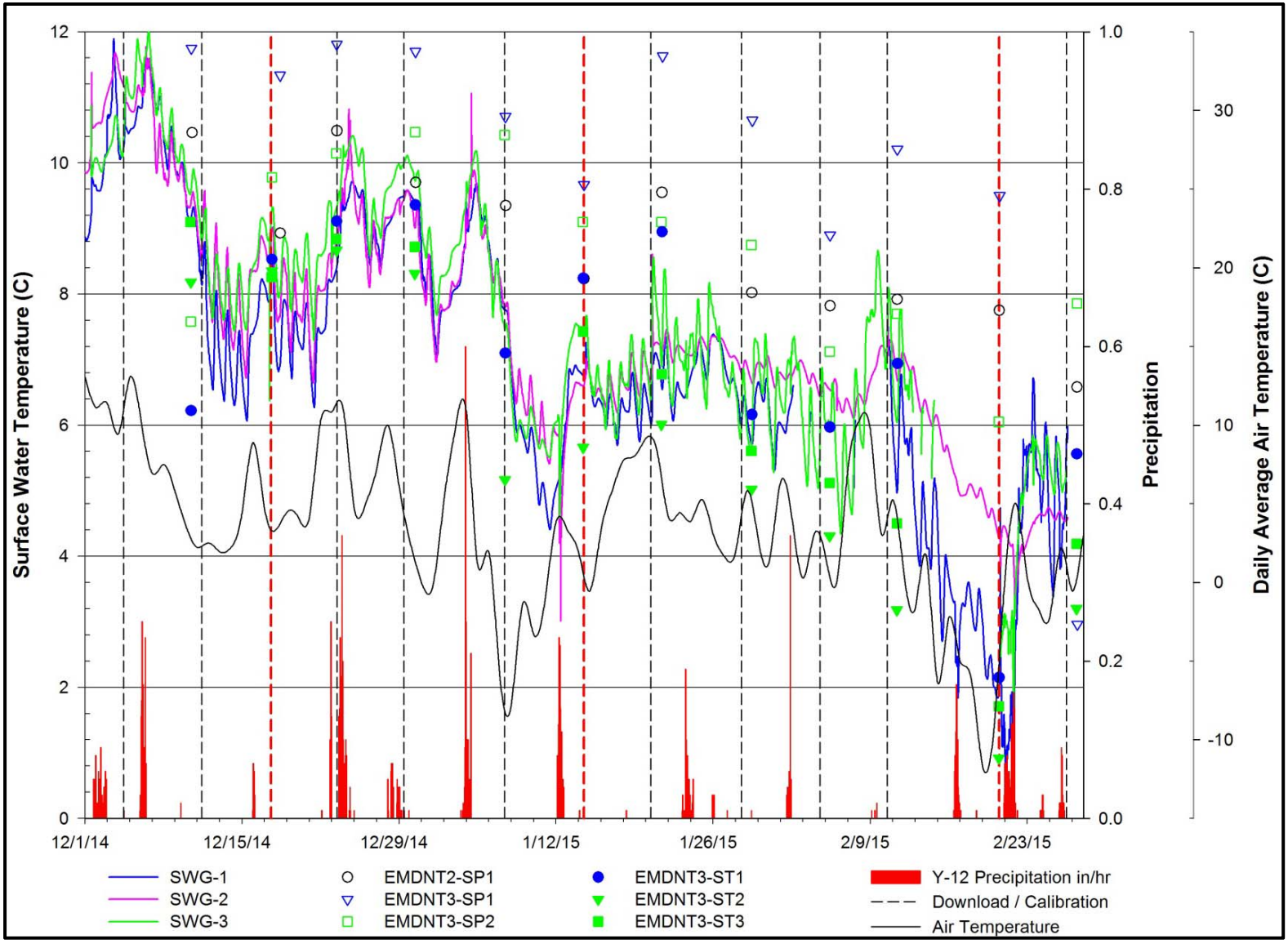
ORP were found to be acceptable, and so characterization of surface water in the following subsections is based solely upon records of water temperature, SpC, and pH. In addition, the records for the latter two parameters were not judged as sufficient for making credible estimates of mean values or observed ranges of values for comparison among surface water stations or among discrete time periods. Consequently, only some general observations about the observed ranges of SpC and pH over the reporting period are presented, along with an illustration of water quality responses to precipitation and runoff during a time period with reliable data.

#### 7.1.5.1 Surface Water Temperatures

Over the three month reporting period, surface water temperatures closely tracked both daily and longer term variations in air temperature measured nearby (see Figure 21). The continuous temperature data appear to be reliable throughout the reporting period, and in general are close to the temperatures measured manually at the observational monitoring stream sites in the SWG-1 subcatchment (EMDNT3-ST1) and SWG -3 subcatchment (EMDNT3 -ST2, and –ST3) . Temperatures measured at the three springs (EMDNT2-SP1, EMDNT3-SP1 and -SP2) were generally higher than temperatures at the surface water stations (SWG-1, -2, and -3) by one to three degrees C (Figure 21), consistent with the difference between ground water temperatures and surface air temperatures (see Section 7.2.3.4, Figure 31, and Figure 32). Temperatures measured at the observational monitoring stream sites were occasionally lower (most commonly at EMDNT3-ST2 and –ST3) or higher (or both, e.g., Jan 14) than temperatures at the surface water stations, depending on the date and time of day of the field measurements (see Figure 21). Note that the colors for the gaging station temperature records and observational monitoring sites in Figures 21 and 22 differentiate data for the SWG-1 subcatchment (blue) and the SWG-3 subcatchment (green). These differences arise in part from daily temperature cycles (field observations were obtained over a period of a few hours during which air temperatures changed), and may also reflect differences in the accuracy of individual instruments.

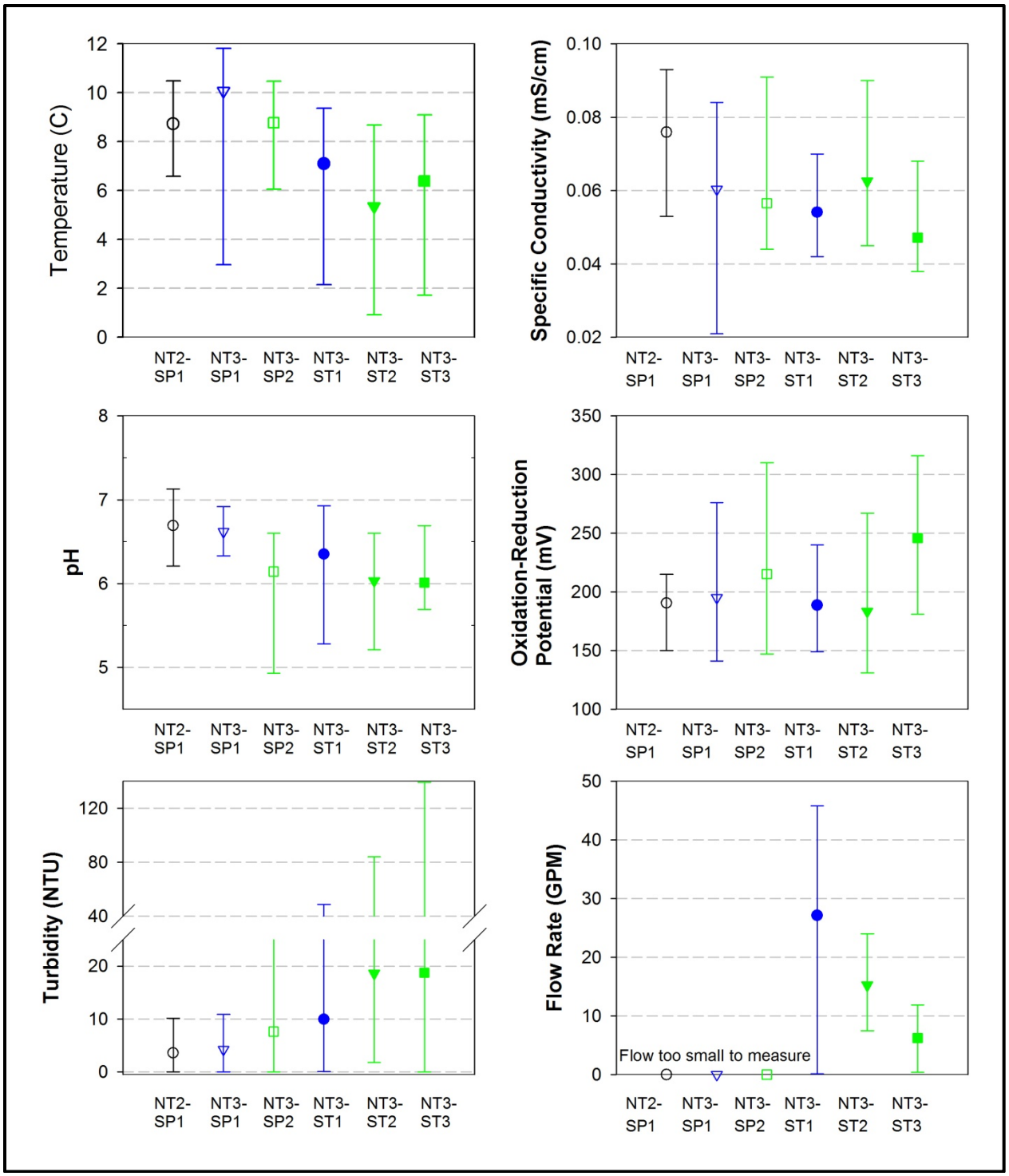
#### 7.1.5.2 Specific Conductivity and pH

SpC recorded at the surface water gaging stations ranged from approximately 0.05–0.35 mS/cm over the reporting period. Observations at SWG-1 and SWG-3 SpC were typically in the range from 0.15–0.35 mS/cm, with SpC rapidly decreasing to lower values during runoff events. In contrast, SpC values at SWG-2 were typically less than 0.13 mS/cm, with rapid, smaller magnitude decreases during storm runoff similar to the other two surface monitoring stations. SpC values measured at the six observational monitoring sites were never greater than 0.1 mS/cm during the three month reporting period (see Figure 22). These field observations of low SpC values at all of the spring and stream sites (in contrast to consistently higher values at SWG-1 and SWG-3) could indicate significant discharge of ion-rich ground water between those locations and the surface water stations. However, given that all of the ground water monitoring wells except for GW-971(S) exhibited SpC values consistently greater than 0.1 mS/cm (see Figure 33), it is also possible that the relatively low SpC values at the observational monitoring sites reflect a persistent difference in calibration between the portable instrument used for the weekly field measurements and the SpC sensors on the multiparameter sondes at the surface water sites and ground water monitoring wells.




Weekly observational data are shown as symbols, continuous data as solid lines.

**Figure 21. Phase I Surface Water Temperature Data**




Symbols represent average values over the the reporting period; error bars indicate minimum and maximum observed values for each parameter.

**Figure 22. Summary of Weekly Surface Water Quality Measurements Collected at the Six Observational Monitoring Sites**

.

Continuous records of pH logged at the three surface water gaging stations ranged between 6 and 7 for all but the early weeks of the record for SWG-1 and SWG-3, when pH values higher than 7 were recorded. Differences between pH recorded at those two stations and at the observational monitoring sites in the SWG-1 and SWG -3 subcatchments (blue and green symbols in Figure 22) were larger during these early weeks than for the remainder of the record, suggesting that some of the earlier high pH readings could be caused by calibration errors or sensor malfunctions. The pH measurements at EMDNT3-ST2 and -ST3 were nearly always lower (typically 0.5–1.5 units lower) than concurrent downstream readings at SWG-3, whereas measurements at EMDNT3-ST1 tended to be within 0.5 units of concurrent downstream pH readings at SWG-1. These apparent increases in pH along surface flow pathways correspond to similar patterns in the SpC data.

SWG-2 pH values were generally lower than for SWG-1 and SWG-3 prior to January 20. Beyond that date SWG-2 pH data are less reliable and relatively large portions of the SWG-1 and SWG-3 data are missing or bad due to instrument failure during cold weather. Variations of surface water pH during runoff events were complex and variable among the three surface water stations and among events, but do show some consistency over time and similarities to SpC variations. Figure 23 illustrates the variation in water quality parameters in response to runoff during a period of the record with reliable data for all three surface water gaging stations and includes data for three stream observational monitoring sites upstream of SWG-1 and SWG-3. Both pH and SpC at the surface water stations decrease rapidly as flow increases in response to precipitation, with the exception of SWG-2 which exhibits more complex responses that include increasing pH during some flow events prior to January 20. Decreasing SpC and pH is consistent with the arrival of relatively dilute, slightly acidic runoff at the surface water gaging stations.

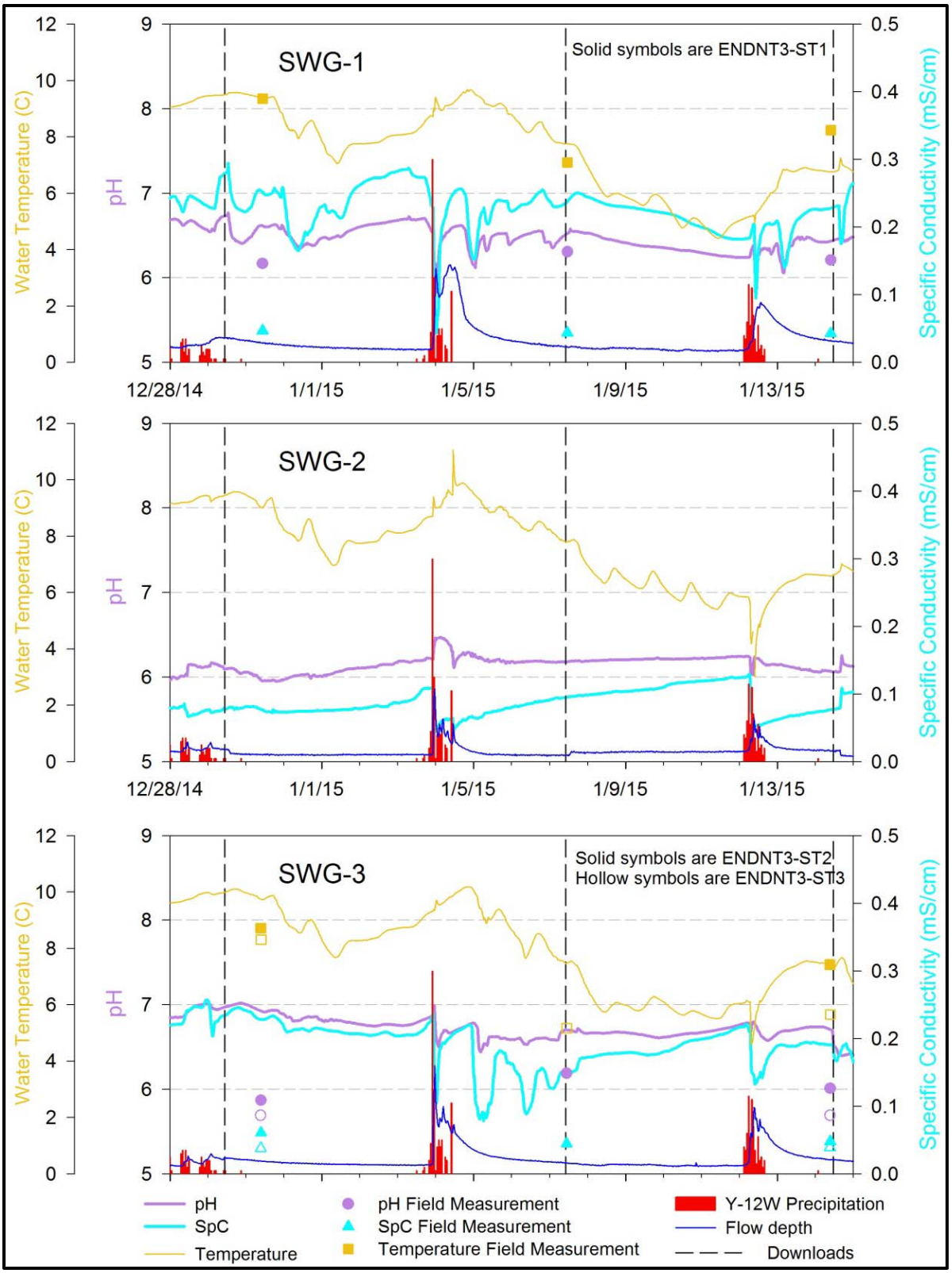
## 7.2 HYDROGEOLOGY

The hydrogeology of the regolith and bedrock at the EMDF are reviewed below based on the limited Phase I results. Geological characteristics (lithologic, stratigraphic, and structural features) combined with subsurface hydrology are fundamental to understanding and estimating subsurface ground water flow paths and flow rates in soils, saprolite, and bedrock. These characteristics are in turn important to risk assessment modeling used to simulate the hypothetical fate and transport of contaminants via ground water and surface water pathways and to back calculate preliminary waste acceptance criteria for the EMDF. The Phase I hydrogeological data support the conceptual engineering design for the three dimensional configuration of the proposed landfill. The Phase I results also provide a foundation for planning a more thorough Phase II investigation to fully characterize the site hydrogeology and to support a detailed engineering design.

The hydrogeology section is introduced with a review of the sequence of geologic formations and the typical vertical subsurface profiles at the EMDF and along strike elsewhere in BCV. Subsequent sections review ground water conditions for the shallow water table and intermediate ground water intervals based on Phase I data. The final sections present and interpret the hydrogeology of the regolith, followed with a review of the hydrogeology of the underlying bedrock materials.

### 7.2.1 Stratigraphic Section

The geologic formations underlying the EMDF site include the Lower Cambrian Rome Formation (Sandstone Member) and the lower four formations of the Middle Cambrian Conasauga Group – in ascending order, the Pumpkin Valley` Shale, the Rutledge Limestone (Friendship Formation), the Rogersville Shale, and the Maryville Limestone (Dismal Gap Formation). The outcrop belts of these sedimentary rock formations are shown on Figure 1 and their general subsurface dip toward the southeast is illustrated in cross sectional views on Plate 3. All but the Rome Formation outcrop directly below the




Symbols are water quality measurements at upstream observational monitoring locations.

**Figure 23. Example of Reliable Water Quality Data at three SWG Stations**

proposed EMDF footprint. The formations typically dip on the order of 45° to the southeast and trend along a strike direction that is parallel with the trend of Pine Ridge and BCV at the EMDF site (N52°E).

The five Phase I well pair locations were originally placed with one pair in each of the five outcrop belts at and near the EMDF site. However as previously noted, the upgradient well pair (GW-968[I]/GW-969[S]) originally intended to penetrate the Rome Formation atop Pine Ridge was moved downhill to a new location within the outcrop belt of the Pumpkin Valley Shale.

The Phase I investigation was not intended to gather data across the entire geologic section below the EMDF site. Missing geological sections are apparent on the cross sections shown in Plates 3 and 4. With site approval, Phase II investigations will provide additional data to close these current data gaps.

### 7.2.2 Typical Subsurface Hydrogeological Profile

The results from the Phase I investigation and from subsurface investigations adjacent to the EMDF site along geologic strike indicate a typical downward subsurface profile in undisturbed upland areas of the EMDF. This profile is illustrated in Figure 24 and includes: (1) a thin topsoil layer, (2) a clayey residuum interval, (3) variably weathered bedrock (saprolite), and (4) unweathered bedrock.

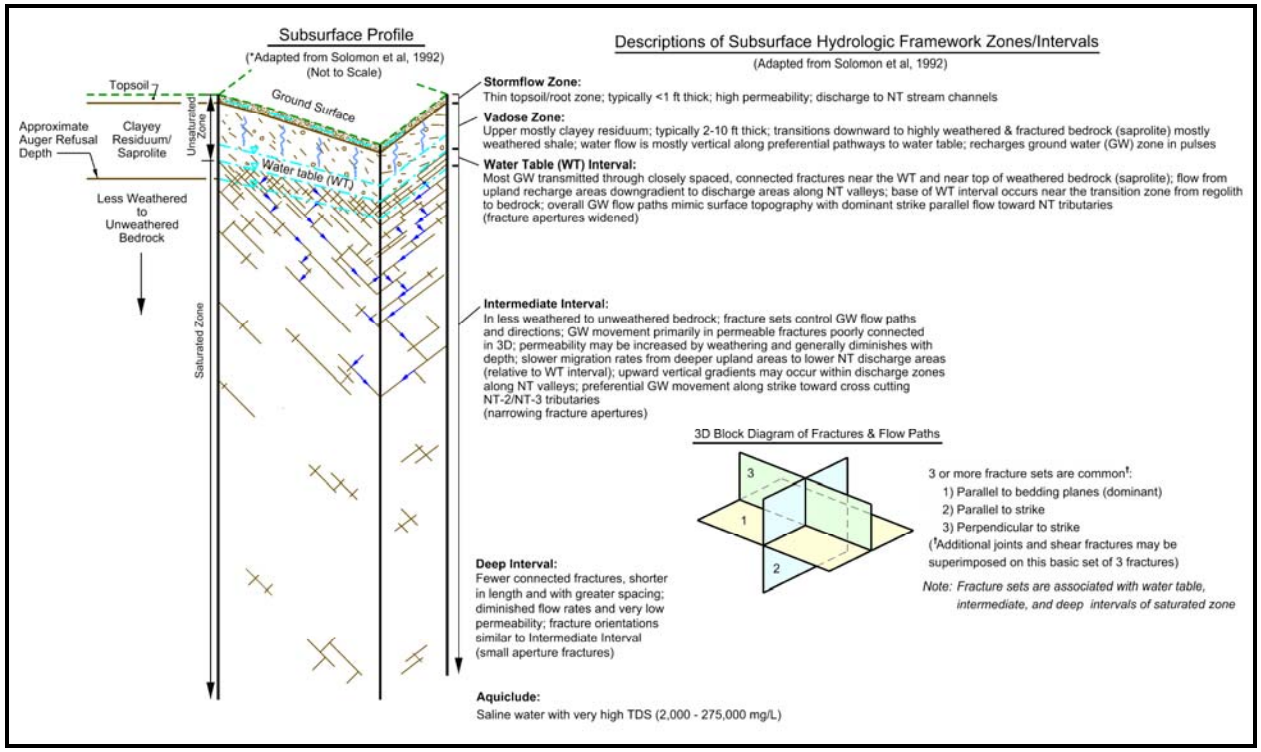



**Figure 24. Typical Subsurface Profile in Relation to the Conceptual Hydrogeological Model for Upland Areas at the EMDF Site**

The natural subsurface profile at the EMDF site typically consists of a thin topsoil layer or root zone of organic rich clayey soils from a few inches to <1 ft thick below the ground surface. Below this relatively more porous and permeable topsoil layer is a zone of clayey/silty residuum that typically varies from less than two to ten feet in thickness. Below this is an interval of weathered fractured sedimentary rocks (saprolite) that can generally be drilled using a HSA rig to refusal atop less weathered or unweathered fractured competent bedrock. The thickness of these intervals and downward transition from one to the next may be fairly sharp or gradual depending in part on the degree of chemical weathering and topography. The degree of weathering and fracturing generally decreases with depth with a typical equivalent decrease in effective porosity, permeability, and ground water flux.

Along the present valley floors of the NT tributaries cross cutting the EMDF footprint, the upper portion of the zone of clayey residuum may be replaced with stream channel and floodplain sediments (alluvium) that vary in width and thickness (see Figure 25). Colluvium also may occur surficially along the lower marginal slopes of these valleys. The nature and extent of alluvium and colluvium is currently undefined at the EMDF but would warrant investigation during a Phase II investigation as these deposits would be removed for placement of the proposed underdrain system and overlying geobuffer. Ancient paleo-colluvial/alluvial deposits may also occur at the site outside of the current NT stream valleys, as demonstrated by detailed soil surveys conducted for the LLWDDD in WBCV (see Figure 26; adapted from Lietzke et al, 1988). However, these loose deposits are anticipated to be relatively minor in extent and would be removed prior to landfill construction.

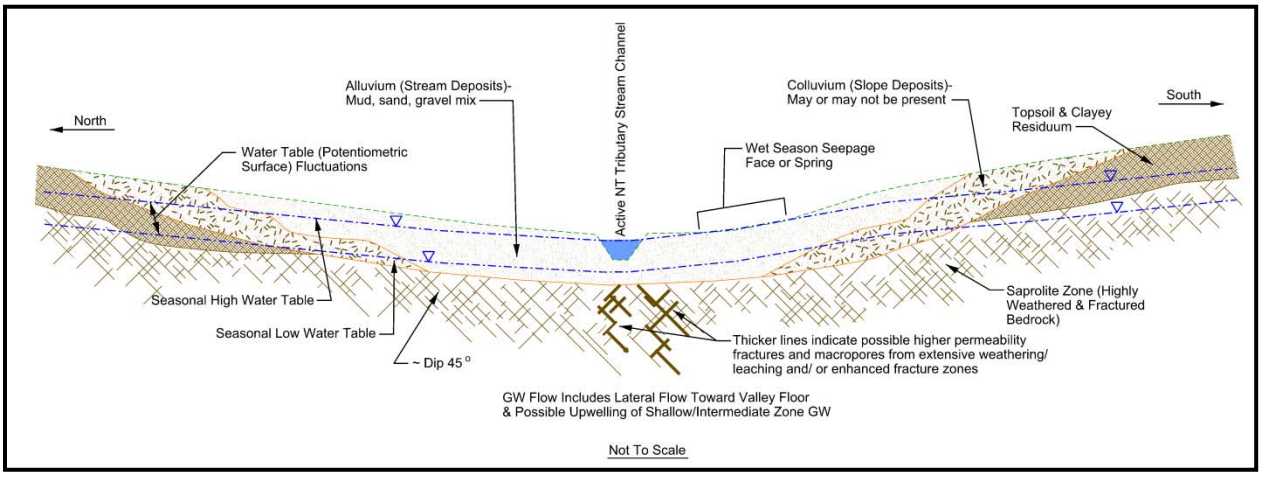



**Figure 25. Typical Subsurface Profile Anticipated Across the Valley of NT-3 near the Center of the EMDF Site**

The depth to ground water or vadose zone thickness within this typical vertical profile varies from upland to lowland areas. Vadose zone thickness is greatest in upland areas such as those along Pine Ridge and the spur ridge along the south side of the EMDF footprint and thins into the NT valley floors where shallow ground water is assumed to converge and seep into surface water stream channels supporting base flow along the valley floors during the wet non-growing season. Shallow ground water also discharges to springs at point locations at the base of tight headwater ravines of the NT-3 tributaries and across seepage faces along portions of the NT valleys (See Figure 15 for the locations of springs, seeps, and wetlands where shallow ground water intersects the surface at and near the EMDF site). Phase I water level data for the wet non-growing season thus far indicate that shallow ground water occurs within regolith materials above auger refusal bedrock depths at all Phase I well locations, except at GW-976(I)/GW-9777(S) where the water table is found roughly 20 ft below the bedrock/regolith interface. The Phase I data are consistent with the migration of shallow water table and intermediate level ground water migration from upland areas downgradient toward discharge zones along the NT valley floors.

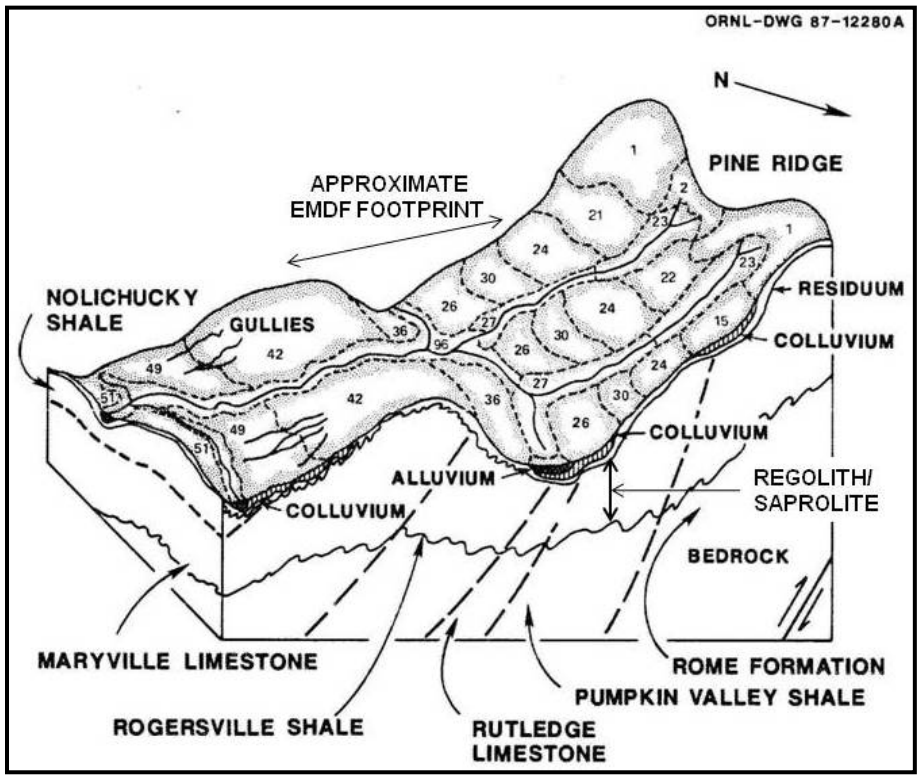



Figure 8a from Lietzke et al 1988, LLWDDD Site.

**Figure 26. Diagram Illustrating Relationships between Alluvium/Colluvium, Residuum, Saprolite, Bedrock, and Topography Anticipated at the EMDF Site**

### 7.2.3 Ground Water

Results from the drilling, testing, and monitoring of the five Phase I well pairs provide preliminary data on ground water conditions for the shallow water table and intermediate intervals at the EMDF. Results associated with ground water are reviewed in the following subsections. Water level hydrographs for the well pairs define water level depths and fluctuations in response to precipitation events. The highest water levels in the shallow wells provide benchmarks for assessing relationships between basal landfill conceptual design features and high ground water levels that occur during each wet non-growing season. Potentiometric surface contour maps for the water table interval define general flow directions and gradients across the EMDF and demonstrate convergence of shallow ground water flow from topographically high recharge areas toward discharge zones along the NT-2/NT-3 tributaries. The water table across much of the EMDF footprint during the wet winter non-growing season monitored thus far occurs within the regolith, except for the area along the south edge of the footprint where the water table occurs at lower elevations down within bedrock. The contour maps and water levels among well pairs provide data for estimating variations in horizontal and vertical gradients. Hydraulic conductivity values were determined for regolith materials based on slug tests in shallow wells and laboratory analysis of Shelby tube samples. Packer tests provide a range of hydraulic conductivity values for selected bedrock intervals. All of these results provide baseline data for further project planning and EMDF design.

#### 7.2.3.1 Phase I Ground Water Level Data

Hydrographs illustrating fluctuations in water level elevations among the five Phase I well pairs are provided in Figures 27 and 28. The figures illustrate the initial period of continuous water level monitoring available for the Phase I report from November 21, 2014, through February 26, 2015. DOE plans to continue with continuous monitoring at least through the end of FY 2015 as long as the proposed EMDF continues to remain a viable disposal site. The hydrographs show the surveyed elevations of the ground surface at each well so that the vadose zone interval is illustrated on the hydrographs. The hydrographs include hourly precipitation data from the Y-12 west tower meteorological station. The hydrographs also show the overall range in water level fluctuations (maximum/minimum elevations) along the left margin for the period of record shown and weekly manual measurements made using an electronic water level indicator. The manual measurements allow for accurate calibration of the downhole In-situ® Troll instruments used for recording continuous water level data at hourly intervals. Where the continuous monitoring data are at odds with the manual measurements, the manual measurements (shown by black triangles in the hydrographs) should be regarded as valid, as there is virtually no potential for instrument error or instrument drift using electronic water level indicators. The high and low water level elevations, depths relative to ground surface, and range of fluctuations in each of the Phase I wells are also presented in Table 9 and illustrated on the cross sections in Plates 2 through 4.

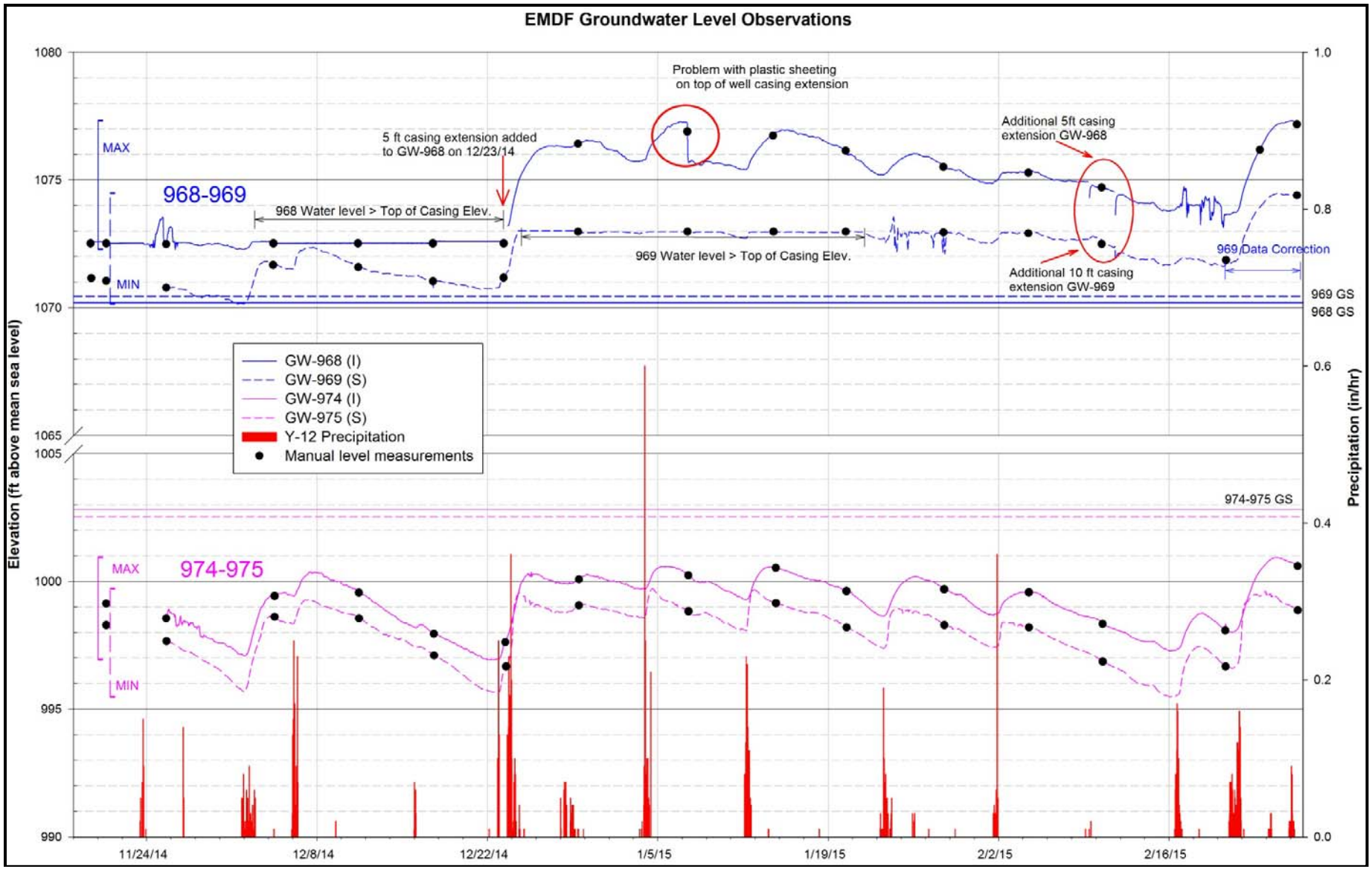



**Figure 27. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs**

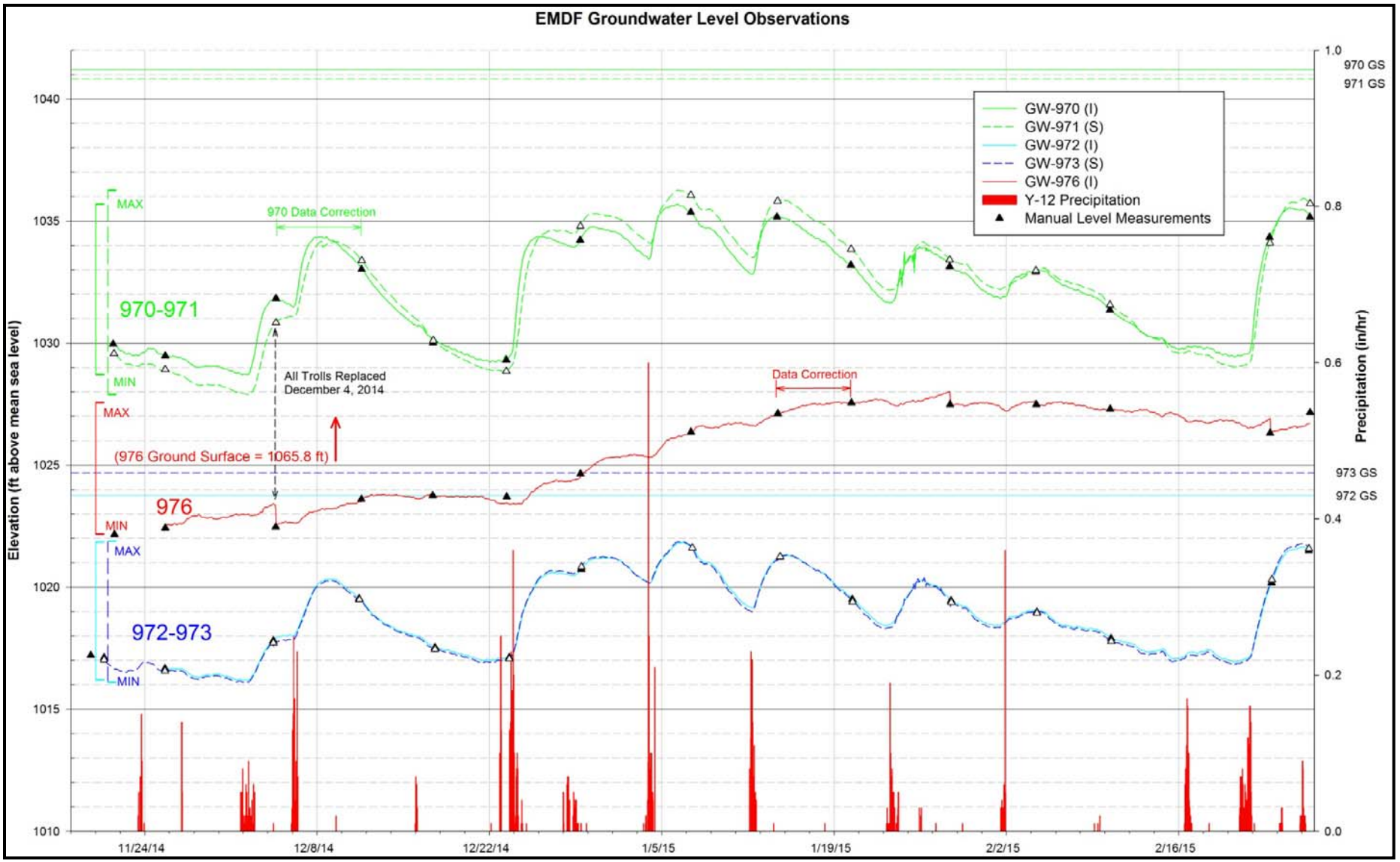



**Figure 28. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs**

**Table 9. Highest and Lowest Water Level (Potentiometric Surface) Elevations in Phase I Wells**

| Well | Lowest Potentiometric Surface | | | Highest Potentiometric Surface | | | |
|---|---|---|---|---|---|---|---|
| | Elevation (ft AMSL) | Date | Depth (ft bgs) | Elevation (ft AMSL) | Date | Depth (ft bgs) | High/Low Difference (ft) |
| GW-968(I) | 1072.29 | 12/1/2014 | -2.1 | 1077.33 | 2/26/2015 | -7.1 | 5.0 |
| GW-969(S) | 1070.15 | 12/1/2014 | 0.3 | 1074.48 | 2/24/2015 | -4.0 | 4.3 |
| GW-970(I) | 1028.72 | 12/1/2014 | 12.2 | 1035.70 | 1/6/2015 | 5.2 | 7.0 |
| GW-971(S) | 1027.90 | 12/2/2014 | 12.8 | 1036.26 | 1/6/2015 | 4.4 | 8.4 |
| GW-972(I) | 1016.19 | 12/2/2014 | 7.4 | 1021.85 | 1/6/2015 | 1.7 | 5.7 |
| GW-973(S) | 1016.11 | 12/1/2014 | 8.4 | 1021.89 | 1/6/2015 | 2.6 | 5.8 |
| GW-974(I) | 996.93 | 12/22/2014 | 5.9 | 1000.95 | 2/24/2015 | 1.9 | 4.0 |
| GW-975(S) | 995.49 | 2/16/2015 | 7.0 | 999.72 | 1/4/2015 | 2.8 | 4.2 |
| GW-976(I) | 1022.17 | 11/21/2014 | 43.7 | 1027.56 | 1/20/2015 | 38.3 | 5.4 |

Notes and Abbreviations:

- For the current three months of continuous monitoring from November 21, 2014, to February 26, 2015.
- Note that GW-976(I) high and low elevations come from manual measurements; all others were obtained from continuous monitoring data
- Data for the approximately three-month period of record available for the Phase I report comes from continuous monitoring using In-situ® Troll instruments with weekly manual calibration measurements made using an electronic water level indicator.

Ft AMSL feet above mean sea level

The close correlation between precipitation events and changes in water levels are obvious for all well pairs except for GW-976(I) where the water level response to precipitation events is much more subdued and gradual. Upward gradients are indicated in Figure 27 for the well pairs GW-968(I)/GW-969(S) and GW-974(I)/GW-975(S), both of which show consistently higher total heads (i.e., water levels) for the deeper versus shallow wells. For the GW-968(I)/GW-969(S) well pair, the water levels in GW-968(I) in early December are about 2.0 ft higher than those in GW-969(S) and about 1.7 ft higher on December 24, 2014, before the water levels in GW-969(S) exceeded the TOC elevation. In the GW-974(I)/GW-975(S) well pair, water levels in GW-974(I) generally average from around 0.5 to 1.3 ft higher than those in GW-975(S). Exceptions occur when water levels rise in both wells in response to precipitation events. During those shorter periods of rising water levels the head differences are reduced and may even be coincident or overlap for short periods where the water levels rise much faster in the shallow wells with respect to the deeper well. This appears reasonable as the shallow well screen/filter pack intervals intersect with the water table surface and would be expected to respond more directly with pulses of recharge water added to the top of the water table with rainfall/recharge events.

Water level conditions in GW-970(I)/GW-971(S) are similar to those in GW-974(I)/GW-975(S) except for a number of shifts between upward and downward gradients during December 2014 and February 2015. For the first 16 days of continuous monitoring upward gradients persist but then transition to downward gradients for about six days (between December 11 and 17, 2014) and then return again to upward gradients for about nine days (between December 17 and 26, 2014). Approximately four weeks into the monitoring period the upward gradients finally change relatively quickly again to downward gradients on December 26, 2014. Thereafter the downward gradients persist through the monitoring

period, except for a period between February 14 and 24 when upward gradients resume. This period occurs toward the end of a relatively longer 16 day period of slow steady water level declines in water levels in both the shallow and deep wells. Once water levels rise sharply again around February 25, the downward gradients resume. The cause(s) for these gradient fluctuations is unclear, but the hydrographs do indicate a consistent pattern of upward gradients when the water levels are in their lowest cycles when the effects of precipitation and recharge taper off. Manual measurements using an electronic water level indicator made weekly by Alliant indicate that the continuous monitoring data are accurate and that the changes do not appear to be associated with instrument or weekly field calibration errors.

Water level elevations in GW-972(I)/GW-973(S) track very closely over time with elevation differences that typically vary less than 0.15 ft. Relative to the other Phase I well pairs these elevations appear close to identical and do not vary greatly during precipitation/recharge events or declining baseline periods as seen in the other three well pairs. Water levels across much of the monitoring period are very slightly higher in the deeper well GW-972(I) suggesting very slight upward gradients. In addition, the vertical separation between the isolation casing in GW-972(I) and the screen/filter pack interval in GW-973(S) is not extensive. The close tracking of water levels in the wells suggests that the water table interval intersected by the shallow well may be well connected to the uppermost part of GW-972(I) at and near the base of the 10 in. diameter isolation casing. In addition, the water level data suggest that the bedrock well has not intercepted fractures with high transmissivity under confined or semi-confined conditions that would exert substantial upward flow gradients (as indicated for other well pairs). The results of packer tests, borehole geophysical logs, and heat pulse flowmeter tests are also consistent with relatively low ground water flux and minimal upward gradients in GW-972(I).

The water level changes in GW-976(I) differ greatly from those at any of the other four Phase I locations. The shallow well, GW-977(S), adjacent to GW-976(I) was completed at auger refusal depth and is dry. No data are therefore available for evaluating vertical gradients by paired well water level elevation differences. However, the water table at the GW-976(I)/GW-977(S) cluster occurs within the open hole interval of GW-976(I) well below the bottom of the isolation casing placed near auger refusal. The top of the saturated zone (water table) or vadose zone thickness along the crest of the spur ridge at GW-976(I) has varied from 38.1 to 43.6 ft bgs between November 22, 2014 through January 23, 2015. This depth range is approximately 14-19 ft below the top of competent bedrock and well below the surficial regolith layers. Water levels in GW-976(I) do not show the dramatic fluctuations in water levels seen in response to precipitation events. With the exception of GW-976(I), the hydrographs in all the Phase I wells show prompt increases and steady declines in their potentiometric surfaces after precipitation events. In contrast, the hydrograph for GW-976(I) shows only very slight adjustments in water levels relative to precipitation events and a gradual increase in water level elevation over time that is not seen in other well pairs. This overall upward increase in water level is about 5.2 ft from November 22, 2014 through January 23, 2015. The relatively rapid decline in water levels following precipitation events seen in all the other Phase I wells suggests a greater rate of ground water flux, drainage, and discharge to the main NT-3 tributary valley than from the ground water mound below the boot-shaped area of the spur ridge encompassing GW-976(I). This apparent higher rate of flux may be influenced by the higher hydraulic heads below and more directly adjacent to Pine Ridge. In addition, the thicker vadose zone below the spur ridge crest may result in a slower rate of recharge to the water table in that area. Ground water fracture flow paths toward the northwest of GW-976(I) may also be more restricted in a direction opposite to the northeast-southwest geologic strike and bedding plane dip direction toward the southeast.

The Phase I data summarized in Table 10 suggest that the wet season water table surface consistently occurs several feet above the regolith/bedrock interface (i.e., above auger refusal depths) across most of the EMDF footprint. The exception occurs below the boot-shaped areas of the spur ridge that occur along the south side of the EMDF footprint, where the water table occurs well below the top of bedrock and where the vadose zone is much thicker. Except for the spur ridge areas, the overall range of these data

between ground surface and 12.8 ft bgs may be typical for the wet season across most of the EMDF site when higher water levels occur.

**Table 10. Relationships between Water Level Depths and Depths to the Regolith/bedrock Interface**

| Well | Depth to Water Table [vadose zone thickness] (ft bgs)* | Auger Refusal Depths [regolith thickness] (ft bgs) |
|---|---|---|
| GW-969(S) | 0.3 to -4.0 | 13.5 |
| GW-971(S) | 4.4 to 12.8 | 23.8 |
| GW-973(S) | 2.6 to 8.4 | 23.0 |
| GW-975(S) | 2.8 to 7.0 | 10.0 |
| GW-976(I) | 38.1 to 43.6 | 24.4 |

Notes and Abbreviations:

- Data in this table are based on Phase I continuous water level monitoring data for the period from late November 2014 through February 26, 2015, that are probably typical for the seasonal wet period when relatively higher ground water levels occur.
- Negative value for ft bgs indicates water levels above ground surface as a result of lowering the original ground surface during site grading for access roads and drilling pads.

Ft bgs feet below ground surface

For the current three months of Phase I monitoring, differences between high and low water levels shown in Table 9 (and on Figures 27 and 28) range from 4.0 ft in GW-974(I) to 8.4 ft in GW-971(S). The lowest range of water level fluctuations occurs in the GW-974(I)/GW-975(S) cluster and the greatest range of water level fluctuations occurs in the GW-970(I)/GW-971(S) cluster. The fluctuation data from GW-968(I) and GW-969(S) were limited over certain time periods before the tops of the casings were extended upward to capture and accurately monitor continuous changes in water levels (see notations on Figure 27).

Water level hydrographs that illustrate seasonal cycles from 2000 to 2014 are available for many of the EMWMF monitoring wells and well clusters (see representative hydrographs in attached Exhibit A.18). These hydrographs show seasonal high water levels that occur consistently in the winter and early spring when recharge and runoff tend to be higher, and evapotranspiration is lowest. The Phase I hydrographs shown in Figures 27 and 28 reflect the winter quarter of these annual seasonal cycles.

#### 7.2.3.2 Potentiometric Surface Contour Maps

Figure 29 illustrates the potentiometric surface for the water table interval at the EMDF site on December 25, 2014. This map is representative of flow directions and gradients for the uppermost water bearing zone below the EMDF site during the wet non-growing season. Control points for the contours shown on Figure 29 are based on synoptic water levels in the *shallow* Phase I wells, except for GW-976(I) where the shallow well (GW-977[S]) is dry. Control points also include nine Phase I surveyed channel bottom elevations at monitoring locations along the NT-3 stream paths. In addition to those control points, the potentiometric surface (water table) is assumed to intersect with ground surface elevations along the NT-2 and NT-3 stream paths. Figure 30 illustrates the model predicted potentiometric surface for the water table interval at the EMDF site based on post-construction steady

state conditions. In comparison with Figure 29, this surface represents predicted declines in the water table surface assuming the low permeability landfill cap is in place significantly limiting recharge, the underdrain is functional, and natural recharge only occurs across a narrow swath of land along the upper south facing slopes of Pine Ridge. The most striking difference is the elimination of the existing ground water mound below the spur ridge along the south side of the EMDF footprint. But elsewhere the water table is lowered and maintained through the combined effects of limited recharge and the underdrain system.

The water level hydrographs (Figures 27 and 28) indicate that the highest water levels reached for the period of record so far occur around January 6, 2015, in most wells except for GW-976(I) where the maximum water level occurs around January 22, 2015. The water level elevations on January 6, 2015, are about 1.5–2 ft higher than those on December 25, 2014, in most wells, except at GW-976(I) where the water level difference is about 2.4 ft higher. The water level in GW-976(I) continues to climb beyond January 6 and reaches a maximum elevation on January 22 that is about 4.0 ft higher than that on December 25, 2014. These highest (and lowest) water level elevations for the Phase I period of record so far are plotted on the site cross sections of Plates 2 through 4. These north/south and east/west cross sections through the EMDF site are cut through the Phase I wells and also illustrate the potentiometric surface for December 25, 2014, which is representative of the relatively high wet season water table.

The vadose zone is believed to thin progressively toward the NT valley floors where the water table during the wet non-growing season seeps into the stream channels providing baseflow for the NT streams. The water table contour map is a subdued version of surface topography with a flattening of the water table and thickening of the vadose zone below topographically high areas such as along the crest of Pine Ridge and the spur ridge where GW-976(I) is located. However, the actual water table surface may be more uneven on a local scale than shown, as shallow ground water occurs and migrates unevenly within macropores and fractures of saprolite and weathered bedrock that are not necessarily of a uniform or even configuration. The configuration of the potentiometric surface at greater depths within the intermediate and deep intervals of the saturated zone would be increasingly less uniform and uneven, according to the complexity of deeper interconnected fractures and depending upon which fractures are penetrated in any given monitoring well.

Relatively flat wetland areas with seeps and springs have been identified along the drainage paths of the NT-2 and NT-3 tributaries crossing and adjacent to the EMDF site (see hatchured areas on Figure 29). These areas have been delineated using GPS field mapping as part of ecological/wetland surveys, and commonly occur at transitions between steeper and flatter slopes where the shallow water table intersects and discharges to the ground surface. These areas would be targeted for Phase II subsurface investigations to provide data for the proper design of the proposed underdrain system. The topographically low areas near seep locations EMDNT2-SE1, EMDNT2-SE2, and EMDNT2-SE3 along the southeast margins of the EMDF site (see locations on Figure 29) were partially excavated and reworked during the Fall of 2014 as part of the UPF haul road construction. But these areas remain as significant discharge areas for shallow/intermediate level ground water emanating from the southeast quarter of the EMDF site. These areas would also be included in future Phase II investigations to support the underdrain system design.

It is noteworthy that the three headwater springs, EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2, all occur consistently at elevations near the 1,050 ft surface elevation contour. These springs do not occur at or near the projected surface contact between the Rome Formation and Pumpkin Valley Shale (see locations and outcrop belts on Figure 1 and Plate 3). This suggests that the location of these springs is influenced primarily by the intersection of the water table with the ground surface within regolith soils/saprolite, and not in relation to springs or seeps that have been conjectured to occur along contacts between geologic formations.

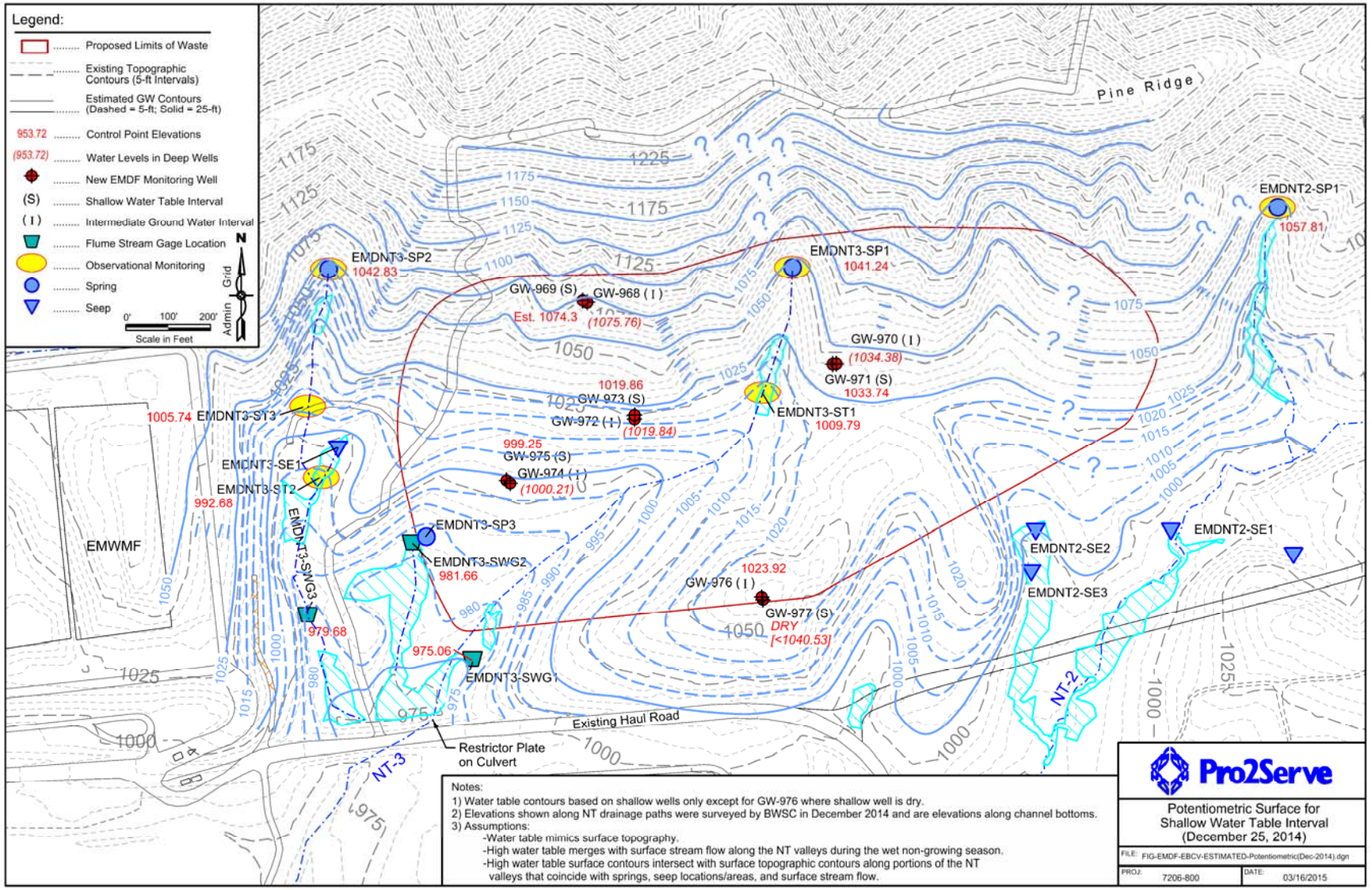



**Figure 29. Contour Map of the Potentiometric Surface for the Shallow Water Table Interval – December 25, 2014**

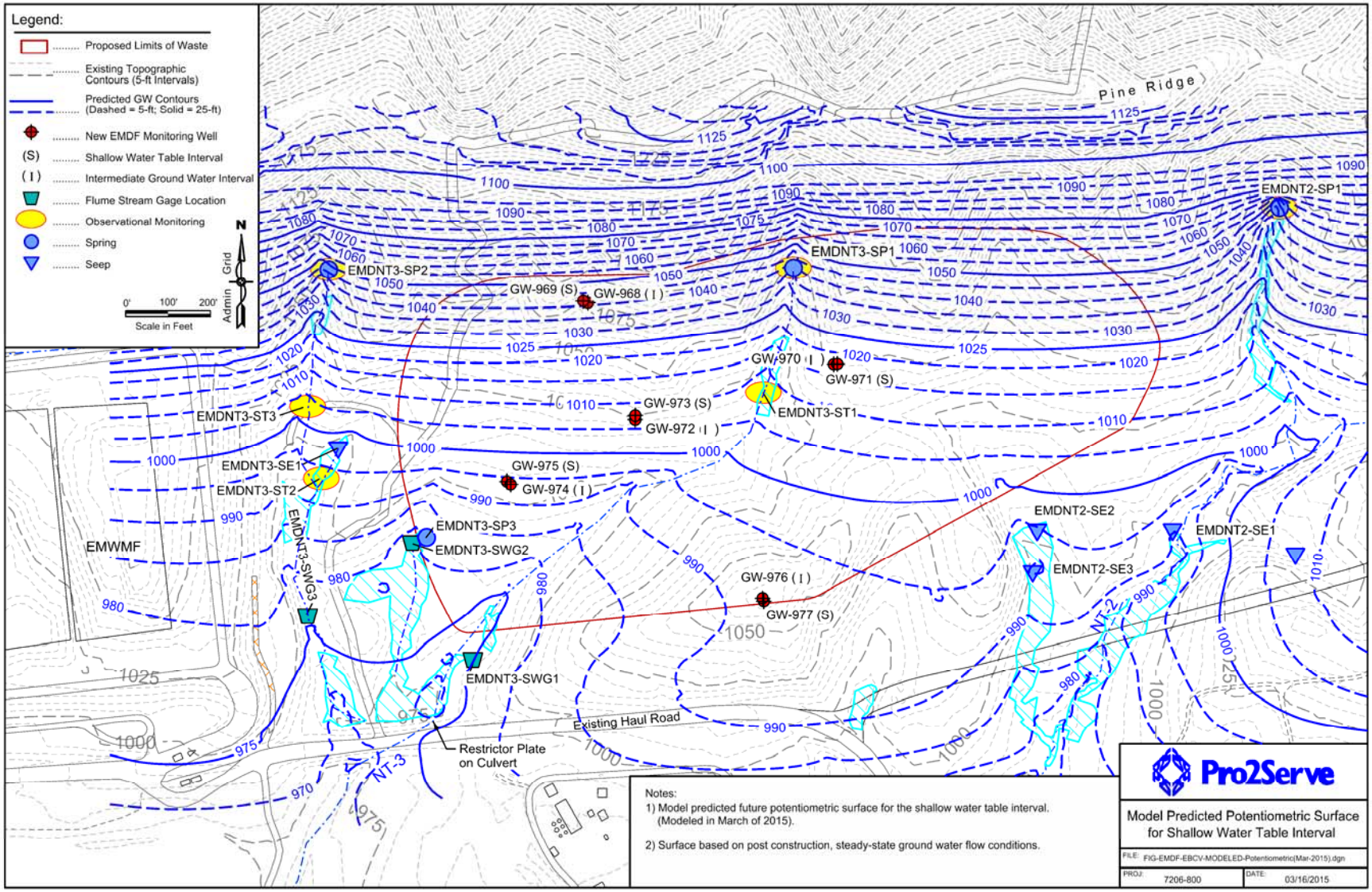



**Figure 30. Contour Map of the Potentiometric Surface for the Shallow Water Table Interval – Model-predicted Post Construction Steady State Ground Water Flow Conditions**

#### 7.2.3.3 Horizontal and Vertical Ground Water Gradients

Horizontal gradients for the water table interval are illustrated in Figure 29 and easily determined by measuring the change in the equipotential contours over a given distance in a direction perpendicular to the potentiometric surface contours. Horizontal gradients for the water table interval at and near the EMDF footprint range from 0.33 to <0.05 flattening out to even lower gradients along the lowest areas of the NT valley floors just downslope of the EMDF waste limit boundary. Near the EMDF footprint, horizontal gradients are steepest in areas along the mid to lower south facing steeper slopes of Pine Ridge. The gradients lessen as the surface topography and underlying water table surface flatten out and merge with the NT valley floors. Horizontal gradients estimated in areas upgradient of GW-969(S) are on the order of 0.33. Horizontal gradients measured between GW-969(S) and GW-973(S) decrease to about 0.24; gradients between GW-973(S) and GW-975(S) are about 0.11; and gradients within an area about 200 ft south of GW-975(S) decrease to around 0.07. Gradients along the main branch of NT-3 near the center of the EMDF footprint are about 0.045. The Phase I data indicate a ground water mound below GW-976(I) along the top of the spur ridge located along the south edge of the EMDF footprint (see Figure 29). Horizontal gradients for the water table interval toward the northwest of GW-976(I) toward NT-3 are about 0.09. This mound below the spur ridge would be dewatered during landfill construction as the northern portion of the ridge would be excavated to allow for placement of the underdrain system, engineered fill, geobuffer clay, and the overlying liner/leachate system (see cross sectional view of EMDF site and conceptual design features on Plate 3).

Vertical ground water gradients shown in Table 11 were calculated based on representative synoptic water levels in the Phase I well pairs. Vertical hydraulic gradients for the four Phase I shallow/intermediate well pairs were calculated to determine the vertical direction (upward or downward) of ground water flow between the water table interval and the deeper intermediate interval. The unitless vertical gradient calculated from a shallow well to a deeper well represents the difference in hydraulic head (in ft) divided by the distance between the midpoints of the screened/filter pack intervals or open borehole for the wells (in ft). For the Phase I calculations, a positive vertical gradient value represents upward gradients and a negative value indicates downward gradients.

The water level hydrographs based on continuous water level monitoring (see Figures 27 and 28) were used to determine a representative synoptic event for calculating vertical hydraulic gradients. January 12, 2015, (at 0 hrs) was selected as a representative date for the four well pairs. This date was selected as it represents one of the few periods in the first two months of monitoring where data were simultaneously available for the GW-968(I)/GW-969(S) well pair, before the original top of casing for GW-969(S) was extended 10 ft higher on February 11, 2015, to prevent overflow of ground water and capture and continuously record water level fluctuations. This date was also selected as representative of typical periods during which water levels are in a natural period of decline between precipitation/recharge events. As shown in Figures 27 and 28, water levels and vertical gradients may change dramatically in response to rainfall/recharge events. In some cases, vertical gradients decrease significantly during periods of rapid water level rise and water level elevation differences between the well pairs may decrease or become zero for relatively short periods (see hydrographs for GW-974[I]/GW-975[S], GW-970[I]/GW-971[S], and GW-972[I]/GW-973[S]).

**Table 11. Vertical Gradients and Related Data**

| Well ID | Surveyed Elevation Top of Ground Surface | Screened or Open Hole Interval (ft bgs) | | Screen or Open Hole Length (ft) | Filter Pack Interval (ft bgs) | | Filter Pack Length (ft) | Midpoint Elevation of Filter Pack or Open Hole | Difference in Midpoint Elevations | Vertical Gradient Data for 1/12/15 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Top | Bottom | | Top | Bottom | | | | Water Level Elevation 1/12/15 | Well Pair WL Difference (+ sign = upward grads) | Vertical Gradient (WL Diff/MP Elev Diff) |
| GW-968(I) | 1070.21 | 12.7 | 82.7 | 70.0 | 9.0 | 92.7 | 83.7 | 1019.36 | | 1075.42 | | |
| | | | | | | | | | 41.59 | | 2.69 | 0.065 |
| GW-969(S) | 1070.45 | 8.4 | 13.4 | 5.0 | 5.5 | 13.5 | 8.0 | 1060.95 | | 1072.73 | | |
| | | | | | | | | | | | | |
| GW-970(I) | 1040.93 | 34.1 | 97.4 | 63.3 | NA | NA | NA | 975.18 | | 1032.92 | | |
| | | | | | | | | | 47.68 | | -0.71 | -0.015* |
| GW-971(S) | 1040.69 | 13.2 | 23.2 | 10.0 | 11.9 | 23.8 | 11.9 | 1022.865 | | 1033.63 | | |
| | | | | | | | | | | | | |
| GW-972(I) | 1023.55 | 23.8 | 99.6 | 75.9 | NA | NA | NA | 961.88 | | 1019.23 | | |
| | | | | | | | | | 45.94 | | 0.15 | 0.003 |
| GW-973(S) | 1024.46 | 12.9 | 22.9 | 10.0 | 10.3 | 23.0 | 12.7 | 1007.81 | | 1019.07 | | |
| | | | | | | | | | | | | |
| GW-974(I) | 1002.80 | 15.0 | 97.9 | 82.9 | NA | NA | NA | 946.35 | | 999.32 | | |
| | | | | | | | | | 49.22 | | 1.20 | 0.024 |
| GW-975(S) | 1002.52 | 4.9 | 9.9 | 5.0 | 3.9 | 10 | 6.1 | 995.57 | | 998.12 | | |

Notes and Abbreviations:

- A negative sign for the vertical gradient indicates a downward gradient, whereas positive signs indicate upward gradients between the well pairs.
- A positive upward vertical gradient of 0.76 was calculated for the GW-970(I)/GW-971(S) well pair based on representative water level elevations of 1028.86 and 1028.10, respectively, for December 1, 2014, during the first two weeks of continuous monitoring when gradients were consistently upward.

Elev elevation
Ft bgs feet below ground surface
Diff difference
MP midpoint
NA not applicable
WL water level

Upward vertical gradients have remained the most consistent for the GW-968(I)/GW-969(S) and GW-974(I)/GW-975(S) well pairs. Among the well pairs, water level differences between GW-968(I)/GW-969(S) have been the highest, with differences on the order of 2 ft or more. These differences are attributed primarily to the location of this well pair near the base of a steep ravine incised into Pine Ridge (see Figure 29). Water level differences between GW-974(I)/GW-975(S) have also been relatively high, as much as 1.3 ft during periods of baseline decline, but with sharp decreases during some precipitation/recharge events. The water level differences for the GW-970(I)/GW-971(S) well pair are unusual and difficult to interpret. Water level differences during periods of baseline decline are typically on the order of 0.5-0.7 ft, but shifts between upward and downward gradients have been recorded at various times that appear to be unrelated to precipitation/recharge events. Water levels initially recorded from late November 2014 up through December 11, 2014, were consistently higher in the deep well (GW-970[I]), but changed to downward gradients from December 11 through December 17, 2014. The water levels then transitioned back to upward gradients until a reversal of gradients again on December 26, 2014 that has remained with water level elevations in the shallow well remaining about 0.5-0.7 ft above those in the deep well (indicating downward vertical gradients). The only exceptions during the latter period have occurred during relatively short periods (roughly 24 hours or less) following rainfall events when water level elevations between the well pairs have equalized. The depth of the isolation casing within the upper part of the bedrock surface below auger refusal may have some influence on water level differences between the well pairs. The greater the depth of the isolation casing placed into bedrock, the more likely the intermediate interval is to be isolated from the shallow water table interval above bedrock auger refusal depths. The range of depths for the isolation casing are presented in Table 1. The separation between the isolation casing and auger refusal is greatest at the GW-970(I)/GW-971(S) well pair and least at the GW-972(I)/GW-973(S) well pair, where the water level elevation differences between the shallow and deep wells are also the least (typically <0.15 ft).

It should be noted that the relatively large open hole intervals in the deep wells (and large screened interval in GW-968[I]) result in a composite hydraulic head distributed across the entire interval in each of the deep wells. Individual or nested wells/piezometers with smaller screen lengths would allow for a more precise determination of the vertical distribution of hydraulic heads at these locations. The broad intervals in the deep wells add uncertainty as to whether the hydraulic heads are attributable to shallow, intermediate, or deeper fracture zones (or some combination) in the deep Phase I wells. Nested wells or piezometers could be installed in the deep open hole Phase I wells to provide more certainty on the vertical distribution of hydraulic heads at the EMDF site. These are recommended for the Phase II investigation. As noted in Section 4.1.7.2, artesian ground water conditions were encountered at GW-968(I) overflowing the top of casing early in the Phase I field program. These were followed later with casing overflow conditions in the adjacent shallow well, GW-969(S). Table 1 includes the pre-Phase I ground surface elevations estimated for these well locations. No springs, seeps, or evidence of continuous or intermittent surface water flow had been identified within the ravine area of this well cluster during previous field reconnaissance work at the EMDF site (including detailed wetland surveys involving GPS delineation of wetland areas). However, the water level monitoring data from GW-968(I)/GW-969(S) well pair suggests that shallow ground water at this location prior to the Phase I effort may have been near the ground surface during the annual wet season. While the Phase I results suggest that the seasonally high water table surface may be relatively shallow near the base of similar ravines at the EMDF site, it is important to note that the current landfill design places the base of the geologic buffer at elevations on the order of 20–30 ft or more above these areas. Each of these ravines would be backfilled with engineered fill prior to placement of the more elevated geologic buffer and overlying liner system. The distance between the waste and the original ground surface at these ravine locations would therefore be on the order of 50 ft or more at locations such as GW-968(I)/GW-969(S).

### 7.2.3.4 Ground Water Quality Parameter Data

Hourly monitoring of temperature, pH, SpC, and ORP collected from the nine ground water monitoring wells during the December 2014 through February 2015 period suggest some persistent differences between the shallow wells (water table interval) and the deeper wells (intermediate bedrock interval). These spatial patterns may reflect hydrogeologic conditions described below and in Sections 7.2.4 and 7.2.5.

Variations in water quality associated with changes in ground water levels in response to precipitation are also evident in the monitoring data, but patterns over time and differences among wells are more difficult to generalize because of data quality problems affecting much of the record. These problems include sensor malfunctions and calibration errors due to a variety of operational and environmental factors, and make it difficult to identify reliable portions of the record with confidence. The remainder of Section 7.2.3.4 includes additional detail on observed ground water quality variations over time and also addresses data quality concerns. The downhole depths and elevations of the sondes used for continuous water quality (YSI™) and water level (In-situ® TROLL) instruments are shown on the well logs of Plate 2 and in Table 4. The sonde depth locations within the saturated zone have some influence on the measured water quality parameters as noted in some cases below.

**Differences between Shallow and Intermediate Interval Ground Water Quality:**

In general, for temperature, pH, and SpC, inter-well differences are large enough relative to variations over time due to environmental changes, instrument calibration, or other causes to differentiate among wells. In contrast, for ORP inter-well differences are small relative to parameter variation over time, reflecting larger data errors and uncertainty in characterizing mean values and the range of variation for that parameter.

**Ground Water Temperatures**

Temperature records from the ground water monitoring wells are perhaps the most reliable data available, and reflect differences among wells as well as seasonal trends and the impact of precipitation events (see Figure 31). For each of the four well pairs for which data are available[1], the deep wells exhibit less water temperature variation than the paired shallow wells (Figure 32). The deep well ground water temperatures are generally warm relative to the paired shallow well in each case except for GW-972(I)/973(S) and, prior to December 23rd, GW-974(I)/975(S). This difference in mean temperature between deep and shallow wells is consistent with the expectation of relatively cold winter air and colder recharging ground water temperatures near the surface, and might be expected to reverse during the warm season. A similar reversal in shallow vs deep ground water temperature is apparent in the GW-974(I)/975(S) record (see Figure 31).

[1] Monitoring well GW-977(S) was dry throughout the reporting period.

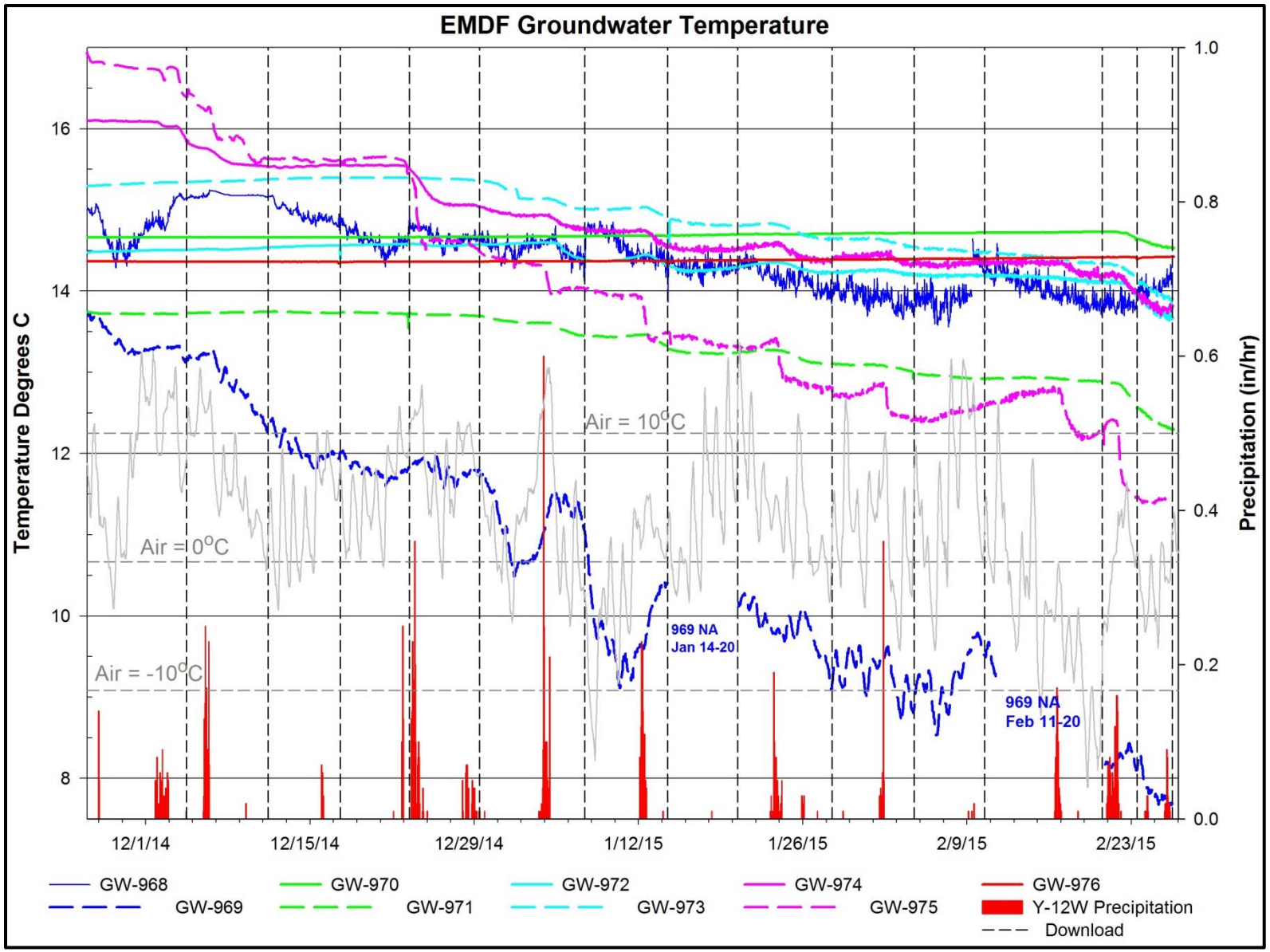



**Figure 31. Ground Water Temperatures Observations during the December 2014 through February 2015 Reporting Period**

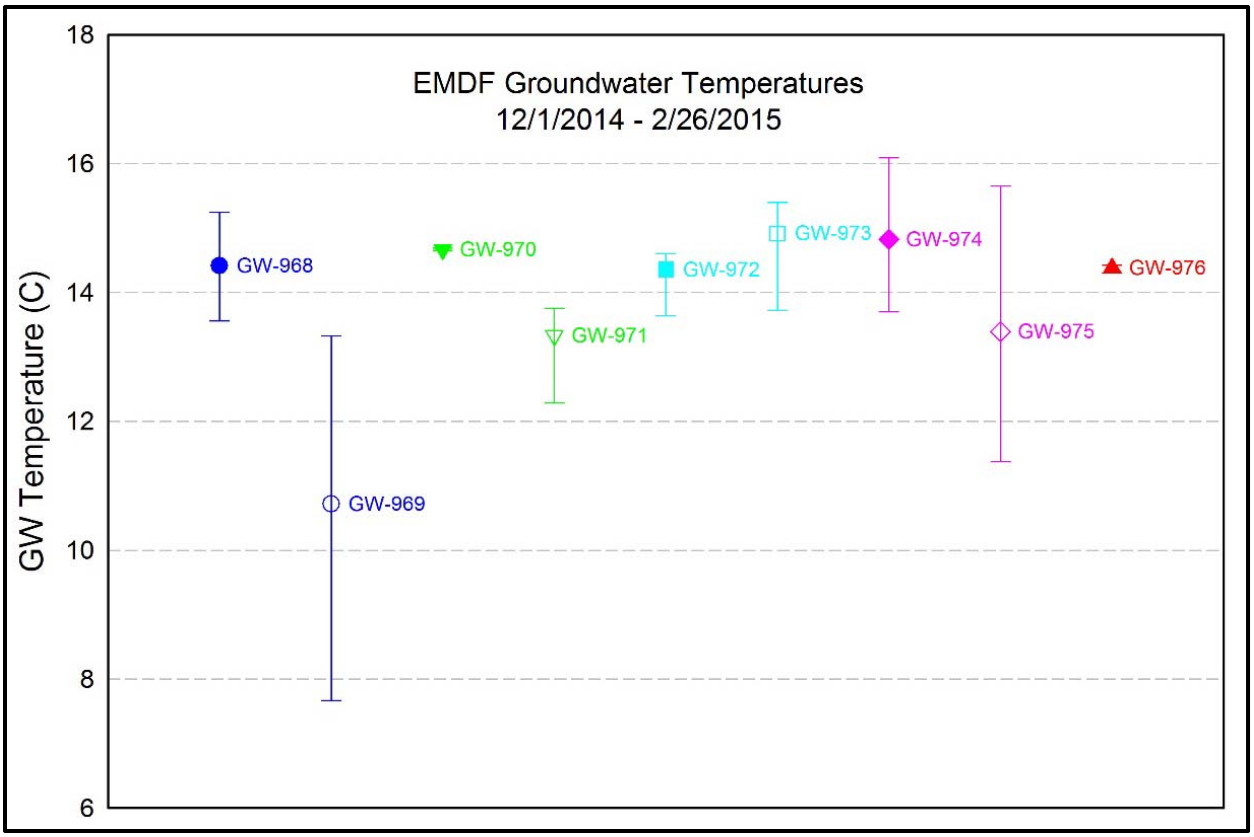



**Figure 32. Average, Minimum, and Maximum Ground Water Temperatures Observed during the December 2014 through February 2015 Reporting Period**

Ground water temperature declined progressively over the reporting period at all wells except for intermediate bedrock interval wells GW-970(I) and GW-976(I), which had almost no variation in temperature prior to February 20th, when the temperature in GW-970(I) began to decrease. The rate of decrease in ground water temperatures observed is not constant and clearly reflects periodic inputs of cold meteoric water. With the exceptions of GW-969(S), -970(I) and -976(I), rapid decreases in ground water temperature occur after precipitation events and these decreases account for essentiallyall of the variation in ground water temperature over the reporting period. The nearly constant temperatures at GW-976(I) and GW-970(I) suggests isolation from the effects of surface temperatures and recharge of cooler water, and for GW-970(I) could be related to upward flux of deep ground water in the well. This interpretation for GW-970(I) is supported by three heat pulse flow meter tests indicating upward vertical flow in the borehole that would keep the YSI sonde at a temperature more representative of intermediate level ground water rather than of the shallow water table interval. In addition, water temperatures recorded simultaneously by the deeper Troll sonde positioned 15 ft below the water quality sonde, are slightly higher than temperatures recorded by the YSI sonde above (see Plate 2 for the locations of the sondes and flow meter test depths and results). The relatively constant ground water temperature in GW-976(I) appears to be related to the much greater depths to ground water (vadose zone thickness) below the crest of the spur ridge, and the more gradual rates of recharge occurring there, which apparently combine to insulate and buffer colder recharge water from the deeper level of the saturated zone.

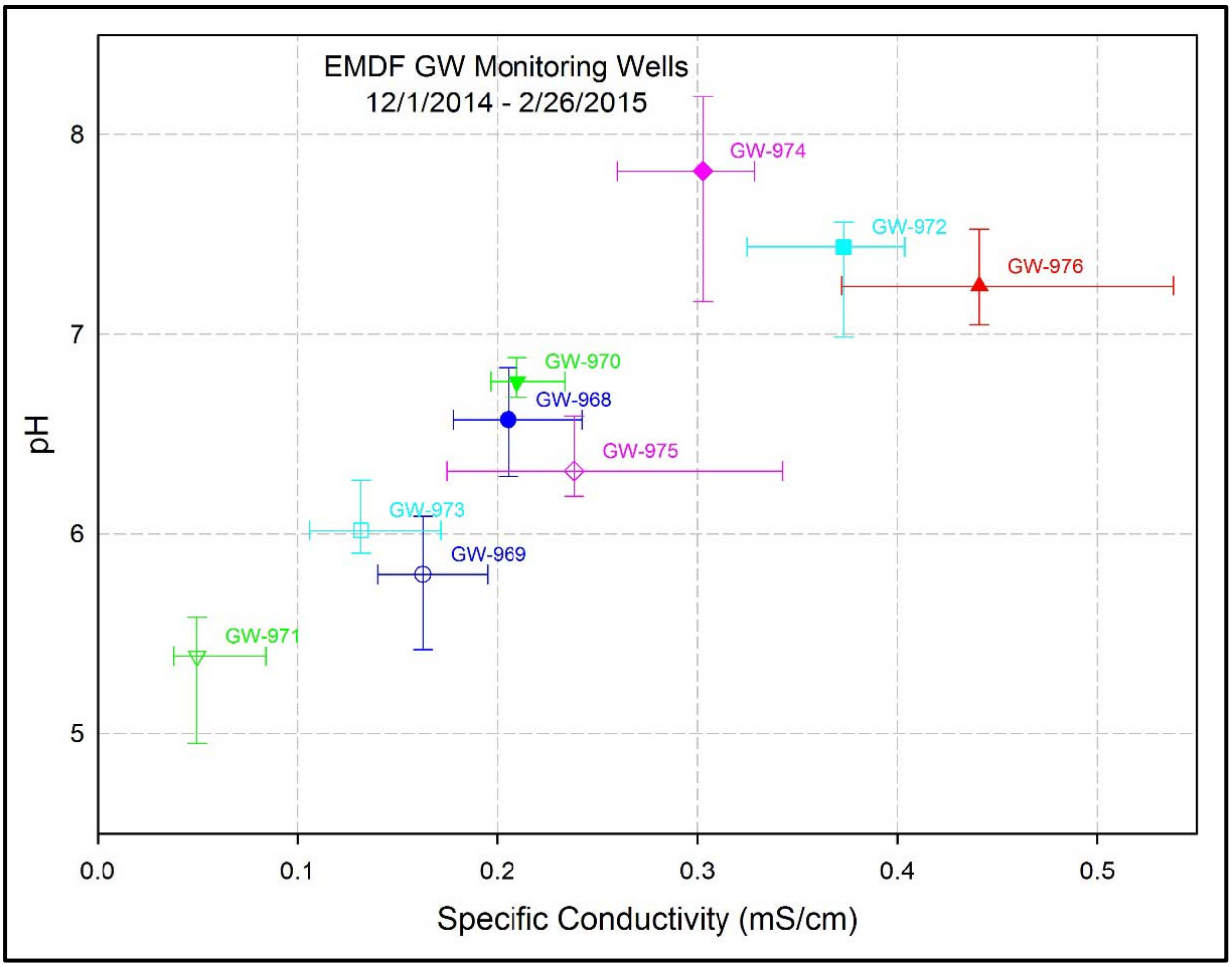
Ground water temperature decreased more quickly over the reporting period in the shallow wells than in the paired deep wells, and decreased the most from observed maximum to minimum at shallow wells GW-969(S) and -975(S) (see Figure 31). These two wells, as well as the deep well GW-968(I) show a less

consistent decrease in temperature over the reporting period, including short term temperature fluctuations that appear to reflect surface air temperature changes, particularly in the shallow wells. GW-969(S) in particular may be uniquely affected by a shallow well (TD – 10 ft bgs) and high water levels (from artesian conditions) that expose the well water in the casing above ground surface to very cold winter outside air temperatures. The cause of the high frequency temperature fluctuations observed at GW-968(I) is unknown, but the pattern is present both of the independent temperature records logged by the water level (In-Situ) and water quality (YSI) instruments.

**Specific Conductivity and pH**

Despite some relatively large calibration uncertainties, and some SpC data that were clearly erroneous and thus eliminated from further analysis, inter-well differences in mean values of pH and SpC clearly illustrate general water quality differences between the deep and shallow wells and reflect the influence of hydrology and lithology on ground water geochemistry.

Over the three month reporting period, the four shallow (water table interval) wells exhibited lower mean SpC and pH than the five deep wells, and minimum-maximum ranges of these two parameters were similarly separated, with some degree of overlap among groups of deep and shallow monitoring wells (see Figure 33). Three deep wells GW-972(I), GW-974(I) and GW-976(I) had consistently higher ground water pH (>7.0) and SpC (>0.25 mS/cm) than the other six wells. The two remaining deep wells (GW-968[I], GW-970[I]) had somewhat lower pH and SpC values that were closer to the upper end of the range of pH and SpC observed at the four shallow wells. Shallow wells GW-969(S), GW-971(S), and GW-973(S) had consistently low pH (< 6.25) and SpC (<0.20 mS/cm), whereas observations at GW-975(S) were similar to those for deep wells GW-968(I) and-970(I). For each of the four monitoring well pairs, mean pH and SpC measured in the shallow well were lower than in the paired deep well (e.g., GW-974[I]/975[S]), with little or no overlap in the observed range of values. These distinctions in the range of observed pH and SpC among monitoring wells are fairly pronounced, even though for the deep wells much of the observed range is due to large changes in values upon instrument calibration. If these calibration uncertainties could be removed from data, the differences among groups of wells would be even more pronounced.




Horizontal (SpC) and vertical (pH) error bars indicate observed minimum and maximum values.

**Figure 33. Average Ground Water pH vs SpC Values observed during the December 2014 through February 2015 Reporting Period**

One basic hydrogeologic explanation for these water quality patterns is that pH and SpC in shallow ground water are strongly influenced by surface infiltration of relatively dilute, slightly acidic rainwater, whereas recharge to deeper ground water involves a longer period of geochemical evolution that is reflected in higher pH and SpC readings in the deep monitoring wells. Bedrock lithology is another factor that may affect differences among wells, in particular the observation that the two deep monitoring wells completed in the Pumpkin Valley Shale (GW-968[I] and -970[I]) have pH and SpC ranges closer to three of the four shallow wells than to the higher ranges observed at the three deep wells completed in the Rutledge Limestone (GW-972[I]), Rogersville Shale (GW-974[I]), and Maryville Limestone (GW-976[I]).

Changes in pH and SpC in response to precipitation varied among wells and among rainfall events. With the exception of GW-968(I), the deeper (intermediate bedrock interval) wells exhibited few changes in pH or SpC that were clearly linked to precipitation events, whereas monitoring wells GW-968(I), GW-969(S), and especially GW-975(S) often exhibited pronounced decreases in pH and/or SpC associated with rising ground water elevations following precipitation. Decreasing pH and SpC in response to infiltration and ground water recharge reflects the input of meteoric water that is dilute and weakly acidic relative to ground water.

**Oxidation-Reduction Potential**

The frequency of sensor malfunctions, extreme calibration shifts, and unexplained, rapid changes in measured values of ground water ORP precluded an effective analysis of these data similar to the observations of inter-well differences in ground water temperature, pH, and SpC and variations in those three parameters over time. In many cases it appears that continuous deployment of ORP sensors in a quasi-static ground water monitoring well environment without provision of fluid circulation via pumps or similar devices does not permit consistent collection of reliable data. If ORP data are required for future ground water characterization, alternative technical approaches for monitoring these parameters should be considered.

### 7.2.3.5 Phase I Hydraulic Conductivity Tests

Phase I K tests included:

- Laboratory analysis of five Shelby tube samples collected from regolith materials.
- Slug tests conducted in four shallow monitoring wells (GW-977[S] was dry).
- Nine packer tests conducted over selected 10 ft intervals of bedrock in the open deep boreholes

Results are presented in the following subsections.

**Slug Test Hydraulic Conductivity Results**

Table 12 summarizes the values for K based on the slug tests conducted in each of the Phase I shallow monitoring wells. The tests use pressure transducer data loggers connected to a laptop computer to continuously record the rate of recovery of water levels after a solid cylinder or "slug" is quickly introduced into or out of the water column inside the well casing. Alliant used the AQTESOLV for Windows program to plot, interpret, and solve for K. The program uses the Bouwer and Rice (1976) method for determining K. The method can be applied to unconfined, semi-confined, or confined/stratified aquifers in partially or fully penetrating wells or piezometers (Bouwer 1989). Details of the tests including plots and tables of head data versus time, and other key data are provided in Exhibit A.10. Additional information on the testing methods are reviewed above in Section 4.1.6.3.

The slug tests provide K values for the shallow water table interval based on the average permeability of the unconsolidated regolith materials over which the shallow wells are screened. The screen lengths were five or ten feet in the shallow wells depending on the depths to auger refusal and the depths to the water table (see data in Table 12). At the time of the tests, the pre-test water table at GW-969(S) and GW-973(S) was located well above the top of the screen interval. At GW-975(S), the pre-test water table was located about one foot below the top of the screen. At GW-971(S), the pre-test water table was located above the top of the screen. However, during the earliest part of the rising head test at GW-971(S), the water level fell below the top of the screen.

Falling head (slug-in) tests were conducted first in each well followed by rising head (slug-out) tests. An exception was made for GW-975(S) where only a rising head test was conducted because the pre-test SWL occurred below the top of the well screen. Errors are possible in wells where the water table falls below the top of the screened interval where "slug-in" tests force water upward and outward into the capillary fringe above the water table, or in "slug-out" tests if the water level falls below the top of the screen causing the filter pack material to drain rapidly into the well casing.

The falling head test results are presented in Table 12 for GW-969(S), GW-971(S), and GW-973(S), as these K values are assumed to be the most representative for these wells. The potential negative effects associated with more rapid drainage of the higher K filter pack material and insufficient time for the well to return to equilibrium conditions were both avoided during the initial slug-in/falling head phase of these

tests. During the slug-in phase, water flow is directed into the formation which has a much lower K value than the filter pack K, which may be two or more orders of magnitude greater than the formation K. The lower K of the regolith materials therefore places a limit on the flow of water into the formation during the initial falling head (slug-in) portion of a test. During the rising head (slug-out) portion of a test faster drainage of water may initially occur from the filter pack material. In particular the rising head results in GW-971(S) were discounted because the water level fell below the top of the screen during the first half hour of the test. This would have allowed for a more rapid water level change during this early period of the test than might have occurred under totally saturated flow conditions. The data also indicate that the recovery period may have been insufficient as the water level was 1.23 ft higher at the onset of the rising head test relative to the initial depth to water.

In GW-975(S), the solid slug was placed in the well on October 28, 2014 at 4:30pm and was allowed to sit overnight until the slug-out/rising head test was conducted at 1pm on the following day. This allowed about 20 hours for the water level to equilibrate in GW-975(S) before conducting the test and provided more confidence in the test results. The plot of water level recovery for GW-975(S) shows an unusual increase in the rate of water level recovery at approximately 1.4 hours into the test (see plot in Exhibit A.10). Precipitation data from the Y-12 west tower indicate 0.67 in. of rainfall from 2–7 A.M. on October 29. The data suggest that this rainfall event may have led to an increase in the recharge rate to the water table interval during the latter 2.5 hours of the test.

The slug tests provide a general order of magnitude range for K from a low of $1.2\times10^{-7}$ cm/sec in GW-971(S) to a high of $1.5\times10^{-6}$ cm/sec in GW-973(S). Hydraulic conductivity is a fundamental parameter used, along with hydraulic gradient and effective porosity (equivalent to specific yield in unconfined aquifers), for estimating ground water flow rates. Given constant gradients and effective porosities, then higher k values result in higher ground water flow rates.

Slug tests conducted in EMWMF site monitoring wells during the pre-design site characterization for the EMWMF were evaluated for comparison with the EMDF results. Six of the tests were conducted in wells screened in the Maryville; the remainders were conducted in wells screened in the Nolichucky Shale. However, examination of the data plots and input parameters for the tests in the Maryville wells suggest that the results are based only on the very earliest water level recovery data within time intervals less than 4 minutes after the start of the tests. Those very early recovery data are typically excluded for determining K values. The results are therefore questionable. The only exception occurred in GW-905 were the test results were based over a period of about 7.3 hours. The K value for GW-905 was reported as $2.67\times10^{-5}$ cm/sec. This well was presented as a “deep” well, with a total depth of 51 ft and a 10 ft screen length, and was located near the southern edge of the Maryville outcrop belt at a location along strike that would fall approximately 400 ft south of the EMDF waste limit footprint (see location on Figure 7). The Pre-Design Site Characterization Report should be reviewed for additional details (BJC, 1999).

Another source of K data along strike with the EMDF comes from investigations at the former LLWWDD site in WBCV. Hydraulic conductivity data from shallow open hole bedrock monitoring wells located at this site are presented in Exhibit A.10. The data were reported in the Performance Assessment for the Class L-II Disposal Facility (ORNL 1997 – Table E.1), based on data from Golder Associates (1988) from rising head slug tests. The K values from 14 wells tested in the Rutledge/Pumpkin Valley (1), Rogersville (3), and Maryville (10) formations span three orders of magnitude, from a low K of $4.24\times10^{-6}$ cm/sec to a high of $3.35\times10^{-4}$ cm/sec. The 14 wells were completed across open hole intervals from the upper portion of the bedrock. The open hole intervals are mostly on the order of 10–13 ft, except for two wells with intervals about 5 and 8 ft.

**Table 12. Slug Test Hydraulic Conductivity Results and Relevant Test Data for Shallow Wells - EMDF Phase I**

| Monitoring Well | Geologic Formation | Hydraulic Conductivity -K (cm/sec) | Date of Slug Test | Initial Water Level Displacement (ft) | Pre-test water column in well (ft) | TOC Elevation (at time of test) | Top GS Elevation | Casing stickup (ft above GS) | Pre-test DTW (ft BTOC) | Pre-test DTW (ft bgs) | Total Depth of Well at Auger Refusal (ft bgs) | Screen Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW-969(S) | Cpv | 7.65E-07 | 10/29/14 | 2.52 up | 13.18 | 1072.98 | 1070.45 | 2.53 | 2.75 | 0.22 | 13.5 | 5.0 |
| GW-971(S) | Cpv | 1.22E-07 | 10/30/14 | 2.31 up | 10.44 | 1043.11 | 1040.69 | 2.42 | 15.18 | 12.76 | 23.8 | 10.0 |
| GW-973(S) | Crt | 1.46E-06 | 10/28/14 | 2.89 up | 15.35 | 1026.96 | 1024.46 | 2.5 | 10.05 | 7.55 | 23.0 | 10.0 |
| GW-975(S) | Crg | 3.43E-07 | 10/29/14 | 2.13 down | 3.97 | 1005.16 | 1002.52 | 2.64 | 8.57 | 5.93 | 10.0 | 5.0 |
| | **Average -** 6.72E-07 | | | | | | | | | | | |

Notes and Abbreviations:

- K values based on falling head data except for GW-975(S) which is based on rising head data.
- GW-977(S) was dry.
- 4 in. diameter casing radius = 0.167 ft; 10 in. diameter borehole radius = 0.417 ft.
- Rainfall of 0.67 in. recorded at Y-12 West Tower from 2-7am on 10/29/14.

bgs below ground surface
cm/sec centimeters per second
Cpv Pumpkin Valley Shale
Crg Rogersville Shale ft feet
Crt Rutledge Limestone (Friendship Formation)
GS ground surface
TOC top of casing

The Phase I slug test results are relatively low compared with the K values from the LLWWDD site, but the Phase I results were determined from wells completed with filter packs and screens in regolith soils and not from open hole wells completed within the upper portion of bedrock. Hydraulic conductivities typically range over several orders of magnitude on the ORR as a result of natural variations in subsurface conditions. Heterogeneities, anisotropy, and preferential pathways for ground water are associated with variations in regolith materials (residuum/alluvium/saprolite), bedrock lithologies, stratigraphic changes, and structural features (fracture density/spacing, joints, bedding planes, folds, faults, shear fractures, etc.). The Phase I slug test data is quite limited. Additional hydraulic conductivity testing is recommended for a Phase II investigation both from regolith and bedrock boreholes/wells.

**Shelby Tube Hydraulic Conductivity Results**

Laboratory test results for hydraulic conductivity from the Phase I Shelby tube samples are presented in Table 13 along with sample depth intervals and laboratory descriptions of the regolith materials. K values range from $3.9\times10^{-7}$ to $6.5\times10^{-6}$ cm/sec with a mean value of $3.2\times10^{-6}$ cm/sec. Each of the tube samples were collected from saprolite, described by the laboratory as silty clay (decomposed shale or decomposed to weathered shale), typical of the highly weathered bedrock residuum present above competent bedrock. The samples from GW-973(S) and GW-977(S) were collected from the vadose zone; the other three samples were collected from within the zone of water table fluctuation of shallow ground water. No obvious correlation exists between sample depths and K values.

Bulk soil samples were collected from two test pits within the EMWMF footprint in 2000 for laboratory analysis that included K by ASTM method D5084. The samples were collected from TP-12 at a depth of 4 ft and TP-16 at a depth of 8 ft and classified as silt (ML) and clay (CH), respectively. TP-12 was located within the outcrop belt of the Rutledge Limestone, and TP-16 was located in the outcrop belt of the upper Maryville Limestone (see locations shown on Figure 7). The results of the tests, $K = 2.9\times10^{-6}$ and $1.8\times10^{-7}$ cm/sec from TP-12 and TP-16, respectively, are within the same order of magnitude as the Phase I tests. Results of the laboratory testing of test pit samples are summarized in the tables in Exhibit A.19. The original report (CH2MHill 2000) should be referenced for additional details.

**Packer Test Hydraulic Conductivity Results**

Nine packer tests were conducted in one or more select intervals in each the five open (uncased) bedrock boreholes of the deep Phase I wells. The packer testing equipment was configured to isolate and test a ten foot interval. Depth intervals were selected based on potential fracture zones identified from the rock cores and borehole geophysical logs. Limitations on the total number of tests precluded systematic vertical profiling for K in each borehole. Only one test was conducted in GW-968(I) and GW-974(I); two tests in GW-972(I) and GW-976(I); and three tests in GW-970(I). Test intervals were selected in part to avoid depths where caliper logs indicated that the borehole wall was uneven or washed out to better ensure a good seal between the packers and the borehole walls. In some cases, shallow interval tests could not be tested because the packers could not be sealed at or near the isolation casing. A summary of the testing methodology and calculations for determining K are presented in Section 4.1.6.2. Detailed test data, spreadsheets, field forms, and results are provided in Exhibit A.9.

**Table 13. Laboratory Test Results for Hydraulic Conductivity (K) from Phase I Shelby Tube Samples**

| Sample ID | Sample Depth Interval (ft bgs) | ASTM D 2487 | ASTM D 5084 |
|---|---|---|---|
| | | Material description | Hydraulic Conductivity - K (cm/sec) |
| GW969-UD-1 (Cpv) | 1.0–3.0 | Clay, silty (decomposed shale), brown, mottled gray w/rock | $3.89\times10^{-7}$ |
| GW971-UD-1 (Cpv) | 17.0–19.0 | Clay, silty (decomposed shale), brown, maroon, mottled | $6.36\times10^{-7}$ |
| GW973-UD-1* (Crt) | 2.0–4.0 | Clay, silty (decomposed to weathered shale), brown, brown to brownish red | $3.53\times10^{-6}$ |
| GW975-UD-1 (Crg) | 7.0–8.5 | Clay, silty (decomposed to weathered shale), light brown, brown, mottled | $6.54\times10^{-6}$ |
| GW977-UD-1* (Cm) | 10.0–10.66 | Clay, silty (decomposed to weathered shale), light brown, brown, mottled | $5.03\times10^{-6}$ |
| | | Mean hydraulic conductivity | $3.23\times10^{-6}$ |

Notes and Abbreviations:

- Samples from GW-973(S) and GW-977(S) were collected from the vadose zone; all other samples were collected from within the zone of water table fluctuation of shallow ground water

Cm Maryville
Cpv Pumpkin Valley
Crt Rutledge
Crg Rogersville
ft bgs feet below ground surface
K hydraulic conductivity in centimeters per second (cm/sec)

Results of the Phase I packer tests are provided in Table 14. A maximum excess injection pressure was calculated for each test to ensure that water injection pressures during the tests would not overpressure and artificially enhance the natural K of the formation. Based on the maximum allowed injection pressures, no consistent flow conditions could be sustained for the two tested intervals in GW-972(I) and the single tested interval in GW-974(I). The results imply relatively low K values, but based on the limitations of the testing methodology, no K values could be calculated for these intervals. As previously noted, the in line flow meter used for the tests was incapable of accurate measurements below approximately 0.5 gpm over the typical time scale of the tests. This constraint appears to have limited the ability of the packer tests to measure order of magnitude K values at and below rates of $10^{-6}$ centimeters per second (cm/sec). Solomon et al (1992, pp. 3–25) reported a geometric mean K of $2.1\times10^{-6}$ cm/sec (standard deviation of 2.9) from 13 packer tests of three wells in east BCV. The wells were completed in the intermediate ground water level within Conasauga Group formations. GW-972(I) and GW-974(I) are located in the outcrop belt of the Rutledge Limestone (Friendship Formation) and Rogersville Shale formations, respectively, both in the Conasauga (individual formations and test depth intervals were not provided). More sensitive packer tests or other downhole methods capable of determining very low K values on the order of $10^{-6}$ to $10^{-8}$ cm/sec are recommended for a Phase II investigation to develop vertical profiles of K for the open hole intervals of the Phase I intermediate level wells.

Elsewhere, K values were all in the range of $10^{-5}$ cm/sec, except for the shallowest interval in GW-970(I) where the K values were an order of magnitude higher, in the $10^{-4}$ cm/sec range. The three K values in GW-970(I) and two in GW-976(I) show progressive decreases in K with depth suggesting a general trend toward lower permeability with depth. The highest K values come from the shallowest interval of 44–54 ft bgs in GW-970(I). These results are consistent with the highest upward flow rates from the heat pulse

flowmeter tests at 45 and 50 ft bgs (0.062 gpm and 0.039 gpm, respectively), and fluid resistivity log data in GW-970(I). The combined results suggest relatively high K in fractured bedrock near the uppermost bedrock interval in GW-970(I).

#### 7.2.3.6 Phase I Heat Pulse Flowmeter Tests

Heat pulse flowmeter tests were conducted as part of the suite of borehole geophysical logs conducted in each of the Phase I open bedrock boreholes. The results are reviewed here as they are related to K and indicate potential fracture flow within the saturated zone of bedrock. The flowmeter testing equipment and test methodology are summarized in Section 4.1.6.1 above and in Exhibit A.8. Test results are summarized in Table 15. The results are also presented on the combination logs in Exhibit A.8 with results in gpm posted next to each test depth.

The flowmeter is capable of detecting ground water flow either vertically upward or downward within the borehole at discrete depths, but only upward flows were detected in the Phase I flowmeter tests. The flowmeter results in combination with the continuous water level monitoring data suggest that vertical gradients among the Phase I well pairs are mostly upward. An exception may occur for GW-976(I) where results are less certain as the shallow well pair (GW-977[S]) was dry and upward flows were not detected among the flowmeter data until depths of 75 and 80.5 ft bgs (see Table 15).

The lowest quantifiable flow rate for the heat pulse instrument is 0.03 gpm (equal to 1.8 gallons per hour [gph] or 43 gallons per day [gpd]), although rates less than this value were plotted on the borehole geophysical logs where multiple tests showed repeatability in two or more tests. As shown in Table 15, the lowest quantifiable flow rate of 0.03 gpm was rarely exceeded during the borehole flowmeter testing. Only four of the 39 borehole flow meter tests (10%) resulted in flow rates >0.03 gpm, 25 of the tests had zero flow, and the remaining 10 tests were all between 0.010 and 0.026 gpm. Flow rates >0.030 gpm occurred only in GW-970(I) at depths of 45, 50, and 57 ft bgs, and in GW-976(I) at a depth of 75 ft bgs. Plate 2 (attached) presents these results in vertical profiles that also illustrate the collective Phase I results from packer tests and potential fracture flow zones identified in rock cores (along with other Phase I results such as K values from slug tests, and shelby tube testing. The flowmeter tests in GW-972(I) and GW-974(I) suggest very low flow conditions over much of the open borehole. However, it should be noted that very low flow conditions on the order of rates <0.01 gpm from multiple fractures could collectively result in significant ground water flux and upward gradients when measured over a relatively large open hole interval of 100 ft or more.

### 7.2.4 Regolith Hydrogeology at the EMDF Site

The regolith includes all unconsolidated materials that overly competent bedrock. Depending on site topography and local conditions, the regolith at the EMDF site may include surficial soils and clayey residuum, colluvium and alluvium along flanks and floors of the NT tributary valleys, and underlying saprolite. For practical purposes, the depth of the regolith may be considered as auger refusal drilling depth. Subsurface geotechnical sampling and engineering test data are focused largely on regolith materials. Sections 7.2.4.1 and 7.2.4.2 review the results of geotechnical sampling and laboratory testing of regolith soils and saprolite from the geologic formations underlying the EMDF site.

Table 16 summarizes regolith materials and thicknesses based on the Phase I borings. Exhibits A.4 and A.5 (attached) include detailed boring log descriptions and split tube photographs of regolith materials. Vertical profiles of regolith materials are illustrated in the cross sections of Plates 2 through 4 for the Phase I borings. Because of the close proximity of the well pairs, the regolith profile was only logged during drilling of the original deep borehole and not repeated during the drilling of the shallow well pair.

**Table 14. Hydraulic Conductivity Data from Packer Tests**

| Open Bedrock Borehole (8 in. diameter) | Test Interval (ft) | Pressure (psi) with Range in Brackets | Hydraulic Conductivity – K For each Pressure Test (cm/sec) | Average Hydraulic Conductivity – K For each Tested Interval (cm/sec) |
|---|---|---|---|---|
| GW-968 | 23-33 | 15 | 3.12E-05 | 3.1E-05 |
| GW-970 | 44-54 | 15 [15-16] | 1.70E-04 | 1.5E-04 |
| | | 30 | 1.34E-04 | |
| | 52-62 | 15 [15-16] | 3.17E-05 | 3.1E-05 |
| | | 30 [29-30] | 2.94E-05 | |
| | 65-75 | 15 | 1.59E-05 | 1.4E-05 |
| | | 30 | 1.36E-05 | |
| | | 45 | 1.35E-05 | |
| GW-972 | 65-75 | 15 [14-18] | No or limited/erratic flow K indeterminate | K indeterminate |
| | | 30 [30-35] | No or limited/erratic flow K indeterminate | |
| | | 45 | No or limited/erratic flow K indeterminate | |
| | 75-85 | 15 | No or limited/erratic flow K indeterminate | K indeterminate |
| | | 45 | No or limited/erratic flow K indeterminate | |
| GW-974 | 33-43 | 15 | No or limited/erratic flow K indeterminate | K indeterminate |
| | | 30 | No or limited/erratic flow K indeterminate | |
| | | 45 | No or limited/erratic flow K indeterminate | |
| GW-976 | 49.5-59.5 | 15 | 4.99E-05 | 5.6E-05 |
| | | 30 [26-29] | 5.75E-05 | |
| | | 45 [40-41] | 5.93E-05 | |
| | 68-78 | 15 | No consistent flow K indeterminate | K indeterminate |
| | | 30 | 1.21E-05 | 1.2E-05 |
| | | 45 | 1.16E-05 | |

**Table 15. Summary of Heat Pulse Flowmeter Tests**

| | GW-968(I) - Heat Pulse Flowmeter Tests | | | | GW-970(I) - Heat Pulse Flowmeter Tests | | | | GW-972(I) - Heat Pulse Flowmeter Tests | | | | GW-974(I) - Heat Pulse Flowmeter Tests | | | | GW-976(I) - Heat Pulse Flowmeter Tests | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth | Flow | Flow | Flow | Depth | Flow | Flow | Flow | Depth | Flow | Flow | Flow | Depth | Flow | Flow | Flow | Depth | Flow | Flow | Flow |
| **Tests** | (ft) | (gpm) | (gph) | (gpd) | (ft) | (gpm) | (gph) | (gpd) | (ft) | (gpm) | (gph) | (gpd) | (ft) | (gpm) | (gph) | (gpd) | (ft) | (gpm) | (gph) | (gpd) |
| **1** | 12 | 0.020 | 1.18 | 28.2 | ***45*** | ***0.062*** | ***3.74*** | ***89.7*** | 26 | 0 | 0.00 | 0.0 | 20 | 0 | 0.00 | 0.0 | 50 | 0 | 0.00 | 0.0 |
| **2** | 17 | 0.022 | 1.33 | 32.0 | ***50*** | ***0.039*** | ***2.34*** | ***56.2*** | 30 | 0 | 0.00 | 0.0 | 26 | 0 | 0.00 | 0.0 | 62.5 | 0 | 0.00 | 0.0 |
| **3** | 25 | 0 | 0 | 0 | ***57*** | ***0.031*** | ***1.87*** | ***44.9*** | 40 | 0 | 0.00 | 0.0 | 35 | 0.016 | 0.94 | 22.6 | 67 | 0 | 0.00 | 0.0 |
| **4** | 26 | 0.015 | 0.91 | 21.8 | 70 | 0.017 | 1.00 | 24.0 | 45 | 0 | 0.00 | 0.0 | 40 | 0 | 0.00 | 0.0 | ***75*** | ***0.034*** | ***2.02*** | ***48.6*** |
| **5** | 27 | 0.019 | 1.16 | 27.9 | 77 | 0 | 0.00 | 0.0 | 51 | 0 | 0.00 | 0.0 | 46.5 | 0 | 0.00 | 0.0 | 80.5 | 0.022 | 1.35 | 32.3 |
| **6** | 35 | 0 | 0 | 0 | 90 | 0 | 0.00 | 0.0 | 61.5 | 0 | 0.00 | 0.0 | 50 | 0 | 0.00 | 0.0 | 88.5 | 0 | 0.00 | 0.0 |
| **7** | 38 | 0 | 0 | 0 | | | | | 70 | 0.026 | 1.55 | 37.1 | 64 | 0 | 0.00 | 0.0 | 93 | 0 | 0.00 | 0.0 |
| **8** | 42 | 0.018 | 1.07 | 25.6 | | | | | 76 | 0 | 0.00 | 0.0 | | | | | | | | |
| **9** | 50 | 0 | 0 | 0 | | | | | | | | | | | | | | | | |
| **10** | 68 | 0.016 | 0.98 | 23.4 | | | | | | | | | | | | | | | | |
| **11** | 71 | 0 | 0 | 0 | | | | | | | | | | | | | | | | |

Notes and Abbreviations:

- All flows were in a vertically upward direction.
- Values in ***bold italics*** exceed the minimum quantifiable flow rate for the heat pulse flowmeter instrument of 0.030 gpm. Values below this level are considered suspect, but were provided where test results showed repeatability in two or more heat pulse tests.

ft feet
gpd gallons per day
gph gallons per hour
gpm gallons per minute

**Table 16. Summary of EMDF Regolith Materials Based on Phase I Results**

| Well ID | Estimated Topsoil Removed for Road Construction | Regolith Soil/Saprolite Thicknesses (ft) | Soil/Saprolite Split-tube & Shelby Tube Descriptions | Depth Increasing Soil Consistency (Based on SPT N Values (blows/ft) |
|---|---|---|---|---|
| GW-968(I) | 7.19 | 9.8 | clayey or sandy SILT (ML) w/ weathered bedrock fragments (saprolite) | very stiff to hard |
| | | 0.2 | weathered sandstone & siltstone | hard |
| | | 10.0 | Total Regolith Thickness (GW-968) | |
| GW-969(S) | 4.65 | 13.5 | Not logged - shelby tube 1.0-3.0 ft bgs - silty clay (decomposed shale) | NA |
| GW-970(I) | 4.37 | 25.6 | clayey or sandy SILT (ML) w/ weathered bedrock fragments (saprolite) | stiff to very stiff to hard |
| | | 25.6 | Total Regolith Thickness (GW-970) | |
| GW-971(S) | 4.31 | 23.8 | Not logged - shelby tube 17.0-19.0 ft bgs - silty clay (decomposed shale) | |
| GW-972(I) | -1.15 | 23.5 | SILT (ML), and clayey SILT (ML) w/ weathered bedrock fragments (saprolite) | medium stiff to very stiff to hard |
| | | 0.7 | Weathered shale | hard |
| | | 24.2 | Total Regolith Thickness (GW-972) | |
| GW-973(S) | 0.54 | 23.0 | Not logged - shelby tube 2.0-4.0 ft bgs - silty clay (decomposed to weathered shale) | |
| GW-974(I) | 0.3 | 10.7 | clayey SILT (ML) w/ weathered bedrock fragments (saprolite) | stiff to hard |
| | | 1.8 | Weathered bedrock (assumed) | hard |
| | | 12.5 | Total Regolith Thickness (GW-974) | |
| GW-975(S) | 0.78 | 10.0 | Not logged - shelby tube 7.0-8.5 ft bgs - silty clay (decomposed to weathered shale) | |
| GW-976(I) | 1.66 | 7.0 | clayey SILT (ML) | very stiff to hard |
| | | 17.0 | clayey SILT (ML) w/ weathered bedrock fragments (saprolite) | hard |
| | | 0.4 | weathered siltstone (saprolite) | hard |
| | | 24.4 | Total Regolith Thickness (GW-976) | |
| GW-977(S) | 1.87 | 25.1 | Not logged - shelby tube 10.0-10.66 ft bgs - silty clay (decomposed to weathered shale) | |

Notes and Abbreviations:

- N values based on blow counts per ASTM Method D1586 for cohesive soils; see boring logs in attached Exhibit A.4.

  ft bgs feet below ground surface
  SPT standard penetration test

The thickness of the regolith (i.e., depth to auger refusal) at the five Phase I well pair locations varies from 10.0 ft at GW-968(I) to 25.6 ft at GW-970(I) (see Table 16). The Phase I well pairs are located approximately 10-15 ft from each other with variations in depth to auger refusal between the well pairs ranging from 0.7 to 3.5 ft. Water level data from the Phase I monitoring wells thus far indicates that the water table occurs well up within the regolith above the top of bedrock (i.e, above auger refusal depths) across most of the EMDF footprint. The exception occurs at GW-976(I) along the spur ridge on the south side of the EMDF footprint, where the water table occurs down 20 ft or more below the top of bedrock, located at auger refusal depths of 24–25 ft bgs. The current water level data reflect the seasonally wet non-growing season when water levels are at their highest. Water level data monitoring on the ORR clearly indicates that water levels decline seasonally with the warmer growing season and depending upon topographic location may fall to levels at or below the regolith/bedrock interface.

Topsoils and a portion of the underlying clayey residuum were removed during the construction of the drilling pads and access roads. The original ground surface was not accurately surveyed prior to construction of the drilling pads so the exact vertical extent of the removal is unknown. However, removal estimates shown in Tables 1 and 16 were made by subtracting the Phase I surveyed ground surface elevations from surface elevations determined from the existing site topographical maps (displayed at 5 ft contour intervals on current site drawings). Estimated topsoil removed for road/drill pad construction are shown in Table 16 and vary from 7.2 ft at GW-968(I) to -1.2 ft at GW-972(I), where the minus sign indicates fill was apparently added to the original undisturbed location.

Because of the site grading and road construction, the Phase I boring logs do not indicate any topsoil or alluvium/colluvium at any location. Except for the GW-968(I)/969(S) location, the Phase I borings were all drilled in upland areas of the site unlikely to encounter any Recent alluvial or colluvial deposits. Any original alluvial/colluvial deposits that may have existed at the undisturbed pre-Phase I GW-968(I)/969(S) location would have been removed and locally reworked during access road and drill pad construction. While not an objective of the Phase I fieldwork, characterization of alluvium and colluvium along the NT tributary valley floors and flanks would be specifically addressed during Phase II site investigations to provide data necessary to properly design the proposed underdrain network.

Except for the upper 6–7 ft of soils at GW-976(I), the split tube samples collected at all other Phase I drilling locations were consistently logged as silt with some portion of weathered bedrock fragments. The logged regolith soils were predominantly saprolitic soils without a surficial zone of clayey/silty residuum. Most of the silty soils were logged as clayey or sandy silt. The upper 6–7 ft of soils at GW-976(I) were logged only as clayey silt and did not include weathered bedrock fragments suggesting a thicker zone of near surface silt/clay residuum there. The lower part of GW-976(I) was logged as clayey silt with weathered rock fragments, similar to the typical saprolite zone seen elsewhere at the site.

Sandy and clayey silt was logged in the regolith soils at the two locations in the Pumpkin Valley Shale (GW-968[I] and GW-970[I]). Elsewhere the logged soils did not include a sandy component. The weathered rock fragments logged in most split tube samples indicate the predominance of variably weathered saprolite soils within the regolith profile. This is consistent with field observations of shallow saprolite across the EMDF site. Cuts from access roads and exposures of large root balls from blown down trees across much of the site consistently reveal saprolite with relict bedding and highly weathered rock fragments within a few feet of the original ground surface.

The Phase I results are reasonably consistent with those from the borings logged adjacent to the EMDF site at Ogden Sites B (27 borings) and C (52 borings) (Ogden 1993a/b), except that virtually all residuum at Sites B and C were field logged predominantly as silty clay (CL), as opposed to clayey silt (ML). In addition, out of a total of 40 *residuum* soil samples submitted by Ogden for geotechnical laboratory analysis, 33 were classified (per Unified Soil Classification Sytem [USCS] laboratory classification) as lean clay (CL), seven were classified as fat clay (CH), and none were classified as silt (ML). Similarly,

residuum from ten test pits excavated within the EMWMF footprint was also field logged as lean clay (CL) with underlying shale saprolite (see CH2MHill 2000). However, the laboratory classification of five residuum soil samples from these test pits showed greater variation among USCS soil classifications, ranging from CL, CH, SM, to two samples as ML. All of the samples reported by Ogden and CH2MHill were collected from the same geologic formations that occur directly adjacent to and along strike with the EMDF footprint. These soil samples should therefore be equivalent to those anticipated at the EMDF site. The five EMDF Phase I shelby tube soil samples submitted for geotechnical laboratory analysis (see Section 7.2.4.1 below) were all logged as "silty clay (decomposed to weathered shale)" (CL), and are consistent with the majority of Ogden and CH2MHill descriptions of predominantly clayey soil residuum within the same geologic formations as those below the EMDF footprint. Differences between the Phase I logged soil descriptions and those from other investigations and similar soils along strike appear to result in part from manual field descriptions that vary depending on the experience and judgment of field geologist/engineers and the subtle differences between silt and clay sized materials.

#### 7.2.4.1 Phase I Results of Geotechnical Laboratory Tests

The laboratory results from testing of the five Phase I Shelby tube samples are shown in Table 17. The complete laboratory data sheets are provided in Exhibit A.3. The Shelby tube samples were targeted for collection from the shallow saturated zone to define the hydraulic conductivity and geotechnical index properties of the water table interval. The sample collection depths were based on water levels measured in open boreholes drilled to auger refusal during the early drilling of the deep well pairs. Water levels measured in open boreholes may vary from final water levels obtained from completed monitoring wells as time is required for water levels to equilibrate within boreholes and wells, and water levels naturally fluctuate seasonally and with precipitation/recharge events. Water level data from the completed shallow wells indicate that only two of the five Shelby tube samples were collected from the vadose zone; those in GW-973(S) and GW-977(S). The remaining samples were collected from depth intervals within the saturated zone of the other three shallow wells.

The tube samples at each location were all described by the laboratory as decomposed to weathered shale (saprolite). It is important to note that the CL and SC classification symbols and percentages of gravel, sand, silt, and clay shown in Table 17 are based on the natural crumbling and disintegration of weathered shale (saprolite) extruded from the Shelby tubes and mechanically sieved. The results therefore simply reflect the range of particle size fractions of the decomposed shale and weathered shale rock fragments. The results are based on a standardized mechanical process normally designed to measure naturally occurring *unconsolidated* "soil" like materials such as mud, sand, and gravel mixtures found in typical soils or alluvial/colluvial materials – not weathered and partially consolidated, fractured sedimentary rocks characteristic of weathered Conasauga Group rock formations. These results should therefore be used and interpreted with these precautions and considerations in mind.

The results of the hydraulic conductivity tests indicate relatively low K values ranging from $3.89\times10^{-7}$ to $6.54\times10^{-6}$ cm/sec, with a mean K of $3.23\times10^{-6}$ cm/sec. Natural moisture contents range from 12.2– 21.2%. Specific gravities range from 2.68–2.73. Liquid and plastic limits range from 29–34, and 20–24, respectively.

#### 7.2.4.2 Results of Geotechnical Laboratory Tests from Adjacent Sites

As noted above in Section 5, a considerable amount of geotechnical test data is available from sites directly adjacent to the EMDF footprint. Because the data were collected from boring locations and test pits directly along geologic strike with the same formations outcropping across the EMDF footprint, they are directly relevant to current and future planning and investigations at the EMDF. A summary of results is provided in Exhibit A. 19. The original reports should be referenced for additional details (Ogden 1993a and b; CH2M Hill 2000).

**Table 17. Summary Results from Geotechnical Laboratory Analysis of Phase I EMDF Shelby Tube Samples**

| Sample ID | Sample Depth Interval (ft bgs) | ASTM D 2487 | | ASTM D 422 | | | | ASTM D 4318 | | | ASTM D 854 | ASTM D 5084 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | USCS Soil Type | Material Description | % Gr | % Sd | % Si | % Cl | NM % | LL | PL | SG | K (cm/sec) |
| GW969-UD-1 | 1.0-3.0 | CL | Clay, silty (decomposed shale), brown, mottled gray w/rock | 15.4 | 34.1 | 26.5 | 24.0 | 15.5 | 29 | 20 | 2.68 | $3.89\times10^{-7}$ |
| GW971-UD-1 | 17.0-19.0 | CL | Clay, silty (decomposed shale), brown, maroon, mottled | 0.1 | 42.8 | 41.3 | 15.8 | 20.0 | 34 | 22 | 2.73 | $6.36\times10^{-7}$ |
| GW973-UD-1 | 2.0-4.0 | SC | Clay, silty (decomposed to weathered shale), brown, brown to brownish red | 16.5 | 49.5 | 25.8 | 8.2 | 21.2 | 34 | 24 | 2.71 | $3.53\times10^{-6}$ |
| GW975-UD-1 | 7.0-8.5 | SC | Clay, silty (decomposed to weathered shale), light brown, brown, mottled | 19.3 | 59.3 | 14.0 | 7.4 | 15.0 | 32 | 22 | 2.71 | $6.54\times10^{-6}$ |
| GW977-UD-1 | 10.0-10.66 | SC | Clay, silty (decomposed to weathered shale), light brown, brown, mottled | 18.1 | 53.5 | 15.8 | 12.6 | 12.2 | 30 | 20 | 2.7 | $5.03\times10^{-6}$ |
| | | | | | | | | | | | Mean K | $3.23\times10^{-6}$ |

Notes and Abbreviations:

- The CL and SC classification symbols and the percentages of gravel, sand, silt, and clay may be misleading because each of the five samples were composed of weathered shale (saprolite) and are not true samples of typical "soil" like materials such as clays, silts, sands and gravels found in unconsolidated residual soils or alluvial/colluvial materials. The sieve analysis results reflect the range of particle size fractions based on the natural crumbling and disintegration of weathered shale extruded from the Shelby tubes and mechanically sieved. These USCS classifications, particularly the SC classifications, therefore have little meaning and should be used with caution.
- Samples from GW-973(S) and GW-977(S) were collected from the vadose zone; all other samples were collected from within the zone of water table fluctuation of shallow ground water.

Cl clay
ft bgs feet below ground surface
Gr gravel
K hydraulic conductivity in centimeters per second (cm/sec)
LL liquid limit
NM natural moisture content
PL plastic limit
Sd sand
SG specific gravity
Si silt

### 7.2.5 Bedrock Hydrogeology at the EMDF Site

The bedrock interval in the 100 ft depth Phase I deep wells varies from 73–90 ft in length (from the base of isolation casing to total depth). The hydrogeology of this bedrock interval is based on and interpreted from:

- Continuous rock cores from GW-972(I) and GW-976(I)
- Borehole geophysical logging in all the deep wells over the bedrock interval (including heat pulse flowmeter results)
- Nine packer tests of selected bedrock intervals to determine K
- Continuous water level monitoring in all deep wells

The results are introduced with a review of general bedrock structures, the Phase I rock core data, borehole geophysical logs, and correlations between the rock core data and the geophysical logs. The site-specific bedrock hydrogeology (stratigraphy, lithology, structural features, and ground water conditions) are then reviewed based on the north to south outcrop belt of the geologic formations directly adjacent to and underlying the EMDF footprint (Upper Rome Formation through the Maryville Limestone). The Phase I results and interpretations are reviewed, and supplemented with sources of relevant geologic data reported from other subsurface investigations in BCV that are along geologic strike with the EMDF footprint. The key stratigraphical, lithological, structural, and hydrological features from Phase I are illustrated in the maps and cross sections of Plates 2 through 4, which should be referenced for supplemental details and visualization of subsurface conditions that are described below. Plate 2 in particular provides a comprehensive illustration of results for each of the Phase I wells/borings including results from packer tests, descriptions and interpretations of lithologies and possible flow zones based on rock core analysis, heat pulse flowmeter test results, and other borehole geophysical logs and structure logs. Plate 2 may be used as a reference tool for the following subsections along with detailed geophysical logs provided in Exhibit A.8.

#### 7.2.5.1 Bedrock Structures

The interconnected subsurface network of naturally occurring structural features (e.g., fractures associated with bedding planes, joints, shear surfaces, folds and faults) dictates the occurrence, distribution, and flow paths of subsurface ground water in bedrock. Hydrogeological investigations on the ORR have demonstrated a tendency for ground water fracture flow to be dominantly strike parallel and for ground water flow and contaminant transport to often be stratabound (Ketelle and Lee, 1992). These features are both dictated largely by fracture systems that are dominant parallel to strike and to fracture/joint controlled systems that may be constrained within bedded intervals that typically dip on the order of 45° to the southeast. The better subsurface fracture systems are characterized, the better the subsurface fracture flow systems can be understood and simulated in site conceptual models and fate and transport modeling. Fracture intervals identified in rock cores at GW-972(I) and GW-976(I) and interpreted from evaluation of borehole geophysical logs are reviewed below by geologic formation. The locations and nature of these features are presented on the cross sections in Plates 2 through 4 (as well as on the boring logs in Exhibit A.4). Rock core photographs in Exhibit A.7 provide close-up examples of key fractured and/or stained and weathered zones suggesting potential ground water flow paths.

#### 7.2.5.2 Phase I EMDF Rock Core Data

Rock cores were collected continuously from the bedrock intervals of two of the five deep well pairs, GW-972(I) and GW-976(I), located within the outcrop belts of the Rutledge Limestone and Maryville Limestone, respectively (see Plates 2 and 3). One of the primary objectives of the Phase I rock coring was to evaluate the occurrences of any limestone beds within the EMDF footprint and their detailed characteristics, including the nature of fracturing, weathering, or dissolution that might be conducive to

ground water flow. Limestone beds have been described within these two formations from boreholes drilled elsewhere in BCV. A second important objective was to obtain direct physical evidence of lithologies and structures in the rock cores that could be correlated against and test the validity of the borehole geophysical logs.

HQ size (2.5 in. diameter) rock cores were recovered from depths at or near auger refusal down to nominal total depths of 100 ft in GW-972(I) and GW-976(I). The overall core lengths in the two boreholes were 77 and 73 ft, respectively. The cores were recovered in lengths of 5ft or less and carefully logged and photographed to document: (1) depths and thicknesses of primary lithologies, (2) the nature of important structural features (e.g., bedding planes, joints, shear fractures), and (3) fractured, weathered, and stained intervals that would be indicative of possible bedrock fractured flow zones within the intermediate ground water interval. Representative maximum dip angles were measured from intact sections of rock cores wherever bedding planes were clearly observed and measureable. Because of the disorientation of the retrieved cores, azimuth strike/dip directions cannot be determined from the core data; only the maximum dip angles are reliable and were assumed to be toward the typical southeast dip direction. Dip angles were measured using a transparent compass and are generally accurate to within ± 1°–2°.

#### 7.2.5.3 Overview of Phase I EMDF Borehole Geophysical Logging

The results of the borehole geophysical logs are reviewed in subsequent sections below according to the Phase I deep borings drilled within the outcrop belt of each of the formations. Log interpretations and conclusions are presented separately in the attached URS geophysical report (see Exhibit A.8). However, the URS report does not include any comparisons and correlations made between the rock core data and the geophysical logs. Nor does the URS report incorporate the findings from the packer tests or the results of continuous ground water monitoring. The URS interpretations have been integrated into the presentation of collective results below drawing from the entire suite of Phase I activities.

The results from the borehole geophysical logs supplement the rock core data from GW-972(I) and GW-976(I), and were the primary source of bedrock data at the remaining three deep borings GW-968(I), GW-970(I), and GW-974(I) where no rock coring occurred. The bedrock borings at GW-968(I), GW-970(I), and GW-974(I) were drilled using an air rotary rig creating a nominal 8 in. diameter borehole before geophysical logging. After completing the rock coring at GW-972(I) and GW-976(I), these two boreholes were reamed with the same air rotary rig. The borehole geophysical logging was thus performed within consistently sized 8 in. diameter boreholes at each location.

The detailed rock core logs (see Exhibit A.4) from GW-972(I) and GW-976(I) were plotted alongside the corresponding borehole geophysical logs to systematically correlate bedrock features observed in the rock cores with corresponding geophysical signatures (if and wherever they might occur). Plate 2 presents the stratigraphic/lithologic profile, potential fractured intervals, and maximum bedding plane dip angles derived from the rock core logs alongside the borehole geophysical logs for GW-972(I) and GW-976(I). The most detailed borehole geophysical logs are provided in Exhibit A.8 which are plotted at a vertical scale of 1 in. equals 2 ft. The depths and thicknesses of fracture intervals (particularly fractures with staining/weathering indicative of possible ground water flow) and lithologic units (e.g., distinct beds and intervals of limestone, shale, and interbedded, laminated shales and limestones, and other characteristic lithologies) were compared against the geophysical signatures from the various logs in an attempt to establish positive correlations that could be used in boreholes without rock core data. With the exception of the OTV log (which is essentially a wide angle downward directed digital camera with radial lights placed at the bottom of the tool), the geophysical instruments provide indirect indications of geological characteristics based on the nature of each instrument. The OTV log is most sensitive to the clarity of the water column in the borehole (or the lack thereof) and its quality generally diminished with reduced downward water clarity in the Phase I boreholes. The SP logs could not be correlated with any features

observed in the Phase I rock cores. The SP logs were therefore not useful for interpreting lithologic or structural features.

Except for the NGR log signature of some relatively thicker beds (generally > 1 ft) of shale and limestone in GW-976(I), the borehole geophysical logs were incapable of accurately defining the depths and thicknesses of distinct basic rock types such as shale, siltstone, and limestone, or of interbedded and laminated sequences comprised of these lithologies. The geophysical logs therefore cannot be used to provide an accurate continuous stratigraphic/lithologic profile at the well locations. Without rock core data there are limited means available for accurately characterizing the detailed stratigraphic/lithologic profile in a bedrock borehole.

The primary strength of the borehole geophysical logs generally came from the OTV and ATV logs, the fluid temperature and fluid resistivity logs, and the heat pulse flowmeter logs. Up to five different structural features were identified by the URS geophysicist using the OTV/ATV logs and those features were plotted on the borehole logs as a "structure log" down the center of the composite borehole logs (see Plate 2 profiles and detailed logs in Exhibit A.8). The structure log was developed by the geophysicist using an image module of WellCAD software that allows for interactive digitizing of structural features with depth. The structure log is subjective and interpretive and relies on the professional judgement of the geophysicist to maintain consistent criteria among boreholes. The structure log also depends upon the quality of the OTV/ATV logs which can vary with depth and among boreholes. The WellCAD software calculates the true strike and dip based on the "mapping" of structural features by the geophysicist. The majority of structural features identified by the geophysicist were surfaces parallel to bedding planes aligned with the regional dip toward the southeast. However, in some boreholes structural features were identified with orientations discordant to the regional bedding plane dip. Up to five different structural features were interpreted and plotted with color codes on the structure logs:

- Major open fracture/joint (red)
- Minor open fracture/joint (purple)
- Partially open fracture/joint (orange)
- Bedding plane (green - bedding/banding/foliation), and
- Filled fracture/joint (gray)

The "filled fracture/joint" features were considered least important because they do not represent features conducive to ground water flow. The open fractures/joints are the most significant features identified on the structure logs as they have the potential to represent depths conducive to ground water flow.

The results of the heat pulse flowmeter logs were reviewed above in Section 7.2.3.6, and are not repeated here. These logs were completed in a final separate phase of the borehole geophysical logging process. Flowmeter results are integrated with the interpretations presented in subsequent sections for each deep well location.

The wellbore deviation logs were run with the ACT/OTV logs and indicate the deviation in borehole angle and azimuths with depth bgs. Key results from the logs are shown in Table 18. The overall lateral deviation relative to the surface location at depths near the bottom of the borings indicates that none of the boreholes deviated significantly from the vertical (see Exhibit A.8 for detailed borehole deviation log profiles and plan views). The results indicate a tendency of the boreholes to deviate slightly toward the northwest in a direction opposite to the typical bedding plane dip direction toward the southeast.

**Table 18. Borehole Deviation Results from Geophysical Logs Run in Deeper Intermediate Zone Wells**

| Well ID | Horizontal deviation (in feet) from surface location at depth shown with general azimuth direction from true north |
|---|---|
| GW-968(I) | 2.4 ft to northwest at 89 ft bgs |
| GW-970(I) | 6.5 ft to northwest at 96.9 ft bgs |
| GW-972(I) | 2.3 ft to northwest at 97 ft bgs |
| GW-974(I) | 9.8 ft to north-northwest at 97 ft bgs |
| GW-976(I) | 1.7 ft to west at 99.6 ft bgs |

Rock cores (along with the packer test results and water level monitoring data) provide the best means of validating the results of the borehole geophysical logs. Although positive correlations were identified between rock cores and the structure logs and other geophysical logs, there are many features identified in the rock cores that are not reflected in the suite of geophysical logs, nor in the structure log based on geophysical interpretations.

### 7.2.5.4 Correlations Between Phase I Rock Core Data and Borehole Geophysical Logs

The rock core data from GW-972(I) and GW-976(I) were plotted alongside the suite of borehole geophysical logs to evaluate potential correlations between lithologies and structures (fractures, joints, etc.) observed in rock cores, and the various borehole geophysical logs and structure logs completed in these boreholes. Correlations could then be made with greater confidence for borehole geophysical logs completed in boreholes without rock cores. The results of this cross correlation process allowed for an assessment of log features against physical data from the cores independent of interpretations made by the geophysicist solely from the geophysical logs.

The only geophysical log found to have any possible correlation with lithologies was the NGR log. Other geophysical logs may provide useful data but generally do not provide a direct indication of lithologic data. The NGR log is measured in terms of Antecedent Precipitation Index (API) units scaled on the logs from 0 to 200 API units (see Exhibit A.8, URS Geophysical report for more details). The key correlations for the two boreholes with rock cores and borehole geophysical logs are summarized below. Note that GW-976(I) was drilled within the outcrop belt of the Maryville Limestone (Dismal Gap Formation) and GW-972(I) was drilled within the outcrop belt of the Rutledge Limestone (Friendship Formation).

**GW-976(I) Rock Core and Borehole Geophysical Log Correlations**

- Shale beds in rock cores greater than about 1 ft in thickness correlate with higher NGR curves, but the API values in these shale beds are comparable with those found in interbedded laminated siltstone and shale sequences higher in the unsaturated section of the borehole (i.e., above approximately 44 ft bgs). The NGR curve therefore does not appear to provide a unique and diagnostic signature for distinguishing between siltstone and shale (or mudstone).
- Shale beds of 1.1, 2.4, and 4.2 ft in rock core thickness showed a relatively high average maximum baseline of approximately 155 API units on the NGR curve.

- Two thicker limestone beds in GW-976(I) rock cores had the lowest API unit readings; much lower than the API responses in predominantly clastic formations.
  - A 1.5 ft thick limestone bed at approximately 91.5 ft bgs reached a low of 92 API units
  - A 1.8 ft thick limestone bed at approximately 76.5 ft bgs reached a low of 85 API units
- Thinner limestone beds less than 1 ft in thickness show relatively higher API units, apparently as a result of shaly beds surrounding the thinner limestone beds, raising the overall API values.
- Interbedded (saturated) laminated shale and limestone sequences from 48-60 ft bgs correlate with API readings typically averaging 120–130 API units (with an overall range of approximately 102–140 API units).
- Interbedded (unsaturated) laminated siltstone and shale (without any calcareous layers) sequences from 27.5–44 ft bgs correlate with API readings averaging approximately 156 API units (with an overall narrower range between approximately 145–165 API units).
- Assuming no influences from saturated versus unsaturated conditions or other unknown factors, the correlations suggest that lower API units may be associated with greater carbonate content.
- A baseline shift occurs in the NGR curve at 45–47 ft bgs that is coincident with the change from an upper non-carbonate to lower carbonate sequence (verified by HCl acid effervescence). The shift is also roughly parallel with changes in fluid resistivity/temperature logs that occur over a 3–4ft interval just below the water table at that time (at 44.3 ft bgs). The shift represents a decrease of about 40 API units.
- Some portions of the caliper log indicating a widened borehole from "washout" intervals correlated reasonably well with intervals of significant core loss (near depths of 45, 52, 72, 74.5, and 77.5 ft bgs). In these intervals borehole diameters widened from 8.5–9.8 in. from the nominal 8 in. diameter borehole (these intervals may represent weak fractured shale beds prone to disintegration during the coring process).

**GW-972(I) Rock Core and Borehole Geophysical Log Correlations**

- No consistent correlation is evident between shale beds and higher NGR curve API units, but the shale beds are mostly relatively thin (less than 0.5 ft thick). Even in the two shale beds with thicknesses of approximately 1.1–1.5 ft thick at depths of approximately 35 and 46 ft bgs, the API units were not elevated, averaging 140 API units.
- The overall NGR curve for GW-972(I) displays far less variation in API units than does the NGR curve for GW-976(I), apparently reflecting the predominant shale/mudstone lithology (approximately 80%) and relatively thin (i.e., <0.2-0.3 ft thick) and limited occurrence of limestone/calcareous siltstone lamina/beds (approximately 20%) in GW-972(I).
- This overall NGR curve shows an average of 142 API units with a range of approximately 121–167 API units.
- The NGR curve appears consistent with the relatively monotonous sequence of interbedded laminated shale and intermittent limestone/calcareous siltstone sequence logged in the rock cores over the entire length of the borehole (see core photographs in Exhibit A.7).

Direct comparisons between the Phase I rock cores and the borehole geophysical logs indicate that none of the geophysical logs are sensitive enough to develop a detailed and accurate stratigraphic section for each of the deep borings. This is particularly true for the relatively thin beds (typically < 1.0 ft thick) and laminated sequences logged in the rock cores of GW-972(I) and GW-976(I), and inferred at the other boring locations. Table 19 summarizes the NGR curve statistics from each of the deep boreholes, illustrating the range and average values for NGR readings, and their relationships with the geologic formations. The results suggest an average (overall baseline) NGR reading that is lowest in the Maryville,

presumably associated with the limestone beds logged in GW-976(I) that have lower API values than the shale beds. The results also suggest a slightly wider range of NGR readings within the Maryville and Rogersville formations than in the other formations.

**Table 19. Statistics for Natural Gamma Ray Logs run in Phase I Deep Borehholes**

| | Natural Gamma Ray Curve Readings in API Units | | | | |
|---|---|---|---|---|---|
| | GW-968(I) | GW-970(I) | GW-972(I) | GW-974(I) | GW-976(I) |
| Average | 147 | 146 | 142 | 139 | 131 |
| Max | 173 | 175 | 167 | 171 | 166 |
| Min | 107 | 127 | 121 | 85 | 85 |
| Range | 66 | 47 | 46 | 86 | 81 |
| Geologic Formation | Cpv | Cpv | Crt | Crg | Cm |
| Bedrock Coring | No | No | Yes | No | Yes |

Abbreviations:

Cm Maryville
Cpv Cambrian Pumpkin Valley
Cr Rutledge
Crg Rogersville

### 7.2.5.5 Other bedrock data in Bear Creek Valley relevant to the EMDF site

Rock core data and geophysical logs from the geologic formations penetrated in the Phase I deep borings were compared against bedrock lithologic data reported elsewhere in BCV along strike to the EMDF. Probably the most extensive rock coring in WBCV (a total of 8,698 ft of rock core) occurred at the former LLWDDD site located approximately 3.5 miles to the southwest of and along geologic strike with the EMDF. Rock coring at the LLWDDD included the entire continuous stratigraphic section from the Upper Rome through the Lower Maynardville formations (Lee and Ketelle, 1989). Each of the geologic formations present below the EMDF site were described by Lee and Ketelle based on the extensive coring completed at the LLWDDD site. Their descriptions also included the basis for establishing formation contacts.

Rock coring data were also compiled and evaluated by King and Haase to define the geological conditions along BCV at and near Y-12. Their report (King and Haase, 1987) includes geologic cross sections at the S-3 Ponds east of the EMDF, and at the Bear Creek Burial Grounds southwest of the EMDF that illustrate the thicknesses of and contacts between Conasauga Group formations underlying the EMDF site. Bedrock lithologic data are also extensively reviewed for the Conasauga Group formations in Hatcher et al (1992).

Table 20 provides descriptions of the geologic formations occurring at the EMDF site (Upper Rome Formation through the Maryville Limestone) based on interpretations of rock cores from the LLWDDD site (Lee and Ketelle, 1989). This report included the most detailed lithologic descriptions for comparison to the Phase I results. The table also includes formation thicknesses (borehole thicknesses and estimated true thicknesses). The table allows for a comparison of the geological data from the limited Phase I investigation results described below with that collected from the same formations along strike in BCV.

Bedrock data from previous investigations at the EMWMF and from investigations at other sites such as the Bear Creek Burial Grounds have included far less extensive and non systematic rock coring data. Much of the bedrock data nearest the EMDF site comes from drilling of boreholes using air rotary rigs which provide very limited detailed lithologic and structural information to accurately characterize the nature and extent of individual fractures or groups of fractures that are fundamental to assessing ground

**Table 20. Descriptions of Geologic Formations Used for Comparison with Phase I Results**

| Geologic Formations at the EMDF Site | Downhole Thickness (in ft) | Equivalent True Thickness Assuming 45˚ dip to SE (in ft) | Descriptions from Lee & Ketelle 1989<br>Based on Extensive Rock Cores Collected at the Proposed LLWDDD Site in WBCV -<br>3.5 Miles Southwest and along Strike with the Proposed EMDF Site |
|---|---|---|---|
| Maryville Limestone - Cmr (Dismal Gap Formation) | 430 | 304 | The Maryville consists of oolitic, intraclastic (flat pebble conglomerate), and thin-bedded limestone interbedded with dark gray shale that typically contains thin, planar, and wavy-laminated, coalesced lenses of light gray limestone and calcareous siltstone. Fine-grained glauconite often occurs at the tops of the thin-laminated limestone lithology. Several isolated dark maroon shale beds typically occur in both the upper and lower Maryville. Although considerable mixing of limestone lithologies is noted, the upper Maryville generally contains greater amounts of intraclastic limestone, while thin-laminated and oolitic limestone is more prevalent in the lower portion. The contact separating these two upper and lower portions is gradational over tens of feet of section. Limestone intraclasts are randomly oriented and roughly 2 to 10 cm in length. In roughly the lower 40 ft of the Maryville, a variable number of prominent, coarse-grained, pinkish limestone beds occur which contain coarser and more abundant glauconite pellets than those higher in the section. |
| Crg/Cmr Contact | | | Abrupt Contact: The Rogersville is terminated abruptly by the occurrence of the comparatively thick limestone beds of the overlying Maryville, with the contact placed at the bottom of the first such limestone. |
| Rogersville Shale - Crg | 90 & 150 | 64 & 106 | The lower Rogersville consists dominantly of dark gray shale containing thin- laminated and bioturbated argillaceous limestone lenses less than 1 in thick. When maroon shales occur in the lower portion, they are thinner and more chocolate brown than the maroon shales in the upper portion. Glauconite partings are commonly interlaminated with the limestones but also occur as bioturbated beds several inches thick. The Craig Member, recognized elsewhere in East TN, is not present at the WBCV site. In the approximate position of the member are a few thin limestone beds which may represent the Craig Member at the site. The beds are 4 to 6 in. thick and composed of interlaminated, light gray, silty limestone and dark gray shale. These beds differ from those in the lower Rogersville principally in thickness and may be more appropriately considered the uppermost portion of the lower Rogersville at the site. The upper Rogersville consists dominantly of maroon shale containing thin (less than 1 in. thick), wavy, light gray, calcareous siltstone or argillaceous limestone lenses in varying amounts. Thin glauconitic partings are liberally incorporated within the siltstone and limestone lenses. The interlamination of these variably colored lithologies gives the upper Rogersville an overall thinly laminated appearance. Thicker beds (more than 1 ft thick) of clean, maroon-to-brownish-maroon shale are occasionally interspersed within the thin-laminated lithology. |
| Crt/Crg Contact | | | Abrupt Contact: The contact with the Rogersville is abrupt and recognized by the absence of 1-ft-thick limestone beds and the introduction of maroon shale. The contact is placed at the top of the uppermost such limestone bed. |
| Rutledge Limestone - Crt (Friendship Formation) | 124 & 126 | 88 & 89 | The Rutledge consists of light gray, bedded limestone, often containing shaley partings interbedded with dark gray or maroon thin-bedded or internally clean shale in beds from 2 to 5 ft thick. Limestones are generally evenly divided between wavy laminated and bioturbated. Horizontal burrows are frequently observed. Maroon shale is more common in the lower Rutledge, and two distinctive beds on the order of 3 ft thick occur at the bottom of the formation, separated by three limestone beds of similar thickness. These limestones are referred to as the "three limestones" of the lower Rutledge, but their lithologic similarity with limestones in the bulk of the Rutledge makes them less distinctive than the two maroon shales. The relatively clean, dark maroon shales in the lower Rutledge give way to dark gray shale with thin calcareous siltstone interbeds. Upper Rutledge interbeds are generally thinner than those below, and more coalescing of lithologies is recognized. Limestone beds are often ribbon or wavy bedded, and some are heavily bioturbated with abundant glauconite pellets. Glauconite stringers also occur commonly within the calcareous siltstone interbeds. |
| Cpv/Crt Contact | | | Abrupt Contact: The contact with the overlying Rutledge is abrupt and placed at the top of generally uninterrupted, thin-bedded, reddish-brown shale and below the interbedded limestone and dark maroon shale of the Rutledge. |
| Pumpkin Valley Shale - Cpv | 376 & 398 | 266 & 281 | The Pumpkin Valley Shale is readily divisible into upper and lower units of nearly equal thickness. The lower Pumpkin Valley consists of reddish brown and gray-to-greenish-gray shale with thin interbeds of siltstone and silty, fine-grained sandstone. Shales typically contain thin, wavy laminated siltstone drapes and discrete laminae of fine-grained glauconite. Silty sandstone interbeds are typically wavy laminated to thin bedded but are often heavily bioturbated. High concentrations of large glauconitic pellets occur in the bioturbated lithology. Decreasing silty sandstone content upward within the lower Pumpkin Valley attests to its transitional nature above the Rome. The upper Pumpkin Valley is laminated to thin-bedded, dominantly reddish-brown, reddish-gray, and gray shale with thin, wavy, and planar-laminated siltstone lenses. Shales are generally fissile and may be massive or thin laminated. Thin partings of fine-grained glauconite pellets are ubiquitously interlaminated within the siltstone lenses. |
| Crm/Cpv Contact | | | Gradational Contact: The contact with the overlying Pumpkin Valley Shale is gradational and placed at the top of the uppermost thick, clean, planar laminated, 8 to 12 in. thick, sandstone bed of the Rome. |
| Rome Formation - Crm | >>195 | >>138 | The Upper Rome consists of thick beds of gray or pale maroon, fine-grained, arkosic to subarkosic sandstone with occassional interbeds of maroon shale that often contain thin siltstone bands. Sandstones are typically planar to wavy-laminated or current-rippled. Vertical burrows are in great abundance in the interbedded lithology but are also recognized in the sandstone-dominated lithology. Burrows diminish in abundance down section. Upper Rome sandstone/shale interbeds occur nonuniformly at the two site locations from which core was acquired. The common occurrence of such interbeds on the western portion of the site is almost entirely replaced in the center of the site by gray or pale maroon sandstone couplets with a total absence of shale. Such lateral facies changes within roughly 1000 ft suggest the Upper Rome was subject to locally variable clastic influx in a low-relief paleodepositional setting. |

Adapted from Lee & Ketelle, 1989

This page intentionally left blank.

water flow conditions. The Site B and C investigations by Ogden (Ogden 1993a/b) included rock coring in bedrock to depths of over 100 ft bgs, however, the coring was limited to locations within the outcrop belts of the Rome and Pumpkin Valley and did not include bedrock borings into the Rutledge, Rogersville, or Maryville formations which also underlay much of the EMDF footprint.

The results from the Phase I rock coring and borehole geophysical logging were compared primarily with the descriptions at the LLWDDD site in WBCV, as these are based on the most extensively characterized site data available within the same fault block as the EMDF bedrock strata. The Phase I rock core intervals comprise only a fraction of the entire stratigraphic section below the proposed EMDF footprint (GW-972[I] and GW-976[I] rock core lengths are 77 ft and 73 ft, respectively), as do the borehole geophysical log intervals in GW-968(I), GW-970(I), and GW-974(I) at 89, 97, and 97 ft, respectively. However, the Phase I results provide initial site-specific data useful for identifying the subsurface conditions at the EMDF, particularly with respect to the more carbonate rich Rutledge and Maryville Limestone formations.

#### 7.2.5.6 Rome Formation Bedrock Hydrogeology

The Rome Formation does not outcrop below the proposed EMDF footprint. The contact between the Rome and Pumpkin Valley occurs about 200 ft north of the proposed waste limits. Detailed conceptual design cross sections indicate that the top of the Rome would occur at minimum depths of 130–150 ft bgs along the northern border of the proposed waste limits (assuming an average dip of 45° to the southeast). South of the northern EMDF border, depths to the Rome would increase significantly as the Rome dips steeply into the deeper subsurface.

No Phase I borings were drilled within the outcrop belt of the upper Sandstone Member of the Rome Formation that outcrops along the spine of Pine Ridge. However, Ogden Site B and C borings drilled within the Rome outcrop belt along the upper slopes and ridge top of Pine Ridge adjacent to and along strike with the EMDF provide useful lithologic and structural data relevant to the EMDF (see locations on Figure 7 and Ogden reports [Ogden 1993 a/b] for additional details and cross sections in Exhibit A.19). These results are useful for properly planning subsurface Phase II investigations in the Rome at the EMDF site. TDEC staff has indicated a desire to monitor ground water conditions in the Rome at the EMDF (see Exhibit A.1).

At Site B northeast of the EMDF, two Ogden borings were drilled in the outcrop belt of the Rome just downslope and south of the top of Pine Ridge. Two other borings were drilled slightly more southward in the outcrop belt of the Pumpkin Valley that penetrated the Rome in the lower bedrock portions of the borings. The borings ranged in depth from 70–108 ft bgs and all were continuously cored into bedrock. The regolith of the two borings in the Rome outcrop belt encountered sand and weathered sandstone saprolite to auger refusal. The Rome bedrock at these locations was logged exclusively as sandstone except for a 10 ft thick siltstone bed logged in one of the borings. In the two other borings, the Pumpkin Valley Shale regolith was logged as surficial clay and weathered shale to auger refusal at competent bedrock. The uppermost bedrock in both borings was logged as siltstone, with the underlying Rome identified exclusively as sandstone to total depths. The contact between the Pumpkin Valley and Rome was placed by Ogden at the interface between the siltstone beds and the underlying sandstone.

At Site C, on the north side of the EMWMF footprint southwest of the EMDF, six borings were drilled within the outcrop belt of the Rome Formation. The borings varied from 30–100 ft in depth. Most were drilled into bedrock, and all the bedrock intervals were continuously cored. Detailed logs and cross sections of these boring show a relatively thinner surficial residuum with much more sand and silt than the clayey residuum further downslope within the outcrop belts of the Pumpkin Valley, Rutledge, Rogersville, and Maryville formations. The saprolite in these borings is similarly more likely to include weathered sandstone and siltstone than weathered shale except for some borings that penetrated thicker

intervals of weathered shale. The Rome bedrock below the regolith was logged as shale, sandstone, and interbedded shale and sandstone. The lithologic variation and thickness of these sequences varies greatly between locations among these borings. Ogden identifies apparent contacts between the Rome and Pumpkin Valley in their detailed cross sections. The fracture density and orientation logged in all the Site B/C bedrock borings varies widely from location to location (see cross section plates in Ogden 1993 a/b). Some borings were logged with few fractures, others show extensively fractured/weathered bedrock intervals, and others are intermediate in terms of fracture density and spacing. The logs suggest that bedrock fracturing is highly variable from location to location.

If the EMDF site is approved, the Phase II site characterization would presumably include borings and monitoring wells to define hydrogeological conditions within the outcrop belt of the Rome Formation along Pine Ridge. Geotechnical data would be collected to support design needs, particularly in relation to slope stability along the steep south facing slope of Pine Ridge.

#### 7.2.5.7 Pumpkin Valley Shale Bedrock Hydrogeology

Two Phase I wells were drilled to nominal 100 ft depths in bedrock at locations within the outcrop belt of the Pumpkin Valley Shale (GW-968[I] and GW-970[I]) using air rotary drilling. Rock coring was not conducted at these locations. The geophysical logs were therefore relied upon to provide an indication of the lithologic sequence and structural features in these boreholes conducive to ground water flow. Comparisons were also made with bedrock lithologic descriptions of the Pumpkin Valley from other investigations in BCV along strike to the EMDF.

**Lithologic Descriptions from BCV Sites along Strike with the EMDF**

Lithologic descriptions of rock core data from the LLWDDD site indicate that the upper Pumpkin Valley is composed predominantly of shale with siltstone lenses, while the lower Pumpkin Valley is composed predominantly of shale with thin interbeds of siltstone and silty, fine-grained sandstone (see Table 20; adapted from Lee and Ketelle 1989, for more detailed formation descriptions). The surface locations of GW-968(I) and GW-970(I) fall within the outcrop belt of the Pumpkin Valley Shale (see Figure 1, Plate 3, and Plate 4). The outcrop pattern of the formation contacts are approximate and based on the work of King and Haase (1987), projected from coreholes located distant to the EMDF site. The GW-968(I) surface location is near the middle of the outcrop belt so that the 100 ft borehole should penetrate portions of the middle to lower part of the Pumpkin Valley. The GW-970(I) surface location is close to the contact between the Pumpkin Valley and Rutledge, so that the 100 ft borehole should penetrate the uppermost section of the Pumpkin Valley.

Ogden Site B and C borings adjacent to and along strike with the EMDF provide useful lithologic and structural data relevant to the EMDF. Boring locations are shown on Figure 7 (see Ogden reports [Ogden 1993 a/b] for additional details and the detailed cross sections in Exhibit A.19). At Site B northeast of the EMDF, nine shallow Ogden borings were drilled in the regolith of the Pumpkin Valley Shale (typical depths of 20 ft bgs). All nine borings were logged with a shallow clay residuum and underlying weathered shale interval. Four deep borings drilled into bedrock (to depths on the order of 70–100 ft bgs) in the Pumpkin Valley and the Pumpkin Valley and Rome formations logged the Pumpkin Valley as predominantly siltstone with minor shale and sandstone beds, and no carbonates.

At Site C (within the EMWMF footprint southwest of EMDF), 12 shallow borings drilled into the regolith of the Pumpkin Valley were also consistently logged with a surficial clayey residuum and underlying weathered shale to total depths typically 20 ft or more bgs. Six deep borings continuously cored in bedrock to depths of 75–115 ft bgs were logged with siltstone and shale or as interbedded sandstone and shale sequences with siltstone intervals. The fracture density and orientation logged in all the Site B/C bedrock borings varies widely from location to location.

**Phase I Borehole Geophysical Logs and Packer Tests for GW-968(I) and GW-970(I)**

***Natural Gamma Ray Logs:*** Correlations between rock cores and NGR logs in GW-972(I) and GW-976(I) suggest that the NGR logs in GW-968(I) and GW-970(I) reflect a predominantly shaley clastic bedrock sequence in both boreholes. As noted above, the geophysical logs are not sensitive enough to develop a detailed and accurate stratigraphic section for each boring. But the average NGR readings and the relatively narrower range of API readings in these logs are similar to the dominantly clastic intervals described from the rock cores over the entire borehole in GW-972(I) and the upper part of GW-976(I).

***Fluid Temperature/resistivity Logs:*** The fluid resistivity log is a reflection of total dissolved solids (TDS) concentrations in well or borehole water, and water producing and water receiving zones may be identified by changes in fluid resistivity (USGS 1996). The fluid resistivity log in GW-968(I) and GW-970(I) both show low resistivity intervals covering the bottom 15–30 ft of the boreholes that transition upward to much higher fluid resistivity values at intermediate to shallower depths. These appear on the logs as "ramps" over specific depth intervals. These transitions suggest possible zones of water level flux assuming that TDS concentrations (particularly colloids) increase with mobilized ground water entering and migrating vertically within the borehole. The transition in GW-968(I) occurs between 39 ft bgs and about 60 ft bgs, with relatively stable resistivity values in the upper and lower sections of the borehole on either side of this interval. Resistivity values decline again within the uppermost 10–15ft of the borehole suggesting potential ground water flux in the uppermost portion of bedrock just below the base of the isolation casing. A narrow zone of very low resistivity at the bottom of the hole from 86–90 ft bgs is reported by URS to be associated with suspended fines at the bottom of the open hole.

The overall appearance of the fluid resistivity log in GW-970(I) resembles that in GW-968(I) with a primary transitional zone between 44 and 67 ft bgs (see detailed logs in Exhibit A.8 and on Plate 2). This transition suggests that ground water flux may be occurring over this interval from one or more fractures. As with the lower portion of the borehole in GW-968(I), the very low and steady values of fluid resistivity from 67–97 ft bgs suggests that ground water flux within the bottom 30 ft of the borehole is very low to nonexistent. This is consistent with the general tendency for bedrock fractures and ground water flux to decrease with depth within clastic formations on the ORR (Solomon et al, 1992). Alternatively this may simply reflect zones of very low permeability and little or no fractures within the lower part of these boreholes. A small decrease in resistivity occurs near the very top of the open hole from about 34–36 ft bgs suggesting limited ground water flux just below the bottom of the isolation casing. The heat pulse flowmeter data from the Phase I deep boreholes suggests that the potential ground water flux indicated by these resistivity curve transitions is probably upward in both wells.

***Structure and Heat Pulse Flowmeter Logs, and Packer Tests – GW-968(I):*** The structure logs, heat pulse flowmeter logs, and packer tests were the most reliable indicators of potential bedrock fractures/joints that might be conducive to ground water flow. Results are reviewed for GW-968(I) followed by those for GW-970(I).

As noted above, a structure log was developed by the URS geophysicist for each of the five deep boreholes based on interpretations of features shown on the ATV and OTV logs. The structure log for GW-968(I) includes a total of 59 structural features that were all "mapped" as parallel to bedding planes (see Figure 34 and structure log in Exhibit A.8). The structure log and related ATV/OTV logs for GW-968(I) do not indicate cross-cutting features that might represent shear fractures, faults, or joints oriented roughly perpendicular to bedding planes (i.e., green features on Figure 34). The logs suggest a relatively undisturbed structural profile in the bedrock borehole of GW-968(I). The mean of these bedding plane features as shown in Figure 34 is:

- Strike: N52°E (perpendicular to the 142° mean dip azimuth)
- Dip: 46° southeast

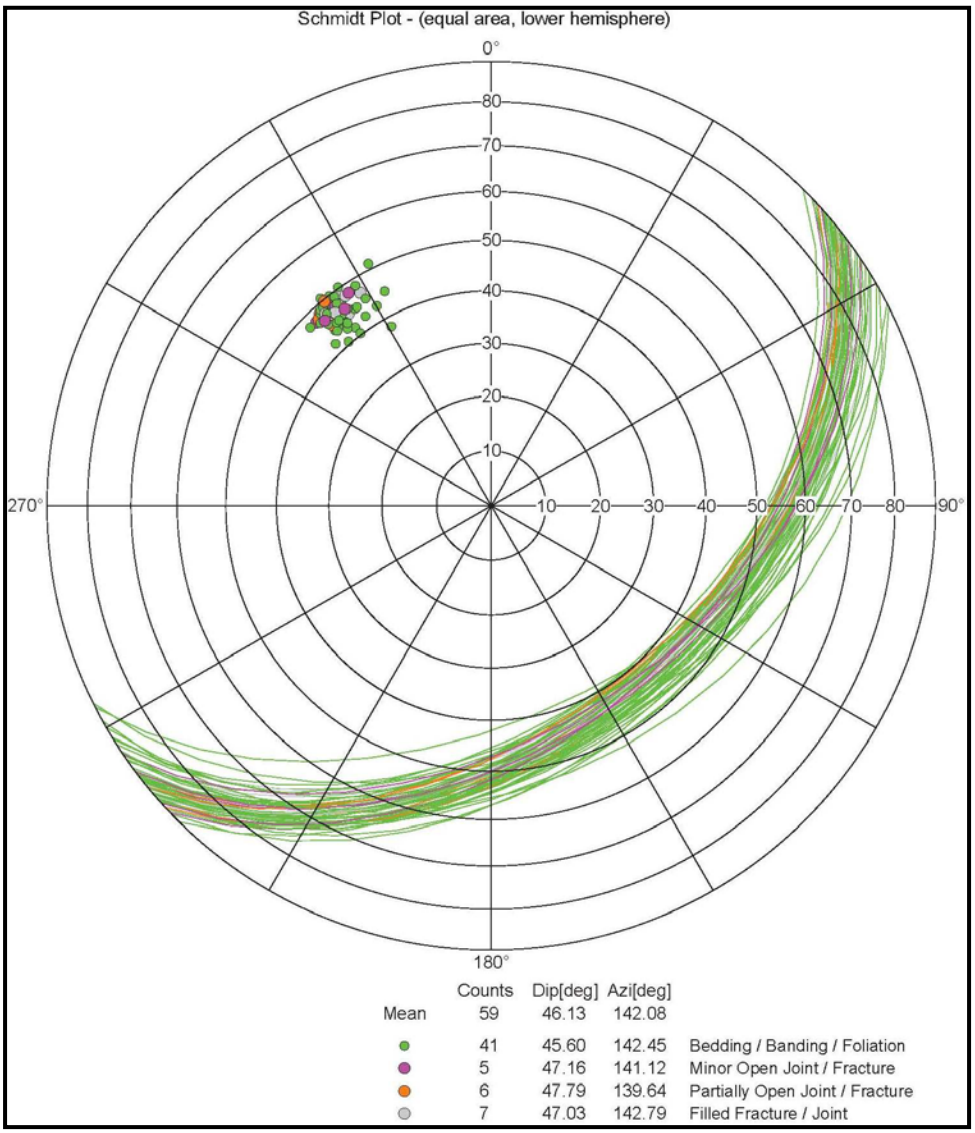



**Figure 34. Schmidt Plot of Interpreted Structure Log Features in GW-968(I) Bedrock – Pumpkin Valley Shale**

Eleven minor to partially open possible joints/fractures were identified on the structure log (identified in purple and orange in Figure 34 and on the detailed structure log provided in Exhibit A.8). Eleven heat pulse flowmeter tests were conducted at various depths from 12–71 ft bgs in GW-968(I). However, none of the tests indicated flow rates above the minimum quantifiable flow rate of 0.03 gpm (see Table 15 above and combination log in Exhibit A.8). Flows less than the quantifiable flow rate are suspect, but they were presented on the logs as there was continuity between repeated measurements at these depths. Six of the tests recorded very low flow rates ranging from 0.015– 0.022 gpm, while the remaining five tests recorded zero flow rates. All measured flow rates were upward (as with all the heat pulse flowmeter tests where flow was indicated). The highest flow rates of 0.020–0.022 gpm were recorded within the upper ten feet of the bedrock interval at depths of 12–17 ft bgs, respectively. These rates may be associated with the four fracture/joint features identified between 13–20 ft bgs, but could be associated with flow from deeper fractures/joints mapped on the structure log. The deepest fractures/joints identified

on the structure log come from three features identified near 70 ft bgs. A flowmeter test located just above those features at 68 ft bgs, recorded a very low flow rate of 0.016 gpm.

Only one packer test was conducted in GW-968(I) (Phase I project budget constraints limited the total number of packer tests). The packer test was conducted over a ten foot interval from 23–33 ft bgs encompassing one fracture/joint identified on the structure log and two flowmeter tests recording very low flow rates of 0.015 and 0.019 gpm at depths of 26 and 27 ft bgs, respectively. Packer test results indicated a K value of $3.1\times10^{-5}$ cm/sec. The packer test results suggest the possibility that this interval could be contributing ground water to the borehole, but the tests are based on controlled water injection and do not indicate natural ground water flow at this interval.

***Overview of Fracture/flow Data in GW-968(I):*** The flowmeter tests did not indicate any upward flow above the quantifiable limit of the instrument anywhere within the vertical profile of the bedrock borehole. Upward flows were recorded below the quantifiable limit at six of the eleven test depths. The packer test results (order of magnitude K of $10^{-5}$ cm/sec) indicate that the interval from 23–33 ft bgs is conducive to ground water flow. The continuous water level monitoring data indicate that upward flow is occurring in GW-968(I). Water levels in the GW-969(S) and GW-968(I) well pair indicate consistent upward vertical gradients in GW-968(I). In addition, artesian flow overflowing the TOC has been observed in GW-968(I) (and in GW-969[S]) since shortly after the original open bedrock borehole was drilled. It is clear that upward flow is occurring within the bedrock section of GW-968(I), however, the precise depth(s), rates, and conditions of the upward flow are unclear.

The absence of any measurable flow above the quantifiable limit of the heat pulse flow meter, suggests that the overall ground water flux within the borehole (and subsequent completed well) is occurring at a very low rate (<0.03 gpm, or 1.8 gph/43 gpd). Whether or not the flow is contributed from multiple fractures/joints at various depths or from one or more fractures/joints more localized to a particular interval is unclear based on the available data and interpretations. In addition, the structure log which is based on interpretations from the ATV/OTV logs is unlikely to identify all fractures/joints within a borehole. The Phase I results from GW-968(I) do not provide a clear indication of fractures or flow rates contributing to the artesian flow seen in GW-968(I). Other more sensitive and systematic testing methods including methods for vertical profiling of K would be required for this determination.

***Structure and Heat Pulse Flowmeter Logs, and Packer Tests – GW-970(I):*** The structure log for GW-970(I) includes a total of 45 features (see Figure 35 and structure log in Exhibit A.8). Most (55%) are bedding plane features (green), but a smaller portion (31% - red, purple, orange) were identified as possible joints/fractures with cross-cutting orientations that differ from the mean bedding plane strike and dip. These cross-cutting features all occur within the upper half of the borehole at depths between the 34 ft isolation casing depth and 56 ft bgs. Four have relatively steep dips approaching vertical (79°–87°S) with an approximate east-west strike; two others with intermediate dip angles toward the west are oriented with a more north-south strike direction These cross-cutting features may represent shear fractures, faults, or joints oriented roughly perpendicular to bedding planes. The mean strike and dip of the 25 bedding plane features in GW-970(I) is:

- Strike: N50°E (perpendicular to the 140° mean dip azimuth)
- Dip: 52° southeast

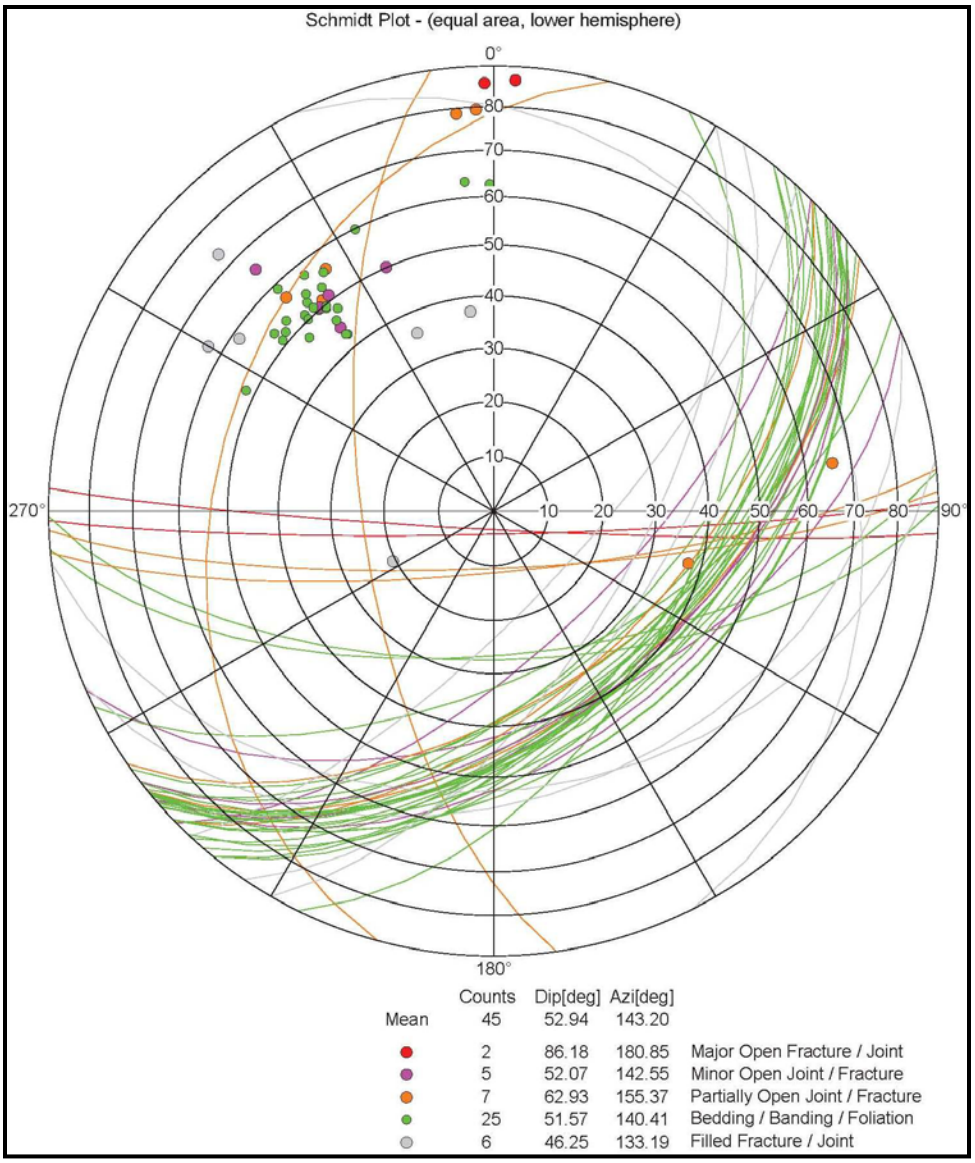
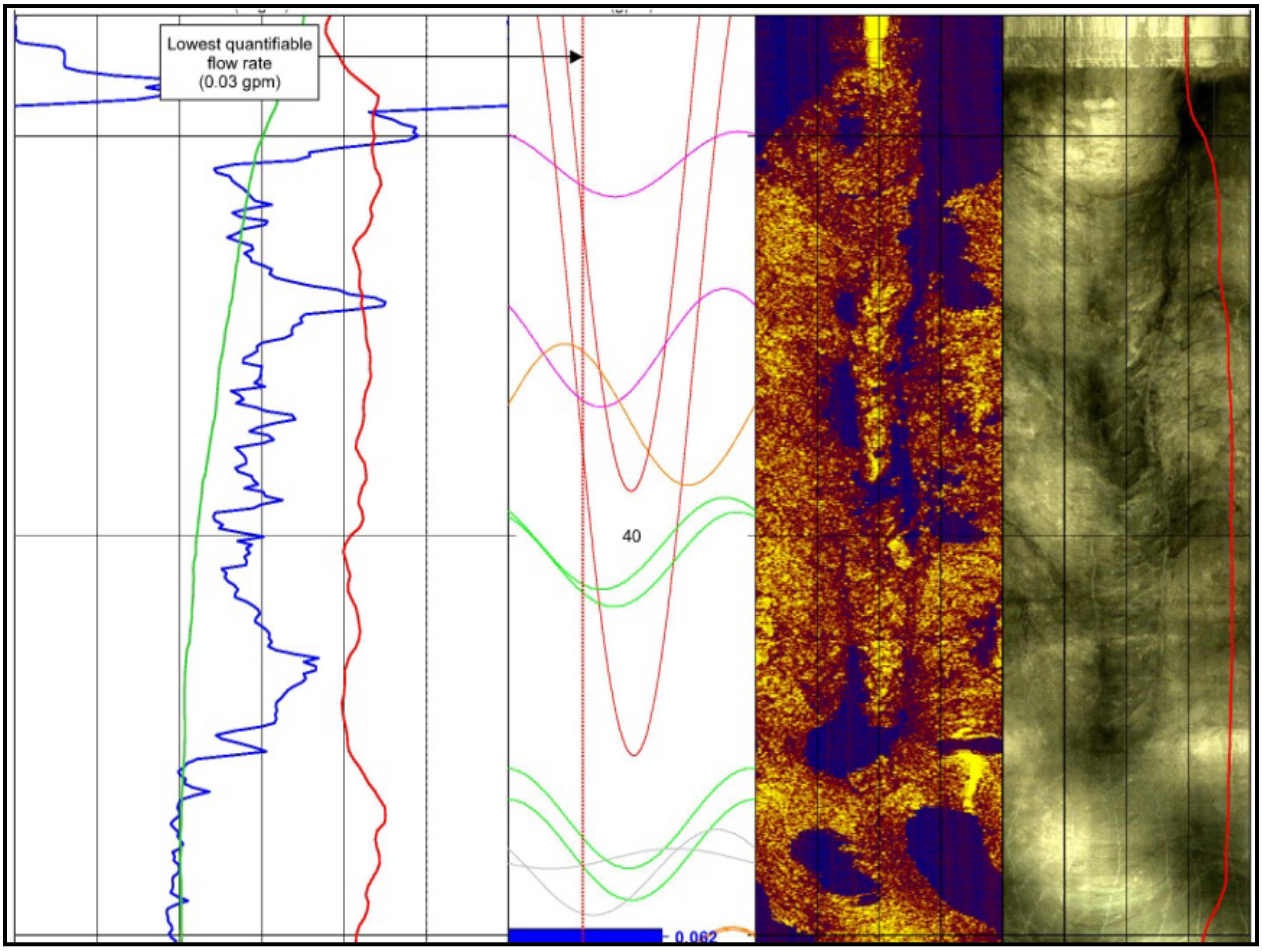



**Figure 35. Schmidt Plot of Interpreted Structure Log Features in GW-970(I) Bedrock – Pumpkin Valley Shale**

**Fracture Interval 34–43 ft bgs**: The two uppermost steeply dipping fractures/joints (shown in red on Figures 35, 36, and on the structure log in Exhibit A.8) are clearly visible on the ATV/OTV logs starting at the top of the open borehole (34.1 ft bgs) down to a depth of 43 ft bgs. The OTV log suggests these fractures may in fact represent one relatively large curvilinear joint/fracture or joint/fracture set. Three other fractures/joints with intermediate dip angles similar to regional bedding plane dips were mapped at depths of 35–38.5 ft bgs within this upper zone of fracturing. This shallowest fractured bedrock interval was not tested with the heat pulse flowmeter or by packer testing, but these features may represent joints/fractures with relatively high K values, particularly the prominent steeply dipping features This fracture/joint interval is also coincident with a "washout" interval on the caliper log, where a widening of the borehole extends from the nominal 8 in. diameter to as much as 9.4 in. in diameter (see caliper log in Figure 36 and Exhibit A.8). It should be noted that the uneven borehole from the washout interval and the proximity of the isolation casing, precluded packer testing of this shallow interval. The nearly vertical orientation of the steeply dipping feature(s) also suggests that it could extend upward into the saprolite

zone. Discrete depth K testing of this interval is recommended if a Phase II investigation occurs. These high and intermediate angle features and borehole widening are shown in Figure 36, extracted from the uppermost portion of the combination log for GW-970(I).



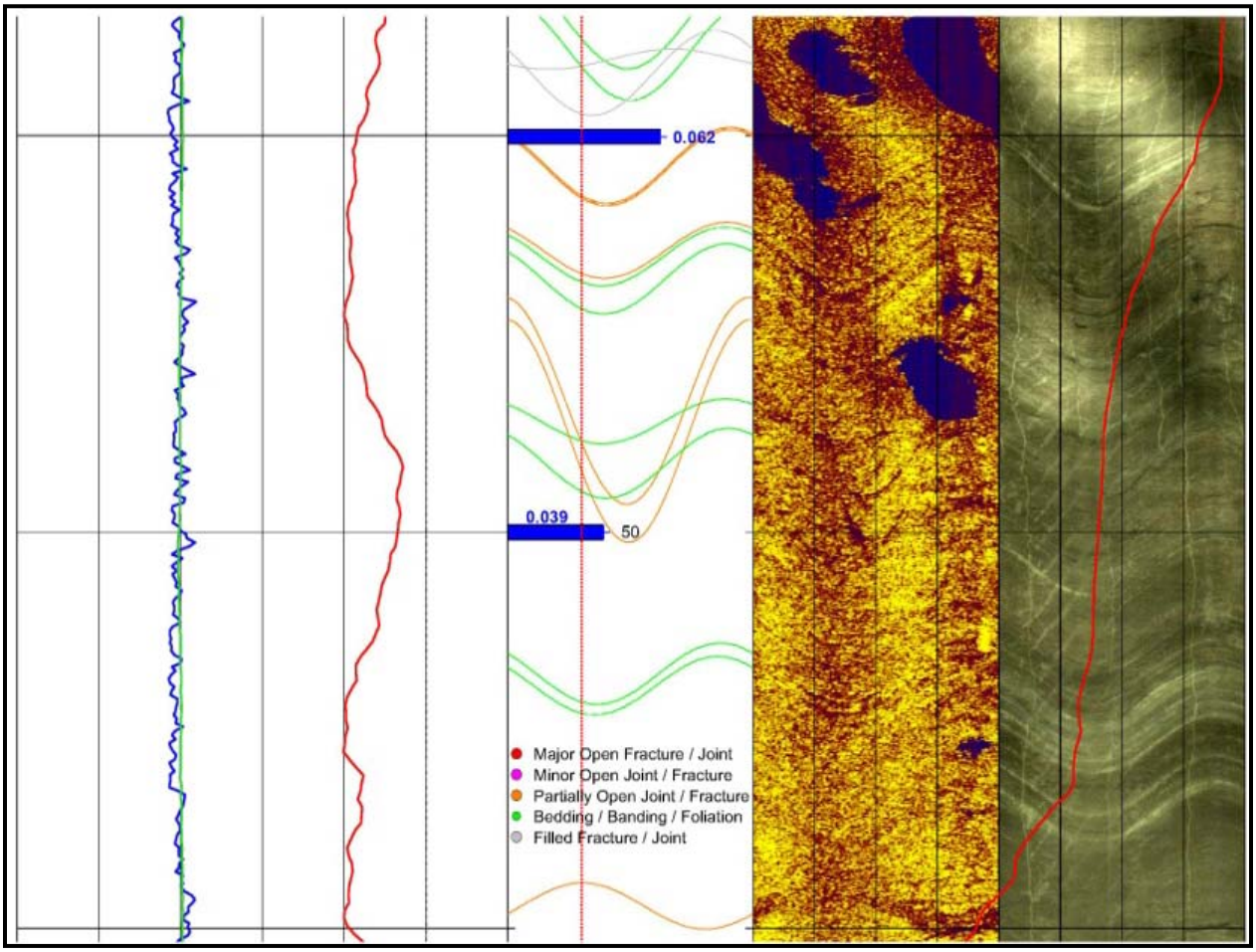

The high and intermediate angle features are shown by the darker patterns on the ATV/OTV logs on the right third of the log that mimic parts of the two parabolas on the structure log in the middle of the figure. Also note the washout interval indicated by the caliper log in blue. See the detailed logs in Exhibit A.8 for log definitions, scales, units, and depths.

**Figure 36. Portion of GW-970(I) Combination Log Showing High Angle Fracture Features from ~34–43 ft bgs**

**Fracture interval 45–50 ft bgs:** Immediately below these shallowest bedrock features, heat pulse flowmeter and packer testing were completed to characterize other fractures/joints identified on the structure log at depths of 45–50 ft bgs. Two steeply dipping fracture/joints were identified at depths between 48 to 50.2 ft bgs (see Figure 37). These features are most obvious on the ATV log but also appear faintly on the adjacent OTV log. Two heat pulse flowmeter log tests were conducted near this interval at depths of 45 and 50 ft bgs. The results indicated upward flow at both of these depths at rates of 0.062 gpm and 0.039 gpm, respectively (above the lowest quantifiable flow rate of 0.03 gpm). Note that these were the highest flowmeter rates (all upward) recorded among the five bedrock boreholes.

A packer test was also conducted over the interval 44–54 ft bgs, encompassing these apparent fractures/joints. The average K of this interval was $1.5\times10^{-4}$ cm/sec (the highest K of any packer tested

interval from the Phase I packer testing). The combined flowmeter and packer test data indicate that these fractures/joints and/or others between 45 and 50 ft bgs are conducive to ground water flow.




Structural features mapped by the geophysicist between 45-55 ft bgs are shown in orange. The high angle features are shown by the darker patterns primarily on the ATV log. Also note the change in the fluid resistivity curve across this interval shown on the right third of the log. See the detailed logs in Exhibit A.8 for log definitions, scales, units, and depths.

**Figure 37. Portion of GW-970(I) Combination Log Showing Potential Fracture Features Discordant to Bedding**

**Fracture Interval 55–60 ft bgs:** Three possible fractures/joints were identified on the structure log centered at depths of 54.7, 56.2, and 59.9 ft bgs. A flowmeter test conducted at 57 ft indicated an upward flow at a rate of 0.031 gpm (at the lowest level of quantifiable flow), suggesting some natural gradient flow from below 57 ft, possibly including flow from the feature at 59.9 ft. A second packer test was conducted in GW-970(I) from 52–62 ft bgs, encompassing these possible fractures. The average K value was $3.1\times10^{-5}$ cm/sec, further suggesting the potential for ground water flow from this interval.

**Potential Fractures at 72 and 91 ft bgs:** One fracture/joint feature was identified on the structure log at 71.7 ft bgs, with a strike and dip similar to nearby bedding planes. A flowmeter test conducted at 70 ft suggested the potential for a slight upward flow at a rate of 0.017 gpm, however, this flow rate is about half the lowest level of quantifiable flow of 0.03 gpm. A third and final packer test was conducted from 65–75 ft bgs, encompassing this feature with an average K value of $1.4\times10^{-5}$ cm/sec, suggesting the

potential for ground water flow from this interval. One last fracture/joint parallel with bedding planes was identified at 91.0 ft bgs, but this feature was not tested.

***Fluid Temperature/resistivity Logs:*** The fluid resistivity log is a reflection of TDS concentrations in well or borehole water, and water producing and water receiving zones may be identified by changes in fluid resistivity (USGS 1996). The fluid resistivity log in GW-970(I) appears reasonably consistent with an upward flux of ground water as described above, assuming that TDS concentrations (particularly colloids) increase with mobilized ground water entering and exiting the borehole. In addition, the very low fluid resistivity from 67–97 ft bgs suggests that ground water flux within the bottom 30 ft of the borehole is very low to nonexistent. This appears consistent with the general tendency for bedrock fractures and ground water flux to decrease with depth within clastic formations on the ORR (Solomon et al, 1992).

***Overview of Fracture/flow Data in GW-970(I:)*** The collective borehole log data and packer test data indicate that vertical flow is occurring within the upper 30 ft of the bedrock borehole in GW-970(I). Ground water from fractures/joints within the interval of 45–60 ft bgs appears to be moving into and upward within the borehole, and exiting the borehole within fractures/joints across a nine foot interval within the uppermost part of the open borehole between the bottom of the isolation casing at 34.1 ft bgs and about 43 ft bgs. This upward flow is artificially induced through the creation of the open borehole but illustrates naturally occurring upward vertical gradients within the upper 25 ft of competent bedrock (i.e., below auger refusal) at GW-970(I). The results also indicate the interconnection between these borehole fractures/joints and upgradient/upslope fractures transmitting relatively shallow ground water from upslope areas of Pine Ridge toward lower elevation downgradient discharge zones along the NT valleys. These findings are consistent with the hydrogeological site conceptual model for the EMDF, and for the Conasauga Group formations of the ORR (see Solomon et al, 1992; and Clapp 1997).

### 7.2.5.8 Rutledge Limestone (Friendship Formation) Bedrock Hydrogeology

Monitoring well GW-972(I) was drilled within the outcrop belt of the Rutledge Limestone. Rock coring was completed over a 76 ft bedrock interval from depths of 24.2–100.3 ft bgs. A detailed boring log with descriptions and interpretations of the rock cores is provided in Exhibit A.4. Photographs of the rock core are provided in Exhibit A.7. The regolith and bedrock stratigraphic sequence encountered at GW-972(I) is also illustrated in the cross sections of Plates 2 through 4. In addition to the lithologic/stratigraphic profile at GW-972(I), these cross sections include the locations of fractured intervals identified in the rock cores that may indicate zones of potential ground water flux, and maximum bedding plane dip angles (toward the southeast) measured from intact portions of the rock cores.

The surface location of GW-972(I) is situated about 30 ft north of the approximate outcrop trace of the Rutledge/Rogersville contact at the EMDF (see Plate 3). This would place the boring at a position to intercept much of the Rutledge.

**Lithologies in GW-972(I) Based on Rock Cores**

The percent recovery and quality of rock cores in GW-972(I) was relatively good. The cores showed little signs of intense weathering or staining, even in the uppermost parts of the core. The zone of water table fluctuation in the adjacent shallow well, GW-973(S), occurs around 3–9 ft bgs, so that the upper bedrock surface at about 24 ft bgs appears to occur well below the base of the unsaturated oxygen rich vadose zone.

The cored interval in GW-972(I) is predominantly a sequence of interbedded mostly laminated shale/mudstone and limestone or calcareous siltstone layers. The darker shale/mudstone laminae are gray to maroon, and the lighter limestone or calcareous siltstone laminae are light to dark gray to white. The limestone/calcareous siltstone layers showed consistent effervescence with hydrochloric acid (10% HCl), and typically comprise a much smaller fraction (roughly estimated at <10-30%) of the typically more

predominant shale/mudstone layers. The lighter colored laminated limestone/calcareous siltstone layers were never found to exceed about 0.1-0.3 ft in thickness. A few shale beds ≤0.5 ft to about 1 ft in thickness occur intermittently within the cored section. Siltstone beds occur infrequently and mostly within the upper 3 ft of bedrock. The uppermost 4 ft of the core is completely clastic. At and below this uppermost interval, the intermittent laminae of limestone/calcareous siltstone occur with moderate to strong HCl effervescence to the total depth of the borehole at 100 ft bgs. None of the limestone/calcareous siltstone layers showed any indication of dissolution. The boring log and rock core photos should be reviewed for additional details. The rock core photos illustrate the entire cored Rutledge sequence and provide representative closeup views of features noted above (see Exhibit A.7).

The absence of any significantly thick limestone beds (i.e., >0.5–1 ft thick) across the cored interval in GW-972(I) appears inconsistent with descriptions of the Rutledge from other reports (Lee and Ketelle, 1989, King and Haase 1987, and Hatcher et al, 1992). The downhole thickness of the entire Rutledge formation based on two rock cored boreholes at the LLWDDD was 124 ft and 126 ft (125 ft of downhole thickness at a 45° dip angle is equivalent to 88 ft true thickness). Assuming the formation thickness at the EMDF is roughly equivalent to that at the LLWDDD site, the 76 ft of thickness penetrated at GW-972(I) would comprise about 60% of the total formation thickness. The absence of thicker limestone beds as reported elsewhere in BCV, could simply be the result of facies changes along strike. Alternatively, the projected formation contacts and boring location may simply have resulted in the cored interval not penetrating equivalent sections of the Rutledge Limestone encountered in cores elsewhere in BCV. The difference may also represent some combination of these factors.

**Rock Core Fractures in GW-972(I)**

The cores from GW-972(I) indicate some orthogonally fractured beds of shale that appear to be natural fractures not artificially induced by the mechanical process of coring. The most visually obvious of those occur at four intervals within the bottom three feet of the borehole. These fracture intervals are shown in the rock core photos in Exhibit A.7. Fractures were observed elsewhere within shaly intervals in the GW-972(I) cores but the nature of the fracturing is less certain because of the relatively poorer quality of the core. The rock core fragments in these intervals are less intact and more freely broken apart. The natural condition and in-situ orientation of the fractures in the recovered core fragments are dislocated and sometimes worn and mechanically fragmented. These apparent fractured intervals may represent naturally occurring fracture zones, or may only reflect mechanical fracturing and reworking of the recovered rock fragments by the coring process. The depths of these fractured shaley intervals in GW-972(I) that *may* be conducive to ground water flow are shown on the detailed boring logs in Exhibit A.4, and vertical profile composite logs on Plate 2. Thirty one possible fracture zones were identified in the rock cores between 33 ft and 97 ft bgs.

None of the fractures (natural or mechanically induced) in the cores of GW-972(I) showed any obvious visual indications of staining or weathering (e.g., orange/brown discoloration from FeO/MgO stained surfaces). In addition, none of the thin and intermittent carbonate layers (i.e., laminated limestone/calcareous siltstone layers) showed signs of dissolution. Most of the fractures observed within intact portions of the rock cores of GW-972(I) are mechanical breaks associated with weak shaly bedding plane partings, with no apparent relationship to natural fractures conducive to flow. No slickensides were observed in the rock cores. White calcite filled extensional fractures occur intermittently but none showed indications of weathering, dissolution, or staining that would reflect potential ground water flow.

**Results from Borehole Geophysical Logs in GW-972(I)**

***Caliper Log:*** The caliper log shows an average borehole diameter of about 8.25 in. except for a widening in the bottom 17 ft of the borehole ranging from 8.5 to 9 in. in diameter between 80.5 and 97.5 ft bgs (the total depth of the log).

***Acoustic and Optical Televiewer Logs:*** The ATV and OTV logs show bedding plane dips that are consistent with the relatively uniform bedding plane dips observed in the rock cores. The quality of the optical log diminishes progressively with depth. This is associated with an assumed increase in turbidity with depth in the borehole, particularly below about 85 ft bgs. After coring, the bedrock borehole was reamed to 101 ft bgs on September 11, 2014, and the logs were completed on October 1, 2014, allowing 20 days for settling of fines within the borehole water column prior to logging. Interpretations of structural features visible on the ATV and OTV logs were plotted by the geophysicist on the Structure Log as described below.

***Natural Gamma Ray Log:*** The NGR log varies from 125–165 API units in GW-972(I), with an average of around 140 ±5 API units. Intermittent shale beds observed in the rock cores and varying in thickness from 0.3 or less to 1.1 ft were plotted against the gamma ray log. No distinct correlation could be made between these beds and the gamma ray log and the gamma ray log could not be used to define bed boundaries. The average gamma ray readings around 140 API units appear to be representative of the overall sequence of interbedded laminated shale and limestone/calcareous siltstone described in the rock cores for GW-972(I). This average value appears to be reasonably consistent with the average gamma ray readings for interbedded laminated shale and limestone observed in the rock cores and gamma ray log in GW-976(I) within the Maryville Limestone formation.

***Structure Log:*** Thirty one planar features were identified on the ATV and OTV logs at irregular depths between 24 and 81.5 ft bgs (the 10 in. diameter casing was set at 24 ft bgs). These features all trend parallel to bedding planes and are consistent with those observed in the rock cores. Most of the features were identified by the geophysicist as bedding surfaces (26); five features were identified as possible joints/fractures ("partially open joints/fractures"). The direct correlation between these features and the ATV/OTV borehole logs are shown by depth on the composite logs in Exhibit A.8. Figure 38 shows these features on a Schmidt plot. The mean value of these bedding plane oriented features in GW-972(I) is:

- Strike: N62°E (perpendicular to the 152° mean dip azimuth)
- Dip: 47° southeast

The structure log and related ATV/OTV logs for GW-972(I) do not indicate any cross-cutting features that might represent shear fractures, faults, or joints oriented roughly perpendicular to bedding planes. The logs suggest a relatively undisturbed structural profile in the bedrock borehole similar to that seen in the rock cores for GW-972(I), and in similar geophysical logs from the bedrock interval of GW-968(I) (compare relatively uniform data plots in both Figures 34 and 38).

***Heat Pulse Flowmeter Log:*** Eight depths were selected in GW-972(I) for flowmeter testing. All but one indicated no flow. The test at 70 ft bgs measured an upward flow rate of 0.026 gpm (1.6 gph, or 37 gpd), however, this value is below the lowest quantifiable flow rate for the instrument of 0.03 gpm (1.8 gph, or 43 gpd). The result is therefore suspect but was included because of similar flow rates in two of the four measurements made at that depth. Packer testing over the interval 65–75 ft bgs, centered on this depth, also resulted in no flow. These results suggest that GW-972(I) does not penetrate bedrock fractures transmitting ground water at relatively higher flow rates such as those observed in GW-970(I).

***Temperature and Fluid Resistivity Logs:*** The 10 in. isolation casing for GW-972(I) was set at 23.75 ft bgs (per the OTV log where it is clearly shown). The temperature and fluid resistivity logs were run from about 10 ft bgs within the casing down to 97 ft near the total depth of the open hole. So there are data for these logs within the casing that are not presented on the geophysical logs in Exhibit A.8 and elsewhere, but were used in interpreting the results from these logs as described below.

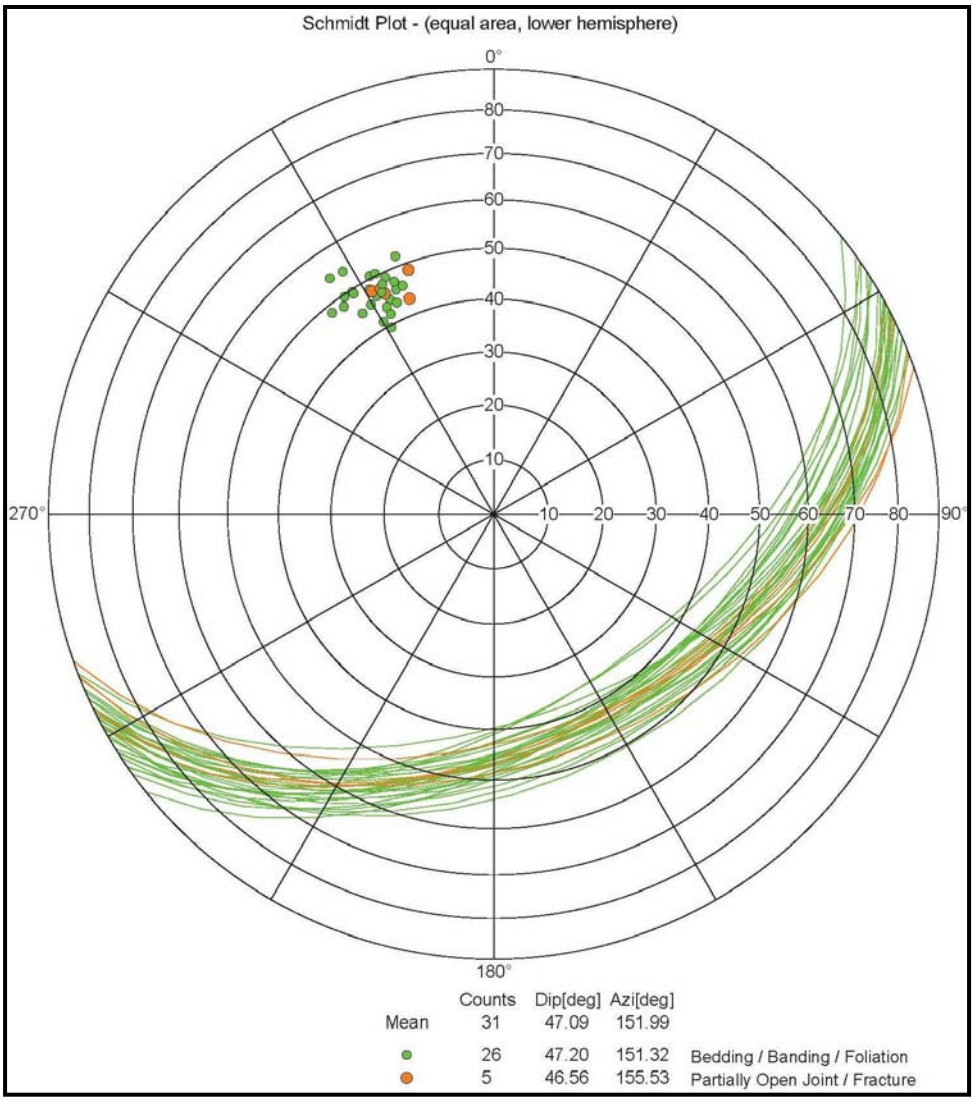



**Figure 38. Schmidt Plot of Interpreted Structure Log Features in GW-972(I)**
**Bedrock – Rutledge Limestone**

Overall the temperature log shows a steady cooling decline that levels out to a baseline not far below the depth of the 10 in. casing. This appears to reflect a natural thermal gradient between warmer outside air temperatures (at that time) and colder ground water. The temperature log shows a progressive drop in water temperature of about 0.25° C from the bottom of the casing at about 24 ft bgs down to a depth of 30 ft bgs. Below the 30 ft depth, temperatures remain fairly constant, except for an apparent very slight temperature (warming by only about 0.02˚ C) increase that occurs at about 44 ft bgs and remains relatively constant thereafter to total depth. Other than the slight change in temperature at 44 ft bgs, the temperature log suggests nothing associated with possible ground water fracture flow.

The fluid resistivity log suggests potential ground water fluxes are occurring at two places in the borehole; (1) near the junction of the casing and open borehole from 24-25 ft, and (2) from about 44–60 ft bgs. The more subtle gradient change at the lower interval suggests that the ground water flux there may be considerably less than the flux occurring near the bottom of the casing. Baseline resistivity readings change dramatically near the bottom of the casing from about 35 ohm-meters (ohm-m) to a baseline around 46 ohm-m up within the 10 in. casing. This suggests that shallow ground water may be entering

the borehole near the casing/borehole junction and flowing upward and commingling with the water column in the casing interval. A more subtle gradient change occurs deeper within the borehole starting abruptly at 44 ft bgs where resistivity declines by about 1 ohm-m within about a one foot interval, and then continues to gradually decline by over another 1 ohm-m down to a baseline level at about 60 ft bgs that continues to total depth (Note that the ohm-meter scale on the geophysical logs varies among the Phase I logs and the resistivity scale difference for GW-972[I] varies by only 6 ohm-m which accentuates this change relative to other resistivity logs).

As previously noted, changes in dissolved solids are reported to correlate with fluid resistivity and may indicate changes in ground water flux within a borehole or well. Relative to the fluid resistivity interval from 44–60 ft bgs, potential fracture zones were identified in the rock cores at nine separate locations between 40 and 60 ft bgs (40.6. 41.1, 42.0, 42.7, 44.8, 45.6, 46.7, 49.7, 54.9, and 59.3 ft bgs). Three of these zones were coincident with possible joint/fractures identified on the structure log. However, the flowmeter tests measuring no flow within and near this interval (at 40, 45, 51, & 61.5 ft bgs) would suggest that the flux if it exists is quite low (well below the 0.03 gpm rate). Packer tests were not conducted near this interval.

**Bedding Plane Dip Angles Measured from Rock Cores**

Bedding plane dip angle measurements were made at 24 depths along the length of the rock cores of GW-972(I) (see rock core photographs and boring logs in Exhibits A.7 and A.4, respectively). The finely laminated bedding planes common throughout the cores provided ideal locations for visually determining maximum dip angles using a transparent compass within accuracies of about ±2°. The bedding plane dips observed in the cores in GW-972(I) were relatively uniform across the entire cored sequence. The dips range from 35°–50° to the southeast with typical dips of 40°–45°. These measurements are reasonably consistent with the structure log data shown in Figure 38 above. No intervals of extreme or anomalous dips were observed that would suggest zones of tight folding, crumpled beds, or shear fractures. This is also consistent with results from the ATV/OTV and structure logs.

**Fracture Interval Packer Testing**

Two Phase I packer tests were conducted in GW-972 (I) at depths of 65–75 ft bgs and 75–85 ft bgs. These test intervals included some of the broken shaley intervals thought to represent potential fractured intervals described above, the single flowmeter test zone at 70 ft bgs that suggested potential upward flow, and two possible fracture/joints identified at 81 ft on the structure log. Neither test interval would sustain any flow under the injection flow pressure limitations of the tests (which are designed to not overpressure and artificially induce fracture flow into the formation). The no flow results from the packer tests were inconclusive but suggest that the potential fracture locations identified in the rock cores and structure logs within the tested intervals do not represent zones of higher hydraulic conductivity or significant ground water flux. Depth discrete downhole testing of fracture zones provides the most conclusive means of determining the permeability of possible fracture zones identified in rock cores or on borehole geophysical logs. More sensitive and depth discrete borehole testing is recommended for Phase II investigations, including the interval between 40–60 ft bgs where the fluid resistivity/temperature gradient occurs.

**Overview of Fracture and Flow Data in GW-972(I)**

Continuous water level readings from the GW-972(I)/GW-973(S) well pair indicate water level elevations that consistently track each and differ periodically by no more than about 0.1 ft. During recharge events these water levels track one another at almost identical elevations. During periods of declining and baseline water levels, the water level elevation in GW-972(I) is about 0.1 ft higher than that in the adjacent shallow well. These data, in combination with the results described above, suggest that shallow regolith ground water may be intersecting the open borehole in GW-972(I) at and just below the bottom

of the isolation casing. With regard to the deeper section of the open borehole, the collective results from GW-972(I) (from rock cores, geophysical logs, packer tests, and continuous water level monitoring) suggest that only the interval from 44–60 ft bgs may be yielding a very slight amount of ground water to the borehole. This could account for the slight increase in head between GW-972(I) and GW-973(S) noted above. More sensitive depth-discrete flow testing could be used to quantify the potential low hydraulic conductivity and/or ground water flux of this interval (as well as others) during a Phase II investigation.

#### 7.2.5.9 Rogersville Shale Bedrock Hydrogeology

One Phase I well, GW-974(I), was drilled to 100 ft in bedrock within the outcrop belt of the Rogersville Shale using air rotary drilling. Rock coring was not conducted at this location. The geophysical logs were therefore relied upon to provide an indication of the lithologic sequence and structural features in the bedrock portion of this borehole. The surface location of GW-974(I) is situated about 60 ft north of the approximate outcrop trace of the Rogersville/Maryville contact at the EMDF (see Figure 1 and Plate 4). This positions the boring to intercept the middle to lower sections of the Rogersville.

**Lithologic Descriptions from BCV Sites along Strike with the EMDF**

Lithologic descriptions of rock core data from the WBCV site (LLWDDD) indicate that the upper Rogersville consists dominantly of maroon shale with thin calcareous siltstone or argillaceous limestone lenses (see Table 20 for more detailed lithologic descriptions from Lee and Ketelle 1989). The lower Rogersville consists dominantly of dark gray shale with thin laminated limestone lenses (a few thin limestone beds may represent the Craig member near the top of the lower Rogersville).

Ogden Site B and C borings adjacent to and along strike with the EMDF did not penetrate the bedrock section of the Rogersville, and other borings/wells drilled within the EMWMF footprint did not include extensive rock coring to provide detailed descriptions of the Rogersville for comparison to the EMDF.

**Results from Borehole Geophysical Logs**

***Natural Gamma Ray Log:*** The NGR log from GW-974(I) provides the only general indication of lithologies for the Rogersville at the EMDF. The NGR log shows a number of deflections with lower API units suggesting the potential for limestone beds within the bedrock sequence of GW-974(I). However, only two of those deflections centered at 23.3 and 52.0 ft bgs fall below 100 API units. Note that two relatively thicker limestone beds (1.5 and 1.8 ft thick) identified in the rock cores of GW-976(I) correlated with lower readings of 85 and 92 API units, whereas thinner limestones interbedded with shales correlated with higher API readings. Without rock core data for confirmation it is impossible to confirm whether or not these or other lower API deflections reflect limestone beds. The majority range of NGR log readings between 120 and 160 API units suggests that most of the bedrock in GW-974(I) is likely to be comprised of the dominant clastic shale and siltstone sequences described elsewhere along strike in BCV.

***Structure log*** The quality of the OTVATV logs from GW-974(I) are poor relative to other boreholes because of relatively high turbidity water in the borehole. Alliant/URS purged the borehole water and ran the OTV log through the open air column of the borehole but the log quality remained relatively poor, although some bedding plane surfaces are clearly visible. However, the image quality of the OTV log below the water level at 59.4 ft bgs was completely obscured by the turbid water. Seventeen planar features were identified on the ATV and OTV logs at irregular depths between 27 and 88 ft bgs (the 10 in. diameter casing was set at 12.5 ft with the inner 8 in. diameter casing set at 15.0 ft bgs). These features all trend parallel to bedding planes. Only one of the features was identified by the geophysicist as a possible joint/fracture. The direct correlation between these features and the ATV/OTV borehole logs are shown by depth on the composite logs in Exhibit A.8.

Figure 39 shows these features on a Schmidt plot. The mean value of the seventeen bedding plane oriented features in GW-974(I) is:

- Strike: N61°E (perpendicular to the 151° mean dip azimuth)
- Dip: 54° southeast

As illustrated in Figure 39, the structure log data have a relatively wider range of strike and dip than in other boreholes, with strike directions ranging from about N45°E to N80°E, and dips ranging from about 42°–73° southeast. Some of this variation may be influenced by the poorer quality of the OTV/ATV logs, but some may result from a greater natural variation in deformation of the Rogersville.

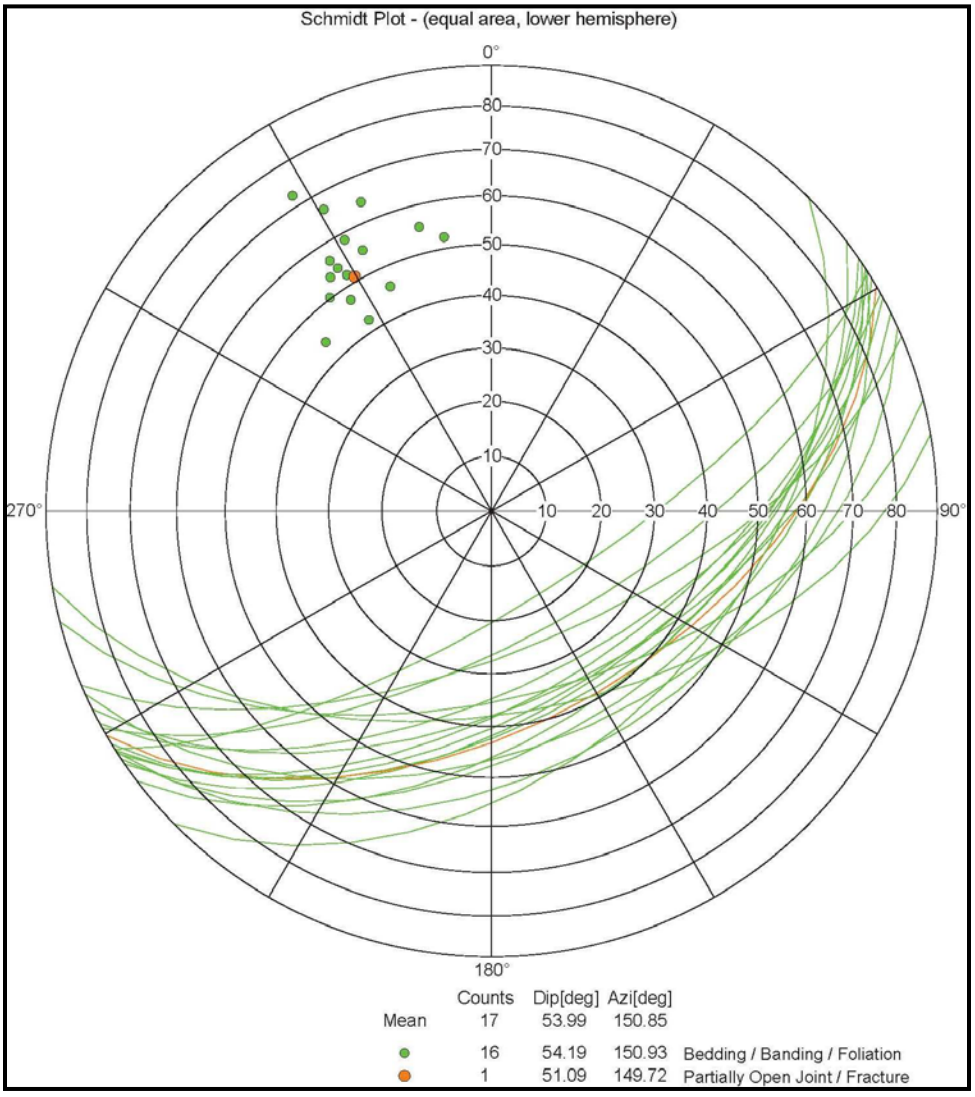



**Figure 39. Schmidt Plot of Interpreted Structure Log Features in GW-974(I) Bedrock – Rogersville Shale**

***Heat Pulse Flowmeter Log:*** Seven depths were selected in GW-974(I) for flowmeter testing at intervals above 65 ft bgs. All but one indicated no flow. A number of tests at 35 ft bgs suggested an average upward flow rate of 0.016 gpm. However, this average value is below the lowest quantifiable flow rate for the instrument of 0.03 gpm, and the overall results from the series of tests at 35 ft bgs were considered by the geophysicist to represent noise and to not reflect a valid flow measurement (see Exhibit A.8 for additional details of these tests). The single packer test conducted in GW-974(I) over the interval 33–43 ft bgs (encompassing the 35 ft depth) also resulted in no flow, within the limits of the packer testing methodology.

***Temperature and Fluid Resistivity Logs:*** The isolation casing for GW-974(I) was set at 15 ft bgs. The temperature and fluid resistivity logs were run from about 10 ft bgs within the casing down to about 95 ft near the total depth of the open hole. So there are data for these logs within the casing that are not presented on the geophysical logs in Exhibit A.8 and elsewhere, but were used in interpreting the results from these logs as described below.

Overall the temperature log shows a steady cooling decline from about 17.8° C within and just below the isolation casing that levels out to a baseline low temperature of about 13.7° C around 25 ft bgs. From 35–95 ft bgs, the fluid temperature then shows a gradual steady increase. This appears to reflect a natural thermal gradient between warmer outside air temperatures at that time and colder ground water.

The fluid resistivity log suggests a potential ground water flux occurring between 16.9 and 17.7 ft bgs where a sharp increase in resistivity occurs from about 24 to 43 ohm-m over a depth interval of less than one foot. This change occurs at 17 ft bgs, about 2 ft below the bottom of the isolation casing at 15.0 ft bgs. Below this sharp resistivity break the fluid resistivity remains steady at around 44 ohm-m to total depth. The data suggest the possibility of a short interval of ground water flux centered around 16.3 ft bgs followed by little or no flux below that depth. There is a suggestion of a possible steeply dipping fracture on the OTV/ATV log from about 18–19.5 ft bgs, however, this feature is visually subtle and may be considered speculative. No packer tests were conducted near this interval to corroborate the results from the resistivity log. More sensitive vertical profiling of ground water flux is recommended for the GW-974(I) borehole to distinguish very low hydraulically conductive intervals/depths from intervals with little or no ground water flow.

**Fracture Interval Packer Testing**

Only one Phase I packer test was conducted in GW-974 (I). The test was conducted over the interval 33–43 ft bgs, based on the results of the flow meter test at 35 ft bgs and a possible joint/fracture at 37.5 ft bgs interpreted by the geophysicist. No flow could be established within the flow and pressure constraints of the packer testing methodology (i.e., tests cannot overpressure the formation and artificially induce flow above anticipated formation pressures at the selected depth of the test).

**Overview of Fracture/flow Data in GW-974(I)**

Continuous water level readings from the GW-974(I)/GW-975(S) well pair indicate water level elevations that consistently track each other and differ by approximately 1.0 to 1.5 ft during baseline flow periods. The water levels in the deeper well pair occur consistently above those in the shallow well, except during relatively brief recharge periods when these water levels track one another at closer elevations. The paired water level data indicate upward ground water flow gradients. The fluid resistivity suggests that ground water could be entering the borehole through a fracture(s) around 17-19 ft bgs. However, the flowmeter tests and packer test performed in GW-974(I) did not identify intervals of potential ground water flux (Note that the flowmeter tests at 20 ft bgs just below the 17-19 ft interval recorded no flow). The collective results suggest that upward flow in GW-974(I) must be occurring at relatively slow rates (incapable of detection by the heat pulse flowmeter or packer tests) at one or more intervals in the borehole that are unclear. More sensitive depth-discrete flow testing could be used to quantify potential

zones of ground water flux within the borehole of GW-974(I) during a Phase II investigation. The Phase I results indicate that as in GW-972(I), the overall ground water flux in GW-974(I) is relatively low and much lower than that observed in GW-970(I).

### 7.2.5.10 Maryville Limestone (Dismal Gap Formation) Bedrock Hydrogeology

Monitoring well GW-976(I) was drilled at the crest of the east-west trending spur ridge that aligns roughly with the southern edge of the EMDF footprint. The surface location is situated about 220 ft south of the approximate outcrop trace of the Rogersville/Maryville contact at the EMDF (see Figure 1 and Plate 3). This locates the boring at a position to roughly intercept the lower one third of the Maryville. Rock coring was completed over a bedrock interval of 71.7 ft from depths of 28.4–100.1 ft bgs (auger refusal occurred at 24.4 ft bgs with 10 in. PVC isolation casing set at 28.4 ft bgs). A detailed boring log with descriptions and interpretations of the rock cores is provided in Exhibit A.4. Photographs of the rock cores are provided in Exhibit A.7. The regolith and bedrock stratigraphic sequence encountered at GW-976(I) is illustrated in the cross sections of Plates 2 through 4. In addition to the lithologic/stratigraphic profile at GW-976(I), these cross sections include the locations of fractured intervals identified in the rock cores that could indicate possible zones of ground water flux. Other structural features such as maximum bedding plane dip angles (toward the southeast) are shown. The azimuth and dip angles of structural features such as bedding planes and potential fractures/joints based on interpretations of the OTV/ATV logs were plotted on the structure log and on a Schmidt plot as shown below and in Exhibit A.8.

**Lithologic Descriptions from BCV Sites along Strike with the EMDF**

Lithologic descriptions of rock core data from the WBCV site (LLWDDD) indicate that the Maryville Limestone consists of limestone interbedded with dark gray shale that typical contains thin lenses of light gray limestone and calcareous siltstone. Maroon shale beds occur in both the upper and lower Maryville. More intraclastic limestone occurs in the upper Maryville, while the lower Maryville includes more thin laminated and oolitic limestone. Pinkish limestone beds occur in the lower 40 ft (see Table 17 for more detailed lithologic descriptions from Lee and Ketelle 1989).

Ogden Site B and C borings adjacent to and along strike with the EMDF did not penetrate the bedrock section of the Maryville, and other borings/wells drilled within the EMWMF footprint did not include extensive rock coring to provide detailed descriptions of the Maryville for nearby comparison to the EMDF.

**Lithologies in GW-976(I) Based on Rock Cores**

Unlike the rock cores from GW-972(I), those from GW-976(I) show evidence of intense weathering and leaching within the uppermost part of the cored section. The upper section of cores from the isolation casing (set at 27.75 bgs) down to about 50 ft bgs has an overall brownish hue that transitions into a lower interval of bedrock with an overall grayish hue. The brownish section correlates with a heavily weathered and chemically leached vadose and upper water table bedrock zone. The lower grayish section correlates with a saturated zone that is far less weathered and less subject to oxidation and chemical leaching. The transition occurs from about 50–54 ft bgs (see rock core photos in Exhibit A.7).

Also in contrast to GW-972(I), the percent recovery and quality of rock cores in GW-976(I) is relatively poor, but improves with depth as the boring was advanced into more competent bedrock. Much of the recovered upper core interval consists of broken rock fragments separated by typically shorter core intervals of intact rock. The upper part of the cored interval from 28–44 ft bgs is composed of interbedded shale, siltstone, and laminated shale and siltstone, with the lowermost 10 ft consisting of laminated shale and siltstone. None of this upper interval contains any limestone or calcareous material that reacts to HCl. Below this upper part of the cored interval, and near the water table (or potentiometric surface), is a 3.2 ft interval from which no core was recovered. The upper part of this interval of no recovery is coincident with an interval (43.5–44.7 ft) where the caliper log indicates a “washout” where the nominal 8 in.

borehole diameter increases from 8.5 –10 in. in diameter (these "washout" zones are highlighted in yellow on the caliper logs of Plate 2). This interval and several others like it, where core was only partially recovered, may be coincident with weaker shaley intervals whose fine-grained clay/silt size particles and shaley rock fragments are disintegrated during the coring process which uses water as a circulation and cooling fluid. These intervals of lost or poor rock core recovery may or may not be coincident with fractured zones conducive to ground water flow. Borehole camera logging (downward and side projected) and discrete depth flow testing could be used to determine the hydraulic conductivity of these intervals in a Phase II effort.

Limestone lamina and beds first occur at and below depths of 47.7 ft bgs, directly below the zone of lost core just noted. All limestone throughout the cores responded readily with HCl effervescence. A relatively thick sequence of laminated shale and limestone about 12.5 ft thick occurs immediately below the upper washout interval at 44 ft bgs, and is followed to total depth with a variable sequence of interbedded limestone, shale, and laminated shale/limestone. The gray limestone beds vary from about 0.9–1.8 ft in thickness, the shale beds vary from about 0.5 ft to as much as 4.2 ft in thickness, and the laminated shale/limestone intervals vary from about 0.5 to 2.3 ft in thickness. The detailed stratigraphic profile is described and illustrated in the boring logs in Exhibit A.4, and illustrated in the cross sections of Plates 2 through 4.

**Fractures Identified in Rock Cores**

Among the lower 60% of the bedrock cored sequence in GW-976(I), are eleven separate intervals of limited/lost core that vary from about 0.5–1.7 ft. As noted above, these may represent intervals composed of weak and possibly fractured shale that were disintegrated during the coring process. The quality of the OTV/ATV logs and sensitivity of other geophysical logs are insufficient to identify the in-situ conditions and structural features of these intervals.

No intervals with voids or sudden sharp losses in circulation were encountered during the drilling and rock coring, or indicated on the geophysical logs that would suggest large scale karst dissolution features or fractures associated with the limestones identified in the rock cores. The driller did note a loss of approximately 30 gallons of fluid during the coring between Pulls 10 and 13, which span the 8.1 ft interval from 49.7–57.8 ft bgs. In addition, fractures with iron oxide staining and weathering were noted in the cores at several depths as indicated on the boring logs. Some of these occur near or above the potentiometric surface in the vadose zone. Four were identified within the saturated zone and may represent fractures conducive to ground water flow. The presumed shaly intervals noted above where core was not recovered may also possibly represent weaker fractured intervals that could be conducive to flow. Discrete borehole interval testing is recommended to determine the hydraulic conductivity of these features during a Phase II investigation.

The rock cores recovered from GW-976(I) vary from highly weathered intervals composed of loose and broken rock fragments to intact sections of core where fractures are easily discerned. Only within the intact portions of the cores can the nature and orientation of fractures be accurately defined. Many of the fractures in the intact sections of cores are mechanical breaks along weak bedding plane surfaces. Other fractures within intact sections of cores judged to be associated with naturally weathered fractures were identified on the detailed boring logs and rock core photos.

**Bedding Plane Dips and Possible Folds Based on Rock Cores**

Maximum bedding plane dip angle measurements were made at representative intervals (37 total) throughout the rock cores of GW-976(I) wherever intact cores were obtained. The bedding planes common throughout the cores along planar laminations provided ideal locations for visually determining maximum dip angles using a transparent compass with accuracies of about ±2°. The azimuth of the rock cores is unknown relative to true north so the in-situ strike of the beds is unknown. The bedding plane

dips observed in GW-976(I) rock cores were not as uniform as those seen in GW-972(I) cores. While relatively uniform dips were observed across some sections of the cored interval, steeper dips in some core segments suggest that intervals of flexed or folded beds occur within some intervals of the Maryville penetrated in GW-976(I). The dips vary from 40°–85° and are assumed to be generally toward the southeast. Relatively steep dips in the range of 70°–85° were identified at depths of 41, 42.5, and 51 ft bgs, and at depths from about 70–74 and 80–85 ft bgs. Steeper dips at these depths and intervals may reflect the effects of localized drag folds or shear fractures consistent with local and regional tectonic stresses and thrusting toward the northwest.

A zone of deformation was reported in the upper part of the Maryville at the WBCV tumulus site (Lee and Ketelle, 1989). This zone contained a relatively thin interval several inches to several feet thick with drag folding, gouge, or vertically extensive shears, observed in six core holes. The zone varied slightly in thickness and character but was found in approximately the same stratigraphic interval between 46 and 79 ft below the Maryville/Nolichucky contact. This deformed interval is stratigraphically well above the location and depth range of the middle to lower Maryville interval cored in GW-976(I), but the steep beds observed in the GW-976 cores may reflect similar structural features. Tight chevron folds are visible in road cuts at Dismal Gap within the lower Maryville about 13 miles northeast of the EMDF along strike with Pine Ridge, suggesting that structural deformation is not uncommon within the Maryville.

**Results from Borehole Geophysical Logs**

As noted above, the bedrock boring log from GW-976(I) based on detailed descriptions of the rock cores were compared with the suite of geophysical logs to establish potential cross correlations between the two sets of data. Results of the log interpretations and correlations with rock cores are reviewed below. GW-976(I) is the only deep borehole location where the unsaturated zone was exposed below the bottom of the isolation casing (at 27.75 ft bgs). The water level in the borehole at the time of the logging was 44.25 ft bgs, exposing a 16.5 ft interval of unsaturated bedrock in the upper portion of the borehole (see geophysical logs in Exhibit A.8).

***Natural Gamma Ray Log:*** In general, the NGR log from GW-976(I) was found to correlate with some of the relatively thicker limestone and shale beds on the order of 1.5–2.0 ft thick. Only rough baseline correlations can be observed between thinner interbedded limestones, shales, and siltstones and the NGR logs. Further interpretations and correlations between rock cores and the NGR log for GW-976(I) are reviewed above in Section 7.2.5.4, and should be referenced for more detail.

***Caliper Log:*** The caliper log for GW-976(I) was placed alongside the bedrock boring log to correlate "washout" intervals with rock core data (i.e. - lithologies, fractures, core recovery, core quality, etc.). The caliper log shows seven "washout" intervals where the nominal 8 in. diameter borehole widens to diameters from 8.5–9.0 in. (shown on Plate 2). The most shallow of these intervals (43.5–44.7 ft) occurs near the potentiometric surface at about 44 ft bgs where a 1.2 ft interval widens to almost 10 in. Other intervals were centered at 52.0 ft bgs (0.7 ft long), 63.7 ft bgs (0.2 ft), 72.2 ft bgs (2.0 ft), 74.4 ft bgs (0.5 ft), 77.9 ft bgs (0.9 ft), and 83.7 ft (0.3 ft). Each of these intervals coincide with depth intervals where core losses occurred. These intervals may represent zones of fractured shale that are more easily broken up and pulverized as the outer core barrel and diamond bit is advanced and recirculating core fluids slurry the soft fine grained clay particles away and slightly widen the borehole in the process. Unfortunately with no core recovery from these intervals, the true lithologic composition and potential fracturing of these zones is uncertain.

***Structure Log:*** A total of 44 structural features were identified on the ATV and OTV logs at irregular depths across the length of the bedrock borehole. Most of the features were identified by the geophysicist as bedding plane surfaces (green - 25); 15 are identified as possible open joints/fractures (orange, red, purple), with four identified as filled joints/fractures (gray). The direct correlation between these features

and the ATV/OTV borehole logs are shown by depth on the composite logs in Exhibit A.8. Figure 40 shows these features on a Schmidt plot. The mean orientation of the 25 bedding plane features in GW-976(I) is:

- Strike: N43°E (perpendicular to the 133° mean dip azimuth)
- Dip: 58° southeast

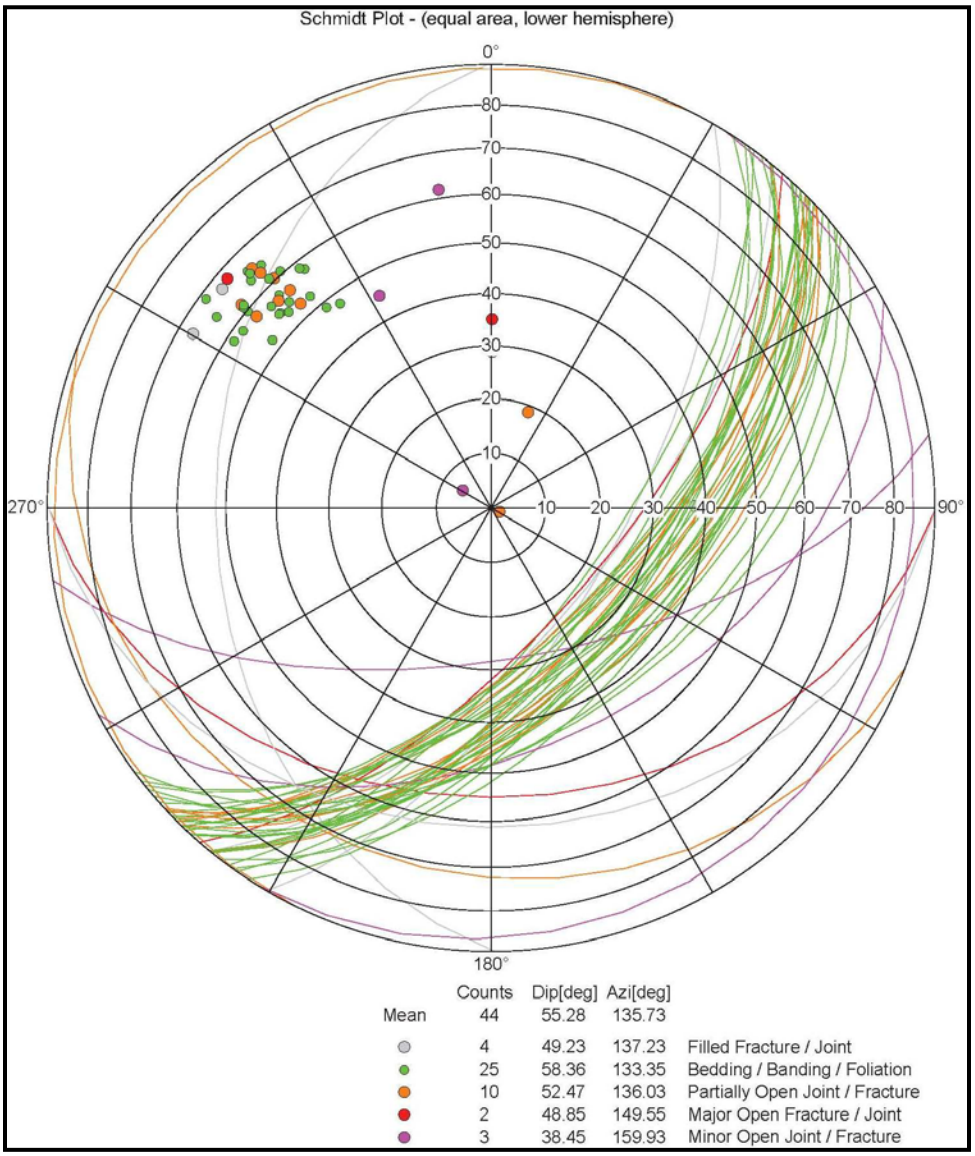



**Figure 40. Schmidt Plot of Interpreted Structure Log Features in GW-976(I) Bedrock – Maryville Limestone**

As shown on Figure 40, six of the 15 possible open joints/fractures have orientations discordant with the bedding planes, while seven of the 15 are within the overall range of the bedding plane features. The structure log bedding plane features show a narrower range of bedding plane dips mostly between 50°–70°, whereas the bedding plane dip measurements made from the rock cores vary from 40°–85°. The specific depths and intervals with steeper dips noted above as measured within intact sections of the rock cores occur where the ATV/OTV log quality is relatively poor and subject to variable interpretations. The rock core dip angles are believed to be more reliable indicators of true maximum dip angles at depths where measured (see boring logs for depths of maximum dip angles measured in rock cores). The number, range, and variation among the features mapped on the structure log is consistent with the wider range of features and dip angles observed in the rock cores of GW-976(I) (compare the relative uniformity of the Schmidt plot data for GW-972[I] versus that for GW-976[I]).

***Heat pulse Flowmeter Log:*** Seven depths were selected in GW-976(I) for flowmeter testing at intervals between 50 and 93 ft bgs. Five of the seven indicated no flow. Two of the tests at 75 and 80.5 ft bgs recorded upward flow rates: 0.034 gpm (2.02 gph or 48.6 gpd) at 75 ft, and 0.022 gpm (1.35 gph or 32.3 gpd) at 80.5 ft. These results suggest ground water flow entering the borehole below 80.5 ft with additional flow contributions between 75 and 80.5 ft bgs increasing the total upward flow rate to levels slightly above the lowest quantifiable flow rate of 0.03 gpm (1.8 gph or 43 gpd). One horizontal feature was identified on the structure log at a depth of 77.7 ft bgs (identified by the geophysicist as a possible "minor open joint/fracture"). This feature is coincident with a significant "washout" interval about 0.7 ft long and interpreted to be the location of 0.9 ft of lost core recovery in Pull 20. This interval as well as other zones of lost core may be associated with relatively weak and fractured shale beds that are disintegrated during the rock coring process. Actual in-situ lithologic and structural conditions are unknown, but the OTV/ATV logs do indicate a horizontal feature at 77.7 ft that may represent a water bearing fracture. One of the two packer tests conducted in GW-976(I) was completed over the interval 68-78 ft bgs. This tested interval encompasses the 77.7 ft feature, as well as two other minor open joints/fractures mapped on the structure log at depths centered near 71.5 and 72.5 ft bgs (but located above the heat pulse test at 75.0 ft with the upward flow rate of 0.034 gpm). The packer test results from 68-78 ft indicated an average K value of $1.2\times10^{-5}$ cm/sec.

The general correlations between the heat pulse flowmeter tests indicating upward flows at 75 and 80.5 ft bgs and the lower packer test and boring/structure log data were not observed at the shallower depths in GW-976(I). Zero flow heat pulse tests at 50, 62.5, and 67 ft bgs suggest either no or extremely low flow (unquantifiable with the heat pulse instrument) within the shallower sections of the open borehole. The shallower packer test in GW-976(I) over the interval from 49.5-59.5 ft bgs indicated an average K value of $5.6\times10^{-5}$ cm/sec. The packer test results suggest that this interval is capable of transmitting ground water, and several possible fractures fractures/joints were identified on the structure log between 51 and 57 ft within this tested interval. In addition, the boring log rock core data also indicate several fractures with evidence of staining/weathering within this packer tested zone. The caliper log also shows a "washout" interval of 0.7 ft from 51.7–52.4 ft bgs that suggests the potential for a weak fractured zone capable of transmitting ground water flow. It is unclear why the heat pulse flowmeter did not detect flow above or below these apparent hydraulically conductive features.

***Temperature and Fluid Resistivity Logs:*** The temperature and fluid resistivity logs both show a similar overall decline from near the water table or potentiometric surface at 44.3 ft bgs down to 65 ft bgs where both curves level off to fairly constant levels between 65 and 81 ft bgs. From 81 ft to total depth around 100 ft, the temperature continues to decline very slightly by around 0.1° C to a low near 13.8° C. Between 81 ft and total depth the fluid resistivity curve increases only very slightly. If changes in fluid resistivity gradients correlate with fluid flow in the borehole (as noted by the USGS 1996), then the resistivity curve would suggest that flow (presumably upward) begins to occur near 65 ft bgs and continues to gradually increase up toward the water table at 44.3 ft. The zero flow data from the heat pulse flowmeter at

50 ft bgs suggests that if borehole flow is occurring across this shallower interval, the flow rates must be very low rates or they may be occurring more laterally across the borehole rather than vertically.

**Overview of Fracture/Flow Data in GW-976(I)**

The saturated zone at GW-976(I) is relatively deep compared with the other Phase I well pairs and located as much as 20 ft below auger refusal down within the zone of competent bedrock. The absence of a shallow well screened exclusively at the water table interval precludes a determination of vertical gradients based on well pair methods such as those described above in Section 7.2.3.3. However, GW-976(I) is located along the crest of a spur ridge more distant and more hydraulically isolated from Pine Ridge. This location means that GW-976(I) is far less likely to be subject to the influence of steep pressure gradients that may occur along the lower flanks immediately south of Pine Ridge (e.g., at locations such as GW-968(I) and GW-970(I). The area available for ground water recharge near GW-976(I) is also considerably less than that for locations directly along the lower slopes of Pine Ridge. The water level hydrograph for GW-976(I) appears to clearly reflect these conditions. The effects of recharge from precipitation events is much more subdued for GW-976(I) relative to the other eight Phase I wells, yet longer term cumulative increases in water levels are seen in relation to precipitation events (at least for the wet non-growing season record so far).

A number of potential fracture intervals were identified in the rock cores from GW-976(I). Potential fractures were also identified at various depths on the structure log. The heat pulse flowmeter results indicated upward borehole flow at 75 ft slightly above the quantifiable flow limit of the instrument and a suggestion of upward flow at a lower flow rate from below the 80.5 ft bgs test depth. Other heat pulse tests above and below these depths indicated no detectable borehole flow up or down. The two packer tests in GW-976(I) indicated intervals with intermediate K values ($10^{-5}$ cm/sec) suggesting that fractures within these ten foot intervals are conducive to ground water flow. Overall vertical gradients cannot be independently assessed at this location without a shallow well pair for comparison of shallow/deep hydraulic heads. The single well at this location precludes a determination of vertical gradients at the GW-976(I) location. More sensitive depth-discrete flow testing could be used to systematically quantify potential zones of ground water flux within the borehole of GW-976(I) during a Phase II investigation. The Phase I results suggest that upward borehole flow may be occurring from a fracture near 78 ft bgs. Borehole flow elsewhere is unclear but the presence of other potential fractures along with the results of the packer tests suggest that other intervals within the borehole are conducive to ground water flow.

### 7.2.5.11 Nolichucky Shale Bedrock Hydrogeology

The contact between the top of the Maryville Limestone and the overlying Nolichucky Shale occurs at distances 400 ft or more south of the southern edge of the proposed waste limits of the EMDF and south of the existing Haul Road. Because of the southeasterly regional dip of the beds, the Nolichucky does not underlay the EMDF footprint, and was excluded from the Phase I investigation.

# 8. CONCLUSIONS AND RECOMMENDATIONS

The limited Phase I site characterization results were intended to provide TDEC and EPA with enough information to make an informed decision regarding site suitability for the EMDF. The major conclusions of the limited Phase I investigation are summarized below in Section 8.1. The key Phase I results related to the EMDF engineering conceptual design and related to questions of site suitability are summarized in Section 8.2. General recommendations for a follow on Phase II investigation are presented in Section 8.3, contingent upon site approval from TDEC and EPA.

## 8.1 PHASE I CONCLUSIONS

General conclusions from the Phase I investigation are presented below according to the same general categories presented above in Section 7. It should be emphasized that the Phase I results were limited in scope to five well pair locations, three stream gaging locations, six observational monitoring locations, and the current three month period of continuous monitoring. The spatial and temporal range of these data are therefore limited, but provide useful baseline data for a follow on Phase II investigation should the site be approved for further investigation and design.

### 8.1.1 Surface Water Hydrology and Water Quality

#### 8.1.1.1 Surface Hydrology

Total rainfall during the three month reporting period from December 2014 through February 2015 is similar to long-term averages and does not constitute a particularly dry or wet condition relative to climatic normals. The largest and most intense precipitation events recorded during the reporting period are not high magnitude events in terms of historical precipitation frequencies. Storms of similar magnitude are expected to occur several times in an average year in the vicinity of the EMDF site. Estimated total surface runoff relative to precipitation inputs analysed for nine runoff events was within a reasonably expected range for the winter wet season. The SWG-2 catchment exhibited low total runoff relative to rainfall, probably due to disturbance of surface drainage patterns and ungaged runoff during high flow events. The SWG-2 and SWG-3 subcatchments responded more quickly to precipitation than did the SWG-1 subcatchment in most cases, reflecting differences in catchment area and hydrologic travel times.

The ranges of peak flow rates observed at the gaging stations during nine runoff events are:

- SWG-1: 0.14-9.63 cfs (62.84–4322 gpm)
- SWG-2: 0.02-0.64 cfs (8.98–287.3 gpm)
- SWG-3: 0.13-2.17 cfs (58.35–974 gpm)

Baseflow rates for SWG-1, SWG-2, and SWG-3 during the current monitoring period fall below the minimum quantifiable flow rates set by the flume vendor of 0.096 cfs (43.3 gpm) for SWG-1 and SWG-3, and 0.037 cfs (16.8 gpm) for SWG-2. Flow rates at the three headwater springs were all estimated at <1gpm for each of the 12 quasi-weekly measurement events to date. Baseflow rates at the downstream intermediate stream channel locations EMDNT3-ST1, -ST2, and –ST3 are quite low and range from 0.007–0.056 cfs (3.1–25.0 gpm).

#### 8.1.1.2 Surface Water Quality

Observed variations in surface water temperatures were consistent with trends in air termperature and with temperatures measured at the six observational monitoring sites. Temperatures recorded at the three spring observational monitoring sites were typically one to three degrees C higher than water temperatures at the surface water gaging stations.

SpC recorded at the surface water gaging stations ranged from approximately 0.05–0.35 mS/cm over the reporting period. The pH values at the surface water gaging stations were generally between 6 and 7. During the early weeks of the pH record for SWG-1 and SWG-3 observed pH was greater than 7.0

Continuous records of SpC from the surface water gaging stations were consistently higher than SpC values measured at the six observational monitoring sites. The pH values measured at the six observational monitoring sites were generally similar to or slightly lower than pH at the surface water gaging stations.

Variations of surface water SpC and pH during runoff events were complex and variable among the three surface water stations and among events. Rapid decreases in SpC and pH during surface flow increases was the most common pattern of variation observed. These patterns are consistent with the arrival of relatively dilute, slightly acidic runoff at the surface water gaging stations.

### 8.1.2 Hydrogeology

Collective Phase I results in Plate 2 illustrate the key hydrogeological features among the ten wells at the EMDF site. Key data shown on Plate 2 include:

- As-built boring/well construction features (i.e., screen, filter pack, bentonite plug, grout).
- Maximum/minimum water levels for the period of continuous hourly monitoring from November 21, 2014, through February 26, 2015, representing a portion of the wet Winter season.
- Profiles of soils/saprolite and bedrock lithologies based on split tube samples, rock cores, and geophysical logs.
- K values from Shelby tube analysis and slug tests in the regolith zone, and from packer tests in the bedrock zone.
- Heat pulse flowmeter test results indicating depths with no to slight upward flow below the quantifiable flow rate of 0.03 gpm, and depths with upward flow above the quantifiable flow rate of 0.03 gpm.
- Possible fracture flow zones based on rock cores.
- Possible fracture flow zones/depths plotted on Structure logs based on ATV/OTV log interpretations.

Plates 3 and 4 illustrate hydrogeological features in relation to primary elements of the EMDF conceptual design. These illustrations along with other report tables and graphics are useful guides for reviewing the conclusions summarized below.

#### 8.1.2.1 Ground Water

**Ground Water Depths and Water Level Fluctuations**

A representative high water table surface and maximum/minimum water levels are shown on the contour map of Figure 29 and cross sections (see Plates 3 and 4). The water table surface and water level fluctuations shown are representative of the typical wet winter/spring non-growing season when water levels are annually at their highest. Winter season depths to ground water are relatively shallow across much of the EMDF footprint (from near surface to 12.7 ft bgs). The water table occurs within regolith soils and saprolite above bedrock, except below the spur ridge area along the south and southeast sides of the EMDF footprint where ground water occurs in bedrock well below the regolith/bedrock interface at depths from 38–44 ft bgs for the current monitoring period.

The overall range in water level fluctuations thus far between highest and lowest elevations varies from 4.0 ft in GW-974(I) to 8.4 ft in GW-970(I). Water levels in all wells (shallow and deep) rise and fall relatively quickly in response to precipitation/recharge events. The only exception occurs in GW-976(I) where responses are subdued and where water levels rose progressively over December and through mid January where they plateau. The unique behavior of water levels in GW-976(I) appears related in part to its location below the spur ridge where recharge may be more restricted and slower, and its isolation from greater hydraulic pressure heads below and more directly south of Pine Ridge. The water level responses to precipitation events and seasonal fluctuations are consistent with well clusters monitored at the EMWMF and elsewhere in BCV. The highest Phase I water levels are representative of higher water table conditions that always occur during the non-growing winter/spring wet seasons.

**Ground Water Flow Directions and Gradients**

Shallow and intermediate level ground water migrates from upland recharge areas to discharge zones along the valley floors of NT-2/NT-3. Ground water seepage and discharge supports baseflow along portions of the larger NT-2/NT-3 tributaries cross cutting the EMDF site. Shallow ground water flow directions and horizontal gradients mimic surface topography and range from 0.33 to <0.05, between the steepest upland areas and relatively flat valley floors. Vertical upward gradients between the intermediate and shallow water table ground water intervals occur consistently at three of the five Phase I well pairs (GW-968[I]/GW-969[S], GW-972[I]/GW-973[S], GW-974[I]/GW-975[S]), and range from 0.003–0.065 based on representative data from January 12, 2015. Vertical gradients between the GW-970(I)/GW-971(S) cluster wells have varied up and down over time. Upward vertical gradients in each of the well clusters may disappear over short timeframes when water levels rise quickly in response to precipitation/recharge events. Vertical gradients at the GW-976(I) location are unclear as the shallow well (GW-977[S]) is dry, although two HPF meter tests suggest upward gradients may exist associated with bedrock fracture flow at depths of 75–80 ft bgs. The relatively large uncased intervals of the bedrock wells limits a precise determination of which depth interval(s) are contributing most to vertical hydraulic gradients.

Artesian conditions at GW-968(I)/GW-969(S) are the result of site grading cuts made well below the original undisturbed ground surface at the base of a narrow ravine below Pine Ridge. Site traverses prior to the Phase I investigation, did not identify springs or seeps at this location indicating that shallow ground water there did not previously intersect the surface.

**Hydraulic Conductivity and Heat Pulse Flow Meter Tests**

Slug tests were conducted in four shallow wells screened across saturated regolith (soils/saprolite) above bedrock. Hydraulic conductivity values from the tests ranged from $1.2\times10^{-7}$ cm/sec to $1.5\times10^{-6}$ cm/sec with an average K of $6.7\times10^{-7}$ cm/sec. Hydraulic conductivity values from laboratory analysis of Shelby tube samples from soils/saprolite range from $3.9\times10^{-7}$ cm/sec to $6.5\times10^{-6}$ cm/sec with an average K of $3.2\times10^{-6}$ cm/sec.

A total of nine injection packer tests were conducted over ten ft intervals in the open bedrock boreholes of the deep Phase I wells. No flow or limited and erratic flow for the two tests in GW-972(I) and the single test in GW-974(I) precluded a determination of K in those wells. While the results were indeterminate for K, the tests suggest that the tested intervals in these wells have relatively low permeabilities ($<<10^{-6}$ cm/sec). The relatively low permeability of the bedrock sequence in these wells was also supported by the HPF meter tests. The HPF meter tests in these two wells measured no flow in 13 out of 15 HPF meter tests with only two tests recording slight possible upward flows below the minimum quantifiable flow rate (0.03 gpm).

Packer test results for the other six tests conducted in the three remaining deep wells (GW-968[I], GW-970[I], and GW-976[I]), indicated K values ranging from $1.4\times10^{-5}$ cm/sec to $1.5\times10^{-4}$ cm/sec. The relatively higher K values from these wells were supported in part by relatively higher and more numerous HPF meter flow rates in these wells. The highest flow rates in the HPF meter tests were coincident with relatively higher K values in the packer tests. The only exception occurred in GW-976(I) where a shallow HPF meter test indicated no flow at 50 ft bgs where the packer test results indicated a relatively high K value over the interval encompassing 50 ft bgs. All of the HPF meter tests indicated upward flow directions.

The range of the K values from the bedrock packer tests is two orders of magnitude greater than those conducted from the shallower saturated and unconsolidated regolith materials. However, the packer tests were limited in number and test depths. In addition, the flow meter used for packer testing limited results to determinations of K values on the order of $10^{-5}$ cm/sec or higher. Additional K testing capable of

determining lower K values in the range of $10^{-6}$ to $10^{-8}$ cm/sec (or lower) are recommended for the Phase II investigation to better characterize the full range of K values in bedrock. With the limited amount of Phase I data it is unclear whether the range of K values in regolith materials is relatively lower on average than those in the underlying fractured bedrock or whether biases exist among the Phase I testing methods. Biases inherent to variations in sampling, testing methodologies, equipment, and analytical methods used for calculating K were not evaluated but could have a significant influence on variations among the results.

A total of 39 HPF meter tests were conducted at various depths among the five deep open bedrock boreholes. The HPF meter tests identified upward flows >0.03 gpm (minimum quantifiable flow rate) at depths of 45, 50, and 57 ft bgs in GW-970(I), and at 75 ft bgs in GW-976(I). Flow at these test depths were corroborated by packer test results indicating relatively higher K values from test intervals encompassing these HPF meter test depths. Elsewhere the HPF meter tests indicated no to very slight flows below the quantifiable limit. In particular, the HPF meter tests were consistent with the no to limited/erratic flow results from the packer tests in GW-972(I) and GW-974(I) suggesting that fracture flow in these bedrock wells is relatively low compared with the other three Phase I bedrock wells.

#### 8.1.2.2 Regolith Hydrogeology

Results from the ten Phase I wells indicate regolith thicknesses that vary from 10.0 to 25.6 ft bgs. Phase I split tube samples from the regolith were logged predominantly as clayey silt (ML) with weathered rock fragments (saprolite). The thin topsoil layer was removed during site grading at the well locations. The split tube log descriptions and engineering geotechnical descriptions and properties from the five Phase I Shelby tube samples are reasonably consistent with clayey/silty soils and saprolite described from hundreds of regolith samples at adjacent sites along geologic strike immediately to the east and west (EMWMF/Ogden Sites B and C; Ogden 1993a/b, and CH2MHill 2000).

SPT "N" values (blow counts) indicate that soil/saprolite consistency increases progressively with depth from stiff to hard as silty/clayey residuum and saprolite grades downward into less weathered saprolite at auger refusal. Natural moisture contents range from 12.2– 21.2%. Specific gravities range from 2.68–2.73. Liquid and plastic limits range from 29–34, and 20–24, respectively.

The Phase I water level data for the wet non-growing season to date suggest that the water table across much of the EMDF footprint occurs within the middle to upper parts of the regolith well above competent bedrock at auger refusal. Regolith materials below the higher elevations of the spur ridge near the southern part of the EMDF footprint are unsaturated where the water table occurs below top of competent bedrock. Micro and macropores and relict features within the saprolite (bedding planes, joints, shear fractures) provide avenues for ground water migration vertically through the vadose zone and laterally through the shallow water table interval. Lateral ground water flow within the regolith provides baseflow for the small surface streams along the NT-2/NT-3 tributaries at and near the EMDF footprint.

#### 8.1.2.3 Bedrock Hydrogeology

Detailed lithologic/stratigraphic sequences were developed from rock cores over bedrock intervals in GW-972(I) and GW-976(I). Natural fractures, particularly those with evidence of staining and weathering, were identified and plotted on logs to indicate zones that might be conducive to fracture flow. The rock cores were cross correlated with the suite of geophysical logs to support the identification of possible fracture flow zones and the selection of zones for packer testing and to evaluate the validity of the various geophysical logs. Rock cores from GW-972(I) in the Rutledge reveal a vertical sequence predominantly composed of shale/mudstone with relatively minor lamina of limestone/calcareous siltstone with a limited number of possible fracture intervals. In constrast, the rock cores from GW-976(I) in the Maryville, reveal a mixed sequence of rocks from shallow non-calcareous shales and siltstones to a lower sequence of mostly interbedded shales and limestone. Intervals of possible fracture zones that may

be conducive to ground water flow are identified in detailed logs and cross sections (Plate 2). Heavily weathered and stained rocks were logged in the uppermost 20 ft of bedrock in GW-976(I) that transition to progressively more unweathered and more competent bedrock at depth. No evidence of staining/weathering was observed in the rock cores of GW-972(I). The rock cores in GW-972(I) indicate relatively uniform bedding plane dips to the southeast, whereas zones of steeply dipping bedding planes in GW-976(I) suggest intervals of folding and/or shearing. No voids or cavernous intervals or evidence of extensive limestone dissolution were identified during drilling or in the cores. The driller noted a loss of 30 gallons of water over the course of rock coring between 50–58 ft bgs. This interval was subsequently packer tested and found have an average K of $5.6x10^{-5}$ cm/sec.

General types of lithologies can be approximately determined from the NGR logs, but the borehole geophysical logs are incapable of accurately defining detailed lithologic and stratigraphic sequences in the Phase I bedrock wells. The results from fluid resistivity logs, ATV/OTV logs, the interpretive structure logs, and the HPF meter logs were useful for identifying the depths of potential fracture and flow zones. Those results were used in combination with packer tests to identify intervals within each of the bedrock wells that may be conducive to ground water flow and influencing upward vertical gradients. Most of the structural features interpreted by the geophysicist as possible fractures/joints are parallel to bedding planes, but exceptional discordant fractures were identified in the upper bedrock sections of GW-970(I), someof which are coincident with relatively high HFP results and packer tests.

Water level differences between most of the shallow/deep well pairs and the consistent upward flow directions indicated by the HPF meter tests suggest that upward vertical gradients may be common within fracture flow zones of the upper to intermediate levels of saturated bedrock. The potentiometric surface data from the five deep Phase I wells are similar to those for the shallow water table interval, generally differing by less than 1–2ft. Potentiometric surface contour maps for the intermediate ground water interval will therefore be very similar to that shown for the water table surface (see Figure 29). Lateral (horizontal) ground water flow paths within the intermediate interval should thus mimic those shown for the water table interval, except that upward gradients will be expressed along with the horizontal flow gradients along three dimensional convergent flow paths toward discharge zones along the NT tributary valleys. The three dimensional flow conditions for intermediate level ground water below the spur ridge area near GW-976(I) are less clear without a shallow well pair (GW-977[S] is dry). The progressive and gradual increase in water levels in GW-976(I) over a period of several weeks are distinctly different from the relatively rapid up and down fluctuations seen over just a few days in all other Phase I wells. The data suggest that recharge and flow conditions below the elevated areas spur ridge are uniquely different from those elsewhere at the EMDF site. The single upward HPF meter test at 75 ft bgs of 0.034 gpm (above the minimum quantifiable flow rate) suggests that upward gradients may exist at depth below the spur ridge area.

The combined results of packer tests, HPF meter tests, structure and fluid resistivity logs, and rock core evaluation, indicate that GW-970(I) has the highest K and HPF meter flow rates. In addition, the structure log indicates high angle fractures discordant to bedding planes in the uppermost bedrock section (34–43 ft bgs) that were not tested for flow or K but suggest a significant potential fracture zone that may be conducive to flow. Similar combined Phase I data suggest bedrock flow conditions in GW-968(I) and GW-976(I) that are less than those in GW-970(I), but greater than those in GW-972(I) and GW-974(I) where the combined results suggest relatively lower K values and the lowest indications of borehole flow according to the HPF meter test results.

## 8.2 PHASE I RESULTS RELATED TO CONCEPTUAL DESIGN AND SITE SUITABILITY

The cross sections on Plates 3 and 4 illustrate the relationships between the Phase I water table and the primary components of the conceptual design for the EMDF. The water table or potentiometric surface of the shallow water table interval shown for December 25, 2014, is representative of the relatively higher

water levels that occur each year during the wet non-growing winter and spring seasons. The cross sections accurately illustrate the surface topography, key hydrogeological conditions identified in Phase I wells, and the configuration of the geobuffer, liner system, and lower and upper boundaries of the waste. The cross sections also illustrate the model predicted post-construction steady state configuration of the water table. After landfill construction, the current recharge area and recharge rates to the shallow water table interval is effectively eliminated across the EMDF footprint. A narrow zone of open recharge to the undisturbed ground surface would remain post construction along the uppermost south facing slopes of Pine Ridge, but elsewhere across the EMDF site, ground water recharge will be greatly reduced to a very low infiltration rate on the order of 0.41 in. per year. The lowered post construction water table reflects the combination of the greatly reduced recharge area and extremely low recharge rates created by the low permeability cap/cover materials (enhanced by the lateral drainage diversion system in the cap/cover). In addition, the conceptual design and the model assume the EMDF underdrain system is functioning effectively to encourage and maintain natural ground water drainage below the landfill footprint. The combined effect is to lower and maintain the current naturally occurring water table to a much lower elevation that does not rise or encroach on the geobuffer, liner system, or waste.

It is also assumed that the ground water mound below the boot shaped spur ridge area below GW-976(I) would be effectively dewatered and reduced during landfill construction. The current conceptual design assumes that a sizable portion of the north side of the spur ridge would require excavation and grading for the placement of the underdrain along the main branch of NT-3, followed by placement of engineering fill, low permeability geobuffer clays, and the liner system. These elements are presented at the south end of cross section in Plate 3. The remaining undisturbed southerly section of the spur ridge would remain as a natural buttress along the southern edge of the landfill. Elsewhere across the EMDF footprint, the water table surface(s) mapped using the highest water table elevations from Phase I data remains below the bottom elevations of the geobuffer, providing ample vertical distance between the waste and the water table.

Surface water conditions associated with springs, seeps, and stream flow along the NTs at the EMDF site are consistent with those originally found at the adjacent EMWMF site and in similar upper watersheds elsewhere in BCV flowing across Conasauga Group formations. The stream channels at the EMDF are relatively small, even at their largest only 1–3 ft wide and a few inches deep. The Phase I results indicate continuous baseflow along the NT stream channels during the wet non-growing season, however, the flows are considered easily manageable during construction and would not place significant constraints on the engineering design for the EMDF. A properly designed and constructed underdrain system, along with surface water runoff controls during construction, and waste limits that are elevated well above base levels would ensure the long-term separation of waste materials from surface and shallow ground water.

The Phase I results do not conflict with the basic elements and configuration of the current conceptual design. Additional borings, wells, monitoring, and testing recommended for a more comprehensive and detailed Phase II investigation will provide additional data necessary for the detailed design of the EMDF.

## 8.3 RECOMMENDATIONS

Assuming the EMDF site is approved for CERCLA disposal, the Phase II site characterization would build on the baseline results from the Phase I investigation. The details of the Phase II site characterization will be formulated among the DOE, TDEC, and EPA in accordance with the data quality objectives (DQO) process which is designed to ensure that data are collected to meet specific needs of a project and end users of the data. DOE and DOE-support contractor(s) would develop preliminary DQOs and host DQO working sessions with the regulatory agencies to reach general agreement on the scope of the Phase II effort. Work plans would then be developed to document the detailed plans for the Phase II investigation and implementation schedule.

The results from ongoing Phase I surface water and ground water monitoring activities should continue to be plotted, analyzed, and periodically presented to project stakeholders. In particular, the future Phase I monitoring of ground water levels and runoff conditions during the coming warm growing season of 2015 warrant analysis and comparison with the current wet non-growing season when water levels and runoff are typically at their highest levels. Future Phase I results will provide data to verify ground water level declines and lower runoff conditions site-specific to the EMDF site that typically occur in the warm growing season.

The Phase II investigation of the proposed EMDF site may include the following general site investigation techniques and methods:

- Additional soil borings to further characterize regolith and bedrock conditions with soil samples and rock coring.
- Geotechnical sampling and field/laboratory testing.
- Soil/rock sampling for laboratory determinations of soil/water partition coefficients ($K_d$) for key contaminants of concern.
- Monitoring well clusters (shallow and intermediate) to define ground water conditions and hydraulic gradients.
- Test pits to characterize the nature and extent of alluvium/colluvium for underdrain design.
- Nested piezometers to evaluate spatial and temporal variations in vertical gradients and surface and ground water interactions along the NT-2/3 valleys.
- Subsurface testing to determine K, and ground water flux and gradients (e.g., conventional depth-discrete K tests such as slug and packer tests, and other borehole flow testing and borehole logging methods).
- Ground water monitoring (via continuous and/or other periodic synoptic measurements [e.g., weekly/monthly] of water levels or other parameters of interest).
- Surface water monitoring (via continuous and/or other periodic synoptic measurements [e.g., weekly/monthly] of water levels or other parameters of interest).
- Soil and ground water sampling and analyses for contaminants, both to ensure site suitability and as to establish background values. Detection limits must be below regulatory limits (e.g., Maximum Contaminant Levels [MCLs] for Preliminary Remediation Goals [PRGs]).

Specific recommendations for consideration in planning for a Phase II investigation include:

- Conduct continuous vertical sampling of regolith soils and saprolite in selected borings to characterize preferential pathways for fluid flow within the vadose and water table intervals above bedrock. Supplement those results with in-situ tests of K to more accurately define the range of K values within regolith materials.
- Consider retrofitting of the open hole intervals in the deeper Phase I well pairs (i.e., GW-970[I], GW-972[I], GW-974[I], GW-976[I]) with "bundled" or nested wells with small diameter casing (e.g., 1 in. or 2 in. diameter PVC) and short screen intervals (2.5 ft , 5 ft, or 10 ft) to more accurately determine vertical gradients across the open hole intervals in these wells (this is low cost, effective, and easily implemented).
- Employ more sensitive packer tests or other downhole methods capable of determining very low K values on the order of $10^{-6}$ to $10^{-8}$ cm/sec to develop vertical profiles of K for the open hole intervals of the Phase I intermediate level wells (and in similar Phase II wells).

- Conduct research into and implement available technologies for determining accurate K values in regolith and bedrock with a much greater level of sensitivity and accuracy, particularly those within or below the range of $10^{-6}$–$10^{-8}$ cm/sec or lower.
- If packer testing methodologies are employed they should be optimized for accurately determining very low flow injection rates well below 1 gpm, which may require flow monitoring devices more sensitive than those commonly employed by drilling companies.
- Consider the use of best available borehole video cameras with downward and sideward viewing options and variable lighting to identify and map the depth intervals of in-situ fracture zones conducive to ground water flow with open-hole sections of bedrock.
- In concert with use of those video cameras, consider rapid draw down of water levels in open holes with high flow rate pumps immediately followed by video logging to identify and film ground water flow from fractures directly into the uncased borehole. Subsequent borehole testing could be performed on those fracture intervals to determine K values from fractured water producing intervals.
- Consider the use of other best available methods and technologies for borehole surveying, testing, and geophysical logging (e.g., HydroPhysical™ logging by COLOG and other logging companies)
- Consider the use of the electromagnetic borehole flowmeter for vertical sequencing of K across the entire of open boreholes in bedrock. This instrument was developed by the Tennessee Valley Authority (Young and Pearson, 1995) and used in previous investigations on the ORR and is commercially available for use.
- Consider the use of ultrasonic drilling for continuous sampling/coring of regolith and bedrock intervals at selected locations across the EMDF site. This method can provide high quality samples/cores that offer advantages over other conventional drilling and sampling methods.
- Consider the acquisition and testing of samples for determination of site-specific partition coefficient ($K_d$) values. Reliable $K_d$ values are essential to accurate fate and transport modeling. Experts should be engaged in the process to ensure the proper collection of representative samples and appropriate methods for testing and reporting.

# 9. REFERENCES


DOE 1997. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*. DOE/OR.01-1455/V3&D2.

DOE 2013a. *Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal, Oak Ridge, Tennessee* DOE/OR/01-2535, D2 and previous DO/D1 versions.

DOE 2013b. *Limited Phase I Site Characterization Plan for the Proposed Environmental Management Disposal Facility Site as Requested by the Tennessee Department of Environment and Conservation* (October 22, 2013).

Bechtel 1984. *Report on Burial Grounds A and B Geology and Hydrogeology,* prepared by Bechtel Civil and Minerals, Inc., for Union Carbide.

BJC 1999. *Predesign Site Characterization Summary Report for the Environmental Management Waste Management Facility, Oak Ridge, Tennessee*, BJC/OR-255, prepared by Jacobs Environmental Management Team, Bechtel Jacobs Company, LLC (BJC), May 1999, Oak Ridge, TN.

Bouwer, H. and R.C. Rice, 1976. *A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells*, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Bouwer, H., 1989. *The Bouwer and Rice slug test--an update*, Ground Water, vol. 27, no. 3, pp. 304-309.

CH2MHill 2000. *Phase IV Final Site Investigation Report, SSRS Item No. 3.3, Rev.1*, for the Environmental Management Waste Management Facility, prepared by CH2MHill Constructors, Inc, under contract to Waste Management Federal Services, Inc., for Bechtel Jacobs Company LLC, Oak Ridge, Tennessee, March 2000.

Clapp, R.B. 1997. *Estimating Groundwater Recharge to the Shale Aquifers in Eastern Tennessee Using a Topography-based, Water-Budget Model*, Abstracts from the Seventh Tennessee Water Resources Symposium and Student Symposium, Nashville, Tennessee, February 1997.

Clapp, R. B, 1998. *Chapter 5.1 – Water Balance Modeling* – in Environmental Sciences Division Groundwater Program Office Report for Fiscal Years 1995-1997, ORNL/GWPO-027.

Hatcher et al, 1992. *Status Report on the Geology of the Oak Ridge Reservation,* Environmental Sciences Division, Publication No. 3860; ORNL/TM-12074.

Ketelle, R.H. and Lee, R.R. 1992. *Migration of a Groundwater Contaminant Plume by Stratabound Flow in Waste Area Grouping 1 at Oak Ridge National Laboratory, Oak Ridge, Tennessee,* ORNL/ER-126.

King, H.L: and Haase, C.S. 1987. *Subsurface-Controlled Geological Maps for the Y-12 Plant and Adjacent Areas of Bear Creek Valley,* ORNL/TM-10112.

Ladd, D.E. and Law, G.S. 2007 *Tennessee StreamStats: A Web-enabled Geographic Information System Application for Automating the Retrieval and Calculation of Streamflow Statistics:* U.S. Geological Survey Fact Sheet 2007-3081, 2p.

Law, G.S. and Tasker, G.D., 2003. *Flood-frequency prediction methods for unregulated streams of Tennessee, 2000:* U.S. Geological Survey Scientific Investigations Report 03-4176, p. 79.

Lietzke, D.A., Lee, S.Y., and Lambert, R.E. 1988. *Soils, Surficial Geology, and Geomorphology of the Bear Creek Valley Low-Level Waste Disposal Development, and Demonstration Program Site,* ORNL/TM-10573.

Lee, R.R. and Ketelle, R.H. 1989. *Geology of the West Bear Creek Site,* ORNL/TM-10887.

Robinson, J.A. and Mitchell III, R. L. 1996. *Gaining, Losing, and Dry Stream Reaches at Bear Creek Valley, Oak Ridge, Tennessee March and September 1994*. U.S.G.S. Open-File Report 96-557.

Robinson, J.A. and Johnson, G.C. 1995. *Results of a Seepage Investigation at Bear Creek Valley, Oak Ridge, Tennessee January through September 1994*. U.S.G.S. Open-File Report 95-459.

Ogden 1993a. *Geotechnical Study, ORR Storage Facility, Site "C", Y-12 Plant, Oak Ridge, Tennessee,* Contract No. 88B-99977V, Release C-53, prepared by Ogden Environmental and Energy Services, May 20, 1993, for Martin Marietta Energy Systems, Inc.

Ogden 1993b. *Geotechnical Study, ORR Storage Facility, Site "B", Y-12 Plant, Oak Ridge, Tennessee,* Contract No. 88B-99977V, Release C-53, prepared by Ogden Environmental and Energy Services, May 7, 1993, for Martin Marietta Energy Systems, Inc.

ORNL (Oak Ridge National Laboratory) 1997. *Performance Assessment for the Class L-II Disposal Facility,* ORNL/TM-13401.

Solomon, D.K., G.K. Moore, L.E. Toran, R.B. Dreier, and W.M. McMaster. 1992. *Status Report: A Hydrologic Framework for the Oak Ridge Reservation,* ORNL/TM-12026.

UCOR (URS/CH2M Oak Ridge LLC) 2013. *Engineering Feasibility Plan for the Elevated Groundwater Levels in the vicinity of PP-01*, EMWMF, Oak Ridge, Tennessee, October 2013, UCOR-4517 *Levels in the vicinity of PP-01*, EMWMF, Oak Ridge, Tennessee, October 2013, UCOR-4517.

USGS (U.S. Geological Survey) 1996. *Borehole Geophysical Logging for Water-Resources Investigations in Pennsylvania*, USGS Fact Sheet 218-95 (FS-218-95), April 1996.

Young, S. C. and Pearson, H. S. 1995. *The Electromagnetic Borehole Flowmeter: Description and Application*. Ground Water Monitoring Review, National Ground Water Association, Fall 1995.

Zlotnick, V., 1994. *Interpretation of slug and packer tests in anisotropic aquifers*, Ground Water, vol. 32, no. 5, pp. 761-766.

# EXHIBIT A.1:
# TDEC TRIP REPORT – JULY 2014
# ALTERNATIVE PROPOSED LOCATION
# FOR GW-968(I)/GW-969(S)

This page intentionally left blank.

**Tennessee Department of Environment and Conservation**
**DOE-Oversight**
**Environmental Monitoring Section**
**Trip Report**

**Trip Date:** 7/29/2014 **By:** Wesley White

**Location:** EMDF

**Purpose of Visit:** Perform site walk over to look at and discuss the alternate well location

**Persons Contacted**: Christopher Wieland, Bill Wilder

**TDEC Personnel Present:** Sid Jones
Wesley White

**Pro2Serve Personnel Present:** Bill Wilder
Christopher Wieland

**DOE Personnel Present:** Steven Clemons

Sid Jones and Wesley White from the DOE Oversight Office met with Christopher Wieland, Bill Wilder, and Steven Clemons at the proposed EMDF site on 7/29/2014. The purpose of the meeting was to discuss moving the proposed wells on Pine Ridge to an area accessible to the current drilling contractor within the allocated budget for this project.

We walked to the proposed alternate location and discussed some of the hazards and benefits of having a well pair (shallow and deep well) there. Then we walked to the initial proposed location along Pine Ridge. We discussed the need for a well in the Rome Formation. In this discussion we looked at DOE's current budget, the shortfall in funding this year, and the various options of getting hydrogeologic information in the Rome Formation.

It was brought up that at GW-918, which is upgradient of EMWMF, exhibits very little seasonal variation with water elevations, yet nearby at GW-946, GW-947, GW-948 and GW-951 there are seasonal variations in water elevations. It is expected that along Pine Ridge, seasonal variations should be pronounced and the possibility for the lack of variations could be GW-918 is acting as a "bath tub" where water is coming in and exiting at a certain elevation above a non-transmissive geologic layer. However, another possibility is that GW-918 is connected to a source or reservoir of groundwater and the layered sandstones in the Rome formations could be that reservoir. During sampling of GW-918, the well has good yield and does not go dry, and the well's construction does not lend itself to a classic "bath tub" well. Thus, it appears there may be a reservoir of

groundwater for GW-918 and as such there may be a reservoir of groundwater above the proposed EMDF facility.

Therefore, Sid and Wes discussed the need for such a well and pushed to see if there were funding options or any reallocations that could be made with Steven Clemons. Unfortunately with the current budget cycle, that is not an option. In fact, it would be a problem to even exceed the planned drilling footage that was scoped for the initial phase.

With the limitations of drilling footage and current funding, and an understanding that groundwater may be deeper than 100 feet along Pine Ridge an alternate location would be needed. The options presented were to either scrap the initial location or to move the initial location to an alternate location and during the second phase of the project get the additional hydrogeologic information at the beginning of that phase. We acknowledge that more hydrogeologic information is better. Therefore, the alternate location was acceptable under this scenario.

**Prepared by:** Wesley White **Date: 7/31/2014**
**CC: HLC___JDR___RCB ___**

# EXHIBIT A.2:
# DOCUMENTATION FOR RADIOLOGICAL SCREENING

This page intentionally left blank.

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409090723 | **Count Date:** | 9/9/2014 7:23:34AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3437 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-972
Box #1

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140909072334-G1 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140909074215-G2 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140909074425-G3 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140909074645-G4 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140909074855-G5 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |

**Reviewed by:** _____ 9/9/14



Print Date 9/9/2014
Print Time 7:51:12AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409090755 | **Count Date:** | 9/9/2014 7:55:34AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3438 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-972
Box #2

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140909075534-G1 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |
| 20140909075824-G2 | Unknown | -0.30 | 0.35 | 5.74 | 7.13 | 4.66 | 13.89 |
| 20140909080034-G3 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140909080244-G4 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140909080454-G5 | Unknown | 1.05 | 1.39 | 5.73 | -4.85 | 1.30 | 14.01 |

**Reviewed by:** 9/9/14



Print Date 9/9/2014
Print Time 8:07:21AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409100721 | **Count Date:** | 9/10/2014 7:21:45AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3442 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-972
Box #3

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140910072145-G1 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140910074026-G2 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140910074236-G3 | Unknown | 1.05 | 1.39 | 5.73 | -3.16 | 2.14 | 14.01 |
| 20140910074456-G4 | Unknown | 1.05 | 1.39 | 5.74 | 1.91 | 3.62 | 14.01 |

**Reviewed by:** _____ 9/10/14



Print Date 9/10/2014
Print Time 7:47:13AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409100821 | **Count Date:** | 9/10/2014 8:21:56AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3443 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-972
Box #4

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140910082156-G1 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140910082616-G2 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140910082826-G3 | Unknown | 1.05 | 1.39 | 5.74 | 5.29 | 4.34 | 14.01 |
| 20140910083036-G4 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |

**Reviewed by:** 9/10/14



Print Date 9/10/2014
Print Time 8:32:54AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409110718 | **Count Date:** | 9/11/2014 7:18:52AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3448 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-972
Box #5

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140911071852-G1 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140911073732-G2 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140911073942-G3 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140911074152-G4 | Unknown | 2.40 | 1.94 | 5.74 | 5.14 | 4.34 | 14.17 |

**Reviewed by:** _____ 9/11/14



Print Date 9/11/2014
Print Time 7:44:09AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409110747 | **Count Date:** | 9/11/2014 7:47:29AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3449 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-912
Box #6

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140911074729-G1 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140911075019-G2 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |

**Reviewed by:** AL C 9/11/14

Page 1 of 1

Print Date 9/11/2014
Print Time 7:52:36AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409171336 | **Count Date:** | 9/17/2014 1:36:05PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3462 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-976
Box #1

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140917133605-G3 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140917135435-G4 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140917135655-G5 | Unknown | 1.05 | 1.39 | 5.74 | 1.91 | 3.62 | 14.01 |
| 20140917135905-G6 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140917140115-G7 | Unknown | -0.30 | 0.35 | 5.74 | 7.13 | 4.66 | 13.89 |
| 20140917140335-G8 | Unknown | -0.29 | 0.35 | 5.73 | -4.70 | 1.30 | 13.89 |

**Reviewed by:** _____ 9/17/14



Print Date 9/17/2014
Print Time 2:05:52PM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409171507 | **Count Date:** | 9/17/2014 3:07:49PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3463 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-976
Box #F 2

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140917150749-G1 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140917151210-G2 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140917151420-G3 | Unknown | 1.05 | 1.39 | 5.74 | 5.29 | 4.34 | 14.01 |
| 20140917151630-G4 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140917151840-G5 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140917152100-G6 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140917152310-G7 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140917152520-G8 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140917152740-G9 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |

**Reviewed by:** 9/17/14



Print Date 9/17/2014
Print Time 3:29:57PM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409171533 | **Count Date:** | 9/17/2014 3:33:08PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3464 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

GW-476
Box #3

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140917153308-G1 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140917153559-G2 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140917153809-G3 | Unknown | 1.05 | 1.39 | 5.73 | -1.47 | 2.72 | 14.01 |
| 20140917154019-G4 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140917154229-G5 | Unknown | 1.05 | 1.39 | 5.73 | 0.22 | 3.21 | 14.01 |
| 20140917154449-G6 | Unknown | 1.05 | 1.39 | 5.73 | -1.47 | 2.72 | 14.01 |

**Reviewed by:** _____ 9/17/14



Print Date 9/17/2014
Print Time 3:47:06PM

# Sample Report

| | | | | | |
|---|---|---|---|---|---|
| **Batch ID:** | Smears - 201409171558 | GW-976 | **Count Date:** | 9/17/2014 | 3:58:18PM |
| **Group:** | G | | **Count Minutes:** | 2.00 | |
| **Device:** | ESH Tennelec 1 | Box #4 | **Count Mode:** | Simultaneous | |
| **Batch Key:** | 3466 | | **Operating Volts:** | 1410 | |
| **Selected Geometry** | 5/16" Stainless Steel | | | | |

| Background (cpm) | | | Efficiency (%) | | | Spillover (%) | |
|---|---|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | | **Alpha:** | 37.05 ± 0.18 | | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | | **Beta:** | 29.57 ± 0.23 | | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140917155818-G1 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140917160119-G2 | Unknown | 1.05 | 1.39 | 5.74 | 5.29 | 4.34 | 14.01 |
| 20140917160329-G3 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140917160539-G4 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140917160759-G5 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |

**Reviewed by:** 9/17/14



Print Date 9/17/2014
Print Time 4:10:16PM

# Sample Report

| | | | | | |
|---|---|---|---|---|---|
| **Batch ID:** | Smears - 201409171612 | GW-976 | **Count Date:** | 9/17/2014 | 4:12:13PM |
| **Group:** | G | | **Count Minutes:** | 2.00 | |
| **Device:** | ESH Tennelec 1 | Box # 5 | **Count Mode:** | Simultaneous | |
| **Batch Key:** | 3467 | | **Operating Volts:** | 1410 | |
| **Selected Geometry** | 5/16" Stainless Steel | | | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140917161213-G1 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140917161503-G2 | Unknown | -0.30 | 0.35 | 5.76 | 18.97 | 6.46 | 13.89 |

**Reviewed by:** _____ 9/17/14



Print Date 9/17/2014
Print Time 4:17:20PM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409181101 | **Count Date:** | 9/18/2014 11:01:33AM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3473 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140918110133-G1 | Unknown | -0.30 | 0.35 | 5.75 | 10.52 | 5.24 | 13.89 |
| 20140918110554-G2 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140918110804-G3 | Unknown | 1.05 | 1.39 | 5.73 | 0.22 | 3.21 | 14.01 |
| 20140918111014-G4 | Unknown | 1.05 | 1.39 | 5.75 | 10.37 | 5.24 | 14.01 |
| 20140918111234-G5 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140918111444-G6 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140918111654-G7 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |
| 20140918111904-G8 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140918112124-G9 | Unknown | 1.05 | 1.39 | 5.74 | 1.91 | 3.62 | 14.01 |
| 20140918112334-G10 | Unknown | -0.30 | 0.35 | 5.74 | 7.13 | 4.66 | 13.89 |
| 20140918112544-G11 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |
| 20140918112804-G12 | Unknown | 1.05 | 1.39 | 5.74 | 1.91 | 3.62 | 14.01 |
| 20140918113014-G13 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140918113224-G14 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140918113434-G15 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140918113654-G16 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140918113904-G17 | Unknown | -0.30 | 0.35 | 5.75 | 8.83 | 4.96 | 13.89 |
| 20140918114114-G18 | Unknown | 2.40 | 1.94 | 5.74 | 5.14 | 4.34 | 14.17 |
| 20140918114334-G19 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140918114544-G20 | Unknown | 2.40 | 1.94 | 5.74 | 6.83 | 4.66 | 14.17 |

Marooka

**Reviewed by:** _____



Print Date 9/18/2014
Print Time 11:48:01AM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409181323 | **Count Date:** | 9/18/2014 1:23:27PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3475 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140918132327-G1 | Unknown | 1.05 | 1.39 | 5.74 | 5.29 | 4.34 | 14.01 |
| 20140918132747-G2 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140918132957-G3 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140918133207-G4 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140918133427-G5 | Unknown | 2.40 | 1.94 | 5.73 | -3.31 | 2.14 | 14.17 |
| 20140918133637-G6 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140918133847-G7 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140918134057-G8 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140918134317-G9 | Unknown | -0.30 | 0.35 | 5.73 | -3.01 | 2.13 | 13.89 |
| 20140918134527-G10 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140918134737-G11 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |
| 20140918134947-G12 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140918135207-G13 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140918135417-G14 | Unknown | -0.30 | 0.35 | 5.74 | 7.13 | 4.66 | 13.89 |
| 20140918135627-G15 | Unknown | -0.30 | 0.35 | 5.73 | -1.32 | 2.72 | 13.89 |
| 20140918135847-G16 | Unknown | 1.05 | 1.39 | 5.74 | 1.91 | 3.62 | 14.01 |
| 20140918140057-G17 | Unknown | 1.05 | 1.39 | 5.74 | 3.60 | 4.00 | 14.01 |
| 20140918140307-G18 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |
| 20140918140517-G19 | Unknown | -0.30 | 0.35 | 5.74 | 3.75 | 4.00 | 13.89 |
| 20140918140737-G20 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |

Red Drill Rig

**Reviewed by:**



Print Date 9/18/2014
Print Time 2:09:55PM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409181203 | **Count Date:** | 9/18/2014 12:03:39PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3474 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140918120339-G1 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |

Shelby tube

**Reviewed by:** _____



Print Date 9/18/2014
Print Time 12:06:36PM

## HEALTH PHYSICS
## MATERIAL TRANSFER CLEARANCE

TAG NUMBER: GT 303923

### SURVEY INFORMATION

| BUILDING | ROOM NO. |
|---|---|
| EMDF | N/A |

| REQUESTED BY | DIVISION |
|---|---|
| Aliant | |

### DESCRIPTION OF MATERIAL/REMARKS

Center Probe, Acoustic Centralizer, Case, Televiewer Probe, Televiewer Centralizer, Case

### SURFACE CONTAMINATION

| | | CHECK IF NONE DETECTED |
|---|---|---|
| MAX. FIXED+REMOVABLE ALPHA | dpm/100cm$^2$ | [X] |
| REMOVABLE ALPHA | dpm/100cm$^2$ | [X] |
| MAX. FIXED+REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | [X] |
| REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | [X] |

### HEALTH PHYSICS INSTRUMENTS USED

| Alpha Instrument I.D. | Beta/Gamma Instrument I.D. |
|---|---|
| 855/669 | 853/913 |

### SURVEY COMPLETED

| DATE | BY (NAME and BADGE NUMBER) |
|---|---|
| 10/1/14 | Howard 140777 |

VOID AFTER: 90 DAYS

UCN-148 (123 7-94)

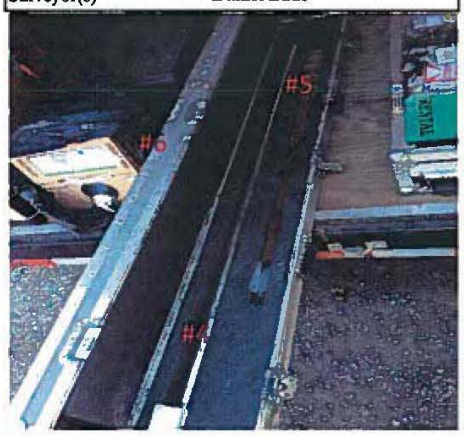
# ES&H Survey Form

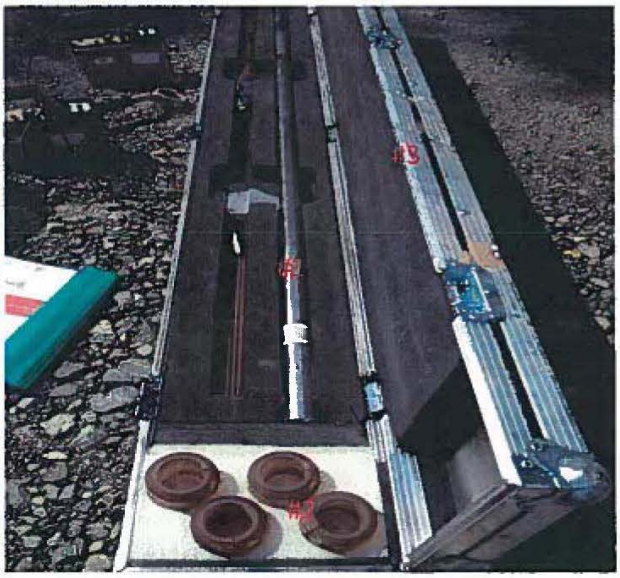
| | Instrument ID# | Probe ID# | Calibration Due Date | Probe Geometry | Static Count Time (minute(s) | Background | Efficiency | MDA dpm/100cm² |
|---|---|---|---|---|---|---|---|---|
| Alpha | 855 | 669 | 1/8/2015 | 1.2 | 1 | 4 | 25% | 49 |
| Beta | 853 | 913 | 1/30/2015 | 0.15 | 2 | 105 | 15% | 1126 |

**Direct & Removable (Smears) Results**

| Map Point | Gross Alpha c/ 1 m | Net Alpha c/ 1 m | Alpha DPM dpm/100cm² | Gross Beta c/ 2 m | Net Beta c/ 2 m | Beta DPM dpm/100cm² | Smear # |
|---|---|---|---|---|---|---|---|
| 1 | 3 | -1 | -3 | 94 | -11 | -244 | 1 |
| 2 | 7 | 3 | 10 | 85 | -20 | -444 | 2 |
| 3 | 3 | -1 | -3 | 96 | -9 | -200 | 3 |
| 4 | 0 | -4 | -13 | 103 | -2 | -44 | 4 |
| 5 | 2 | -2 | -7 | 103 | -2 | -44 | 5 |
| 6 | 10 | 6 | 20 | 107 | 2 | 44 | 6 |
| | | | | | | | |
| | | | | A | | | |
| | | | N | | | | |
| | | | | | | | |

| | |
|---|---|
| Equipment | Various Equipment |
| Serial # | |
| Green Tag # | 303923 |
| Date | 10/1/2014 |
| Surveyor(s) | Daniel Edds |




Calculations by: Seth Howard Date: 10/1/2014 Comments: Smear results attached.

Reviewed by: Seth Howard Date: 10/1/14

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201409301557 | **Count Date:** | 9/30/2014 3:57:27PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3513 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20140930155727-G1 | Unknown | -0.30 | 0.35 | 5.74 | 2.06 | 3.62 | 13.89 |
| 20140930160018-G2 | Unknown | 1.05 | 1.39 | 5.73 | -4.85 | 1.30 | 14.01 |
| 20140930160228-G3 | Unknown | 2.40 | 1.94 | 5.73 | -3.31 | 2.14 | 14.17 |
| 20140930160438-G4 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140930160648-G5 | Unknown | -0.30 | 0.35 | 5.73 | 0.37 | 3.20 | 13.89 |
| 20140930160908-G6 | Unknown | 1.05 | 1.39 | 5.74 | 5.29 | 4.34 | 14.01 |

S.H. S.H.

**Reviewed by:** _____



Print Date 9/30/2014
Print Time 4:11:25PM

# Sample Report

| | | | | | |
|---|---|---|---|---|---|
| **Batch ID:** | Smears - 201410061415 | EMDF GW-968 plastic smear | **Count Date:** | 10/6/2014 | 2:15:56PM |
| **Group:** | G | | **Count Minutes:** | 2.00 | |
| **Device:** | ESH Tennelec 1 | | **Count Mode:** | Simultaneous | |
| **Batch Key:** | 3525 | | **Operating Volts:** | 1410 | |
| **Selected Geometry** | 5/16" Stainless Steel | | | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20141006141556-G1 | Unknown | 1.05 | 1.39 | 5.75 | 13.75 | 5.76 | 14.01 |

**Reviewed by:** Charles W Sloff



**Print Date** 10/6/2014
**Print Time** 2:18:34PM

# Sample Report

| | | | | | |
|---|---|---|---|---|---|
| **Batch ID:** | Smears - 201410061412 | EmDF GW-474 plastic smear | **Count Date:** | 10/6/2014 | 2:12:44PM |
| **Group:** | G | | **Count Minutes:** | 2.00 | |
| **Device:** | ESH Tennelec 1 | | **Count Mode:** | Simultaneous | |
| **Batch Key:** | 3524 | | **Operating Volts:** | 1410 | |
| **Selected Geometry** | 5/16" Stainless Steel | | | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20141006141244-G1 | Unknown | -0.30 | 0.35 | 5.74 | 5.44 | 4.34 | 13.89 |

**Reviewed by:** Chad W Sloff



Print Date 10/6/2014
Print Time 2:15:41PM

# Sample Report

| | | | | | |
|---|---|---|---|---|---|
| **Batch ID:** | Smears - 201410061340 | EMDF GW-476 plastic | **Count Date:** | 10/6/2014 | 1:40:09PM |
| **Group:** | G | | **Count Minutes:** | 2.00 | |
| **Device:** | ESH Tennelec 1 | | **Count Mode:** | Simultaneous | |
| **Batch Key:** | 3522 | | **Operating Volts:** | 1410 | |
| **Selected Geometry** | 5/16" Stainless Steel | | | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20141006134009-G1 | Unknown | 1.05 | 1.39 | 5.75 | 10.37 | 5.24 | 14.01 |

**Reviewed by:** Charles W Sasser



Print Date 10/6/2014
Print Time 1:58:56PM

# Sample Report

| | | | | | |
|---|---|---|---|---|---|
| **Batch ID:** | Smears - 201410061408 | EMDF | **Count Date:** | 10/6/2014 | 2:08:28PM |
| **Group:** | G | GW-972 | **Count Minutes:** | 2.00 | |
| **Device:** | ESH Tennelec 1 | | **Count Mode:** | Simultaneous | |
| **Batch Key:** | 3523 | Plastic Smear | **Operating Volts:** | 1410 | |
| **Selected Geometry** | 5/16" Stainless Steel | | | | |

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20141006140828-G1 | Unknown | 3.75 | 2.36 | 5.75 | 10.06 | 5.24 | 14.32 |

**Reviewed by:** _____



Print Date 10/6/2014
Print Time 2:11:26PM

# Sample Report

| | | | |
|---|---|---|---|
| **Batch ID:** | Smears - 201410061424 | **Count Date:** | 10/6/2014 2:24:17PM |
| **Group:** | G | **Count Minutes:** | 2.00 |
| **Device:** | ESH Tennelec 1 | **Count Mode:** | Simultaneous |
| **Batch Key:** | 3527 | **Operating Volts:** | 1410 |
| **Selected Geometry** | 5/16" Stainless Steel | | |

EMDF
GW-970
plastic smear

| Background (cpm) | | Efficiency (%) | | Spillover (%) | |
|---|---|---|---|---|---|
| **Alpha Rate:** | 0.11 ± 0.13 | **Alpha:** | 37.05 ± 0.18 | **Alpha to Beta:** | 8.90 |
| **Beta Rate:** | 1.40 ± 0.38 | **Beta:** | 29.57 ± 0.23 | **Beta to Alpha:** | 0.05 |

| Sample ID | Sample Type | Alpha (dpm) | Unc | Alpha MDA (dpm) | Beta (dpm) | Unc | Beta MDA (dpm) |
|---|---|---|---|---|---|---|---|
| 20141006142417-G1 | Unknown | 1.05 | 1.39 | 5.75 | 8.67 | 4.96 | 14.01 |

**Reviewed by:** Charles W Schaff



**Print Date** 10/6/2014
**Print Time** 2:27:15PM

# EXHIBIT A.3:
# LABORATORY RESULTS OF SHELBY TUBE SAMPLES

This page intentionally left blank.

# Particle Size Distribution Report

| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 15.4 | 5.8 | 8.8 | 19.5 | 26.5 | 24.0 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | | GW969 | 1.0-3.0 | 09/29/14 | CL | Clay, silty (decomposed shale), brown, mottled gray w/rock | 15.5 | 29 | 20 |
| | | UD1 | | | | | | | |

Client Alliant Corporation

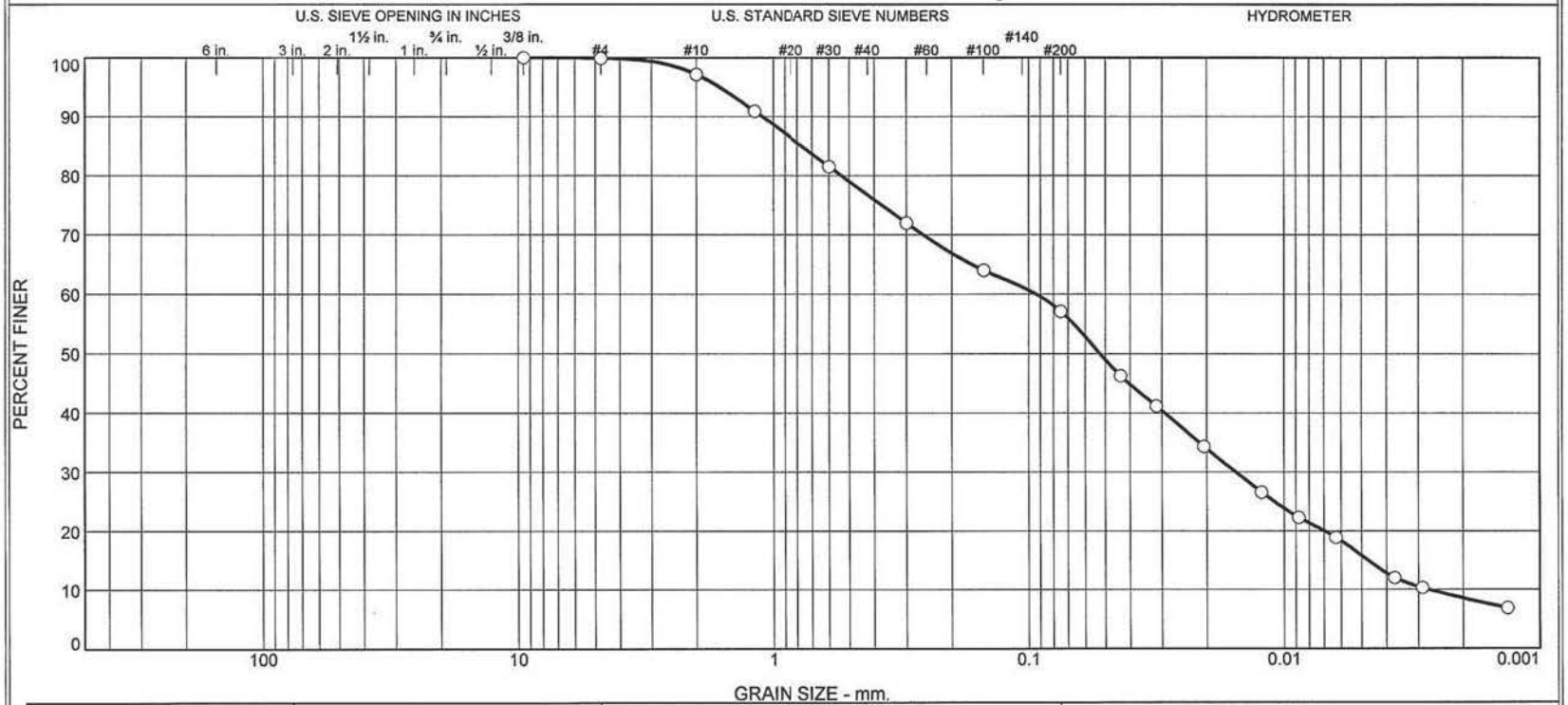
Project EMDF Phase I Site Characterization

Project No. 14055011.00 | Figure

**Geo/Environmental Associates, Inc. Knoxville, Tennessee**

○ Specific Gravity : 2.68

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.1 | 2.7 | 20.5 | 19.6 | 41.3 | 15.8 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | | GW971 | 17.0-19.0 | 09/23/14 | CL | Clay, silty (decomposed shale), brown, maroon, mottled | 20.0 | 34 | 22 |
| | | UD1 | | | | | | | |

Client Alliant Corporation

Project EMDF Phase I Site Characterization

Project No. 14055011.00 | Figure

**Geo/Environmental Associates, Inc.**
**Knoxville, Tennessee**

○ Specific Gravity : 2.73

# Particle Size Distribution Report

| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 16.5 | 18.3 | 24.0 | 7.2 | 25.8 | 8.2 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | | GW973 | 2.0-4.0 | 09/29/14 | SC | Clay, silty (decomposed to weathered shale), brown, brown to | 21.2 | 34 | 24 |
| | | UD1 | | | | brownish red | | | |

Client Alliant Corporation

Project EMDF Phase I Site Characterization

Project No. 14055011.00 Figure

**Geo/Environmental Associates, Inc. Knoxville, Tennessee**

○ Specific Gravity : 2.71

# Particle Size Distribution Report

| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 2.2 | 17.1 | 21.7 | 29.0 | 8.6 | 14.0 | 7.4 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | | GW975 | 7.0-8.5 | 10/03/14 | SC | Clay, silty (decomposed to weathered shale), light brown, brown, | 15.0 | 32 | 22 |
| | | UD1 | | | | mottled | | | |

Client Alliant Corporation

Project EMDF Phase I Site Characterization

Project No. 14055011.00 | Figure

**Geo/Environmental Associates, Inc.**
**Knoxville, Tennessee**

○ Specific Gravity : 2.71

# Particle Size Distribution Report

| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 18.1 | 19.9 | 25.9 | 7.7 | 15.8 | 12.6 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | | GW977 | 10.0-10.66 | 09/29/14 | SC | Clay, silty (decomposed to weathered shale), light brown, brown, mottled | 12.2 | 30 | 20 |
| | | UD1 | | | | | | | |

Client Alliant Corporation

Project EMDF Phase I Site Characterization

Project No. 14055011.00 Figure

**Geo/Environmental Associates, Inc. Knoxville, Tennessee**

○ Specific Gravity : 2.70

Geo/Environmental Associates, Inc.
3502 Overlook Circle • Knoxville, TN 37909 • 865-584-0344 • Fax 865-584-0778 • www.geoe.com

# CONSTANT HEAD PERMEABILITY TESTING
# ASTM D5084

**PROJECT NAME** : EMDF Phase I Site Characterization **PROJECT NUMBER** : 14055011.00

**CLIENT** : Alliant Corporation **DATE** : October 01, 2014

## SAMPLE LOCATION AND CONDITIONS

**Sample Id.:** GW969-UD-1 **Sample Depth :** 1.0-3.0

**Sample Remolded:** No **Sample Type :** In Situ

**Sample Description :** Clay, silty (decomposed shale), brown, mottled gray w/rock

## INITIAL SPECIMEN PROPERTIES

| | | | | | |
|---|---|---|---|---|---|
| **Length (in.):** | 3.39 | **Volume ($ft^3$):** | 0.01260 | **Wet Density (PCF):** | 135.1 |
| **Diameter (in.):** | 2.86 | **Weight (lbs):** | 1.702 | **Dry Density (PCF):** | 117.0 |
| **Area ($ft^2$):** | 0.04461 | **Moisture (%):** | 15.5 | | |

## PERMEABILITY CALCULATIONS

k = Hydraulic Conductivity, (cm/sec)

$$k = \frac{QL}{Ath} = \text{cm/sec}$$

L = Length of Sample, along path of flow, (cm)

Q = Quantity of flow, taken as the average of inflow and outflow, ($cm^3$)

$$= \frac{(128.4)(8.61)}{(41.45)(324{,}600)(211.01)}$$

A = Cross-sectional area of specimen, ($cm^2$)

$$= \frac{1{,}105.52}{2{,}839{,}069{,}916.70}$$

t = Interval of time, over which the flow Q occurs, (sec)

h = Difference in hydraulic head across specimen, (cm)

$$= 3.89 \times 10^{-7} \text{ cm/sec}$$

Geo/Environmental Associates, Inc.
3502 Overlook Circle • Knoxville, TN 37909 • 865-584-0344 • Fax 865-584-0778 • www.geoe.com

# CONSTANT HEAD PERMEABILITY TESTING
# ASTM D5084

**PROJECT NAME** : EMDF Phase I Site Characterization

**PROJECT NUMBER** : 14055011.00

**CLIENT** : Alliant Corporation

**DATE** : September 24, 2014

## SAMPLE LOCATION AND CONDITIONS

**Sample Id.:** GW971-UD-1

**Sample Depth :** 17.0-19.0

**Sample Remolded:** No

**Sample Type :** In Situ

**Sample Description :** Clay, silty (decomposed shale), brown, maroon, mottled

## INITIAL SPECIMEN PROPERTIES

| | | | | | |
|---|---|---|---|---|---|
| **Length (in.):** | 4.22 | **Volume ($ft^3$):** | 0.01580 | **Wet Density (PCF):** | 130.7 |
| **Diameter (in.):** | 2.87 | **Weight (lbs):** | 2.064 | **Dry Density (PCF):** | 108.9 |
| **Area ($ft^2$):** | 0.04493 | **Moisture (%):** | 20.0 | | |

## PERMEABILITY CALCULATIONS

k = Hydraulic Conductivity, (cm/sec)

$$k = \frac{QL}{Ath} = \text{cm/sec}$$

L = Length of Sample, along path of flow, (cm)

$$= \frac{(211.6)(10.72)}{(41.74)(405{,}000)(211.01)}$$

Q = Quantity of flow, taken as the average of inflow and outflow, ($cm^3$)

A = Cross-sectional area of specimen, ($cm^2$)

$$= \frac{2{,}268.35}{3{,}567{,}060{,}747.00}$$

t = Interval of time, over which the flow Q occurs, (sec)

h = Difference in hydraulic head across specimen, (cm)

$$= 6.36 \times 10^{-7} \text{ cm/sec}$$

*Geo/Environmental Associates, Inc.*

3502 Overlook Circle • Knoxville, TN 37909 • 865-584-0344 • Fax 865-584-0778 • www.geoe.com

# CONSTANT HEAD PERMEABILITY TESTING
# ASTM D5084

**PROJECT NAME** : EMDF Phase I Site Characterization **PROJECT NUMBER** : 14055011.00

**CLIENT** : Alliant Corporation **DATE** : October 03, 2014

## SAMPLE LOCATION AND CONDITIONS

**Sample Id.:** GW973-UD-1 **Sample Depth :** 2.0-4.0

**Sample Remolded:** No **Sample Type :** In Situ

**Sample Description :** Clay, silty (decomposed to weathered shale), brown, brown to brownish red

## INITIAL SPECIMEN PROPERTIES

| | | | | | |
|---|---|---|---|---|---|
| **Length (in.):** | 3.35 | **Volume ($ft^3$):** | 0.01254 | **Wet Density (PCF):** | 130.9 |
| **Diameter (in.):** | 2.87 | **Weight (lbs):** | 1.642 | **Dry Density (PCF):** | 108.0 |
| **Area ($ft^2$):** | 0.04493 | **Moisture (%):** | 21.2 | | |

## PERMEABILITY CALCULATIONS

k = Hydraulic Conductivity, (cm/sec)

$$k = \frac{QL}{Ath} = \text{cm/sec}$$

L = Length of Sample, along path of flow, (cm)

$$= \frac{(289.2)(8.51)}{(41.74)(79,200)(211.01)}$$

Q = Quantity of flow, taken as the average of inflow and outflow, ($cm^3$)

$$= \frac{2,461.09}{697,558,546.08}$$

A = Cross-sectional area of specimen, ($cm^2$)

t = Interval of time, over which the flow Q occurs, (sec)

h = Difference in hydraulic head across specimen, (cm)

$$= 3.53 \times 10^{-6} \text{ cm/sec}$$

Geo/Environmental Associates, Inc.

3502 Overlook Circle • Knoxville, TN 37909 • 865-584-0344 • Fax 865-584-0778 • www.geoe.com

# CONSTANT HEAD PERMEABILITY TESTING
# ASTM D5084

**PROJECT NAME** : EMDF Phase I Site Characterization **PROJECT NUMBER** : 14055011.00

**CLIENT** : Alliant Corporation **DATE** : October 03, 2014

## SAMPLE LOCATION AND CONDITIONS

**Sample Id.:** GW975-UD-1 **Sample Depth :** 7.0-8.5

**Sample Remolded:** No **Sample Type :** In Situ

**Sample Description :** Clay, silty (decomposed to weathered shale), light brown, brown, mottled

## INITIAL SPECIMEN PROPERTIES

| | | | | | |
|---|---|---|---|---|---|
| **Length (in.):** | 3.38 | **Volume ($ft^3$):** | 0.01265 | **Wet Density (PCF):** | 134.1 |
| **Diameter (in.):** | 2.87 | **Weight (lbs):** | 1.697 | **Dry Density (PCF):** | 116.7 |
| **Area ($ft^2$):** | 0.04493 | **Moisture (%):** | 15.0 | | |

## PERMEABILITY CALCULATIONS

k = Hydraulic Conductivity, (cm/sec)

$$k = \frac{QL}{Ath} = \text{cm/sec}$$

L = Length of Sample, along path of flow, (cm)

$$= \frac{(500.0)(8.59)}{(41.74)(74{,}580)(211.01)}$$

Q = Quantity of flow, taken as the average of inflow and outflow, ($cm^3$)

$$= \frac{4{,}295.00}{656{,}867{,}630.89}$$

A = Cross-sectional area of specimen, ($cm^2$)

t = Interval of time, over which the flow Q occurs, (sec)

$$= 6.54 \times 10^{-6} \text{ cm/sec}$$

h = Difference in hydraulic head across specimen, (cm)

Geo/Environmental Associates, Inc.
3502 Overlook Circle • Knoxville, TN 37909 • 865-584-0344 • Fax 865-584-0778 • www.geoe.com

# CONSTANT HEAD PERMEABILITY TESTING
# ASTM D5084

**PROJECT NAME** : EMDF Phase I Site Characterization

**PROJECT NUMBER** : 14055011.00

**CLIENT** : Alliant Corporation

**DATE** : October 01, 2014

## SAMPLE LOCATION AND CONDITIONS

**Sample Id.:** GW977-UD-1

**Sample Depth :** 10.0-10.66

**Sample Remolded:** No

**Sample Type :** In Situ

**Sample Description :** Clay, silty (decomposed to weathered shale), light brown, brown, mottled

## INITIAL SPECIMEN PROPERTIES

| | | | | | |
|---|---|---|---|---|---|
| **Length (in.):** | 3.10 | **Volume ($ft^3$):** | 0.01161 | **Wet Density (PCF):** | 129.4 |
| **Diameter (in.):** | 2.87 | **Weight (lbs):** | 1.502 | **Dry Density (PCF):** | 115.3 |
| **Area ($ft^2$):** | 0.04493 | **Moisture (%):** | 12.2 | | |

## PERMEABILITY CALCULATIONS

k = Hydraulic Conductivity, (cm/sec)

$$k = \frac{QL}{Ath} = \text{cm/sec}$$

L = Length of Sample, along path of flow, (cm)

$$= \frac{(500.0)(7.87)}{(41.74)(88{,}740)(211.01)}$$

Q = Quantity of flow, taken as the average of inflow and outflow, ($cm^3$)

$$= \frac{3{,}935.00}{781{,}582{,}643.68}$$

A = Cross-sectional area of specimen, ($cm^2$)

t = Interval of time, over which the flow Q occurs, (sec)

h = Difference in hydraulic head across specimen, (cm)

$$= 5.03 \times 10^{-6} \text{ cm/sec}$$

# EXHIBIT A.4:
# PHASE I BORING LOGS

This page intentionally left blank.

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 10 FT
DEPTH DRILLED INTO ROCK: 90 FT
TOTAL DEPTH OF HOLE: 100 FT

ALLIANT

# DRILLING LOG
# GW-968

DATE HOLE STARTED: 09-03-14
DATE HOLE COMPLETED: 09-10-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

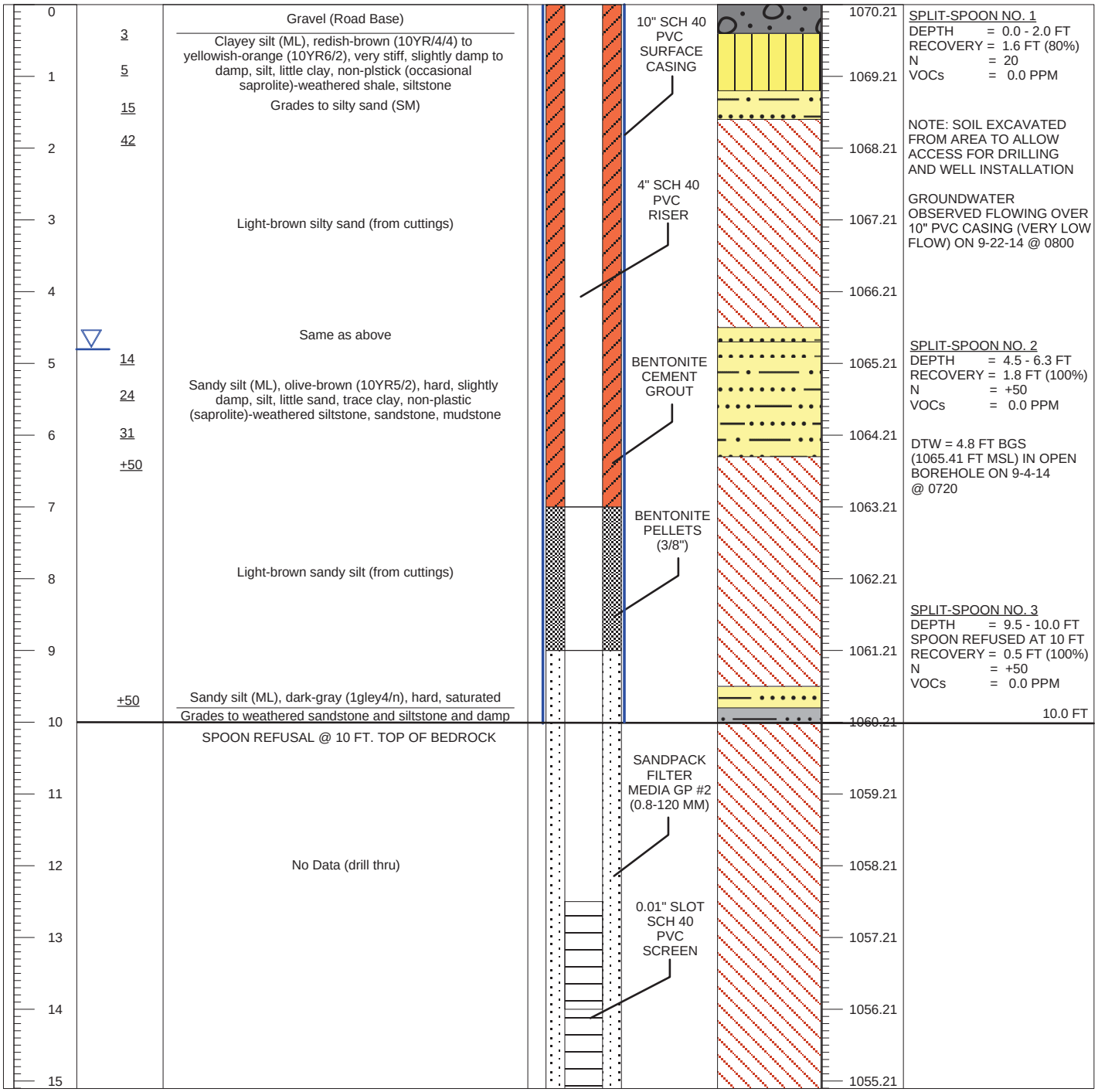
TOTAL NO. OF OVERBURDEN SAMPLES:
3 DISTURBED 0 UNDISTURBED

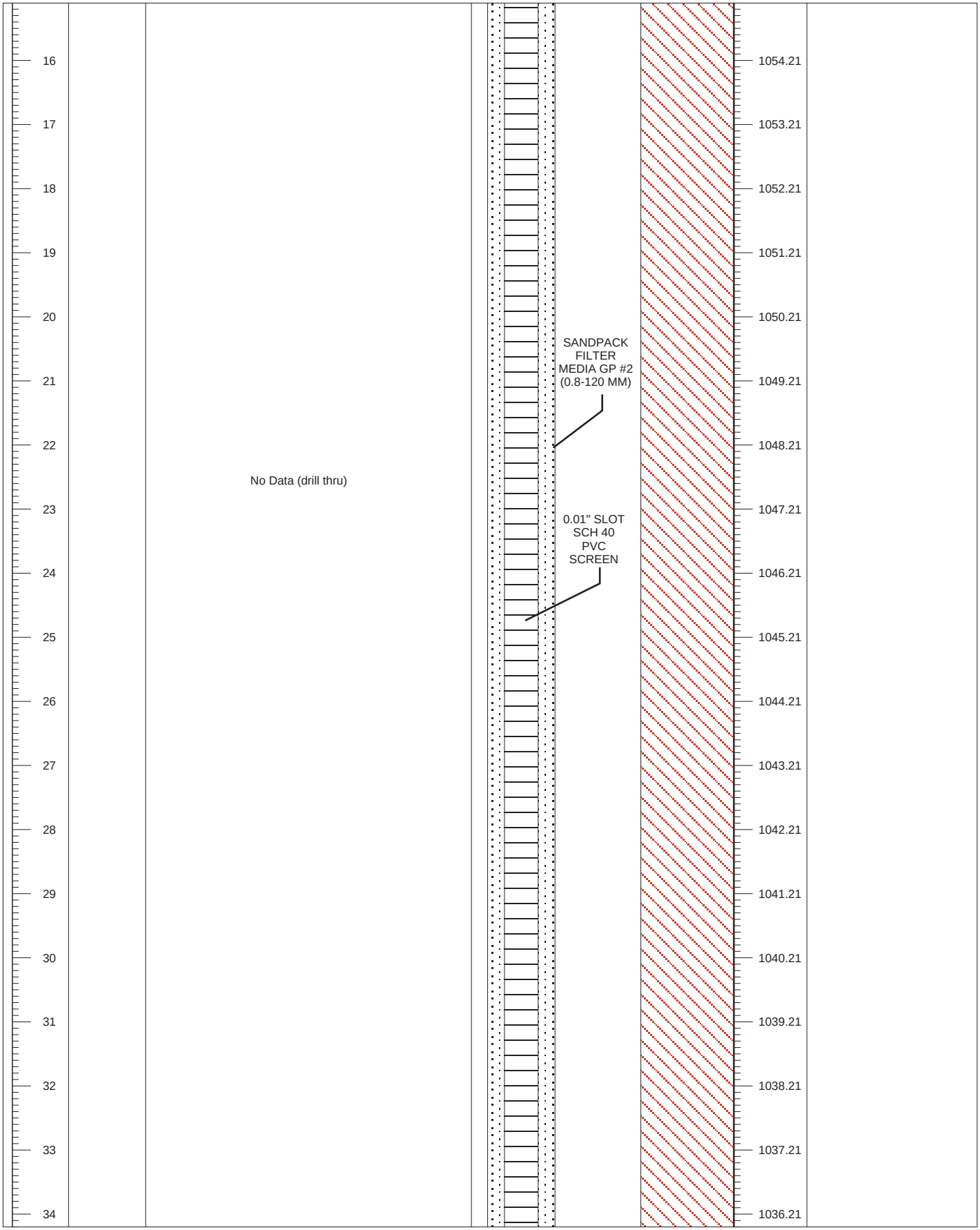
TOTAL NO. OF CORE BOXES: 0

ELEVATION OF GROUNDWATER:
1065.41 FT ON 9/4/14 (OPEN BOREHOLE)

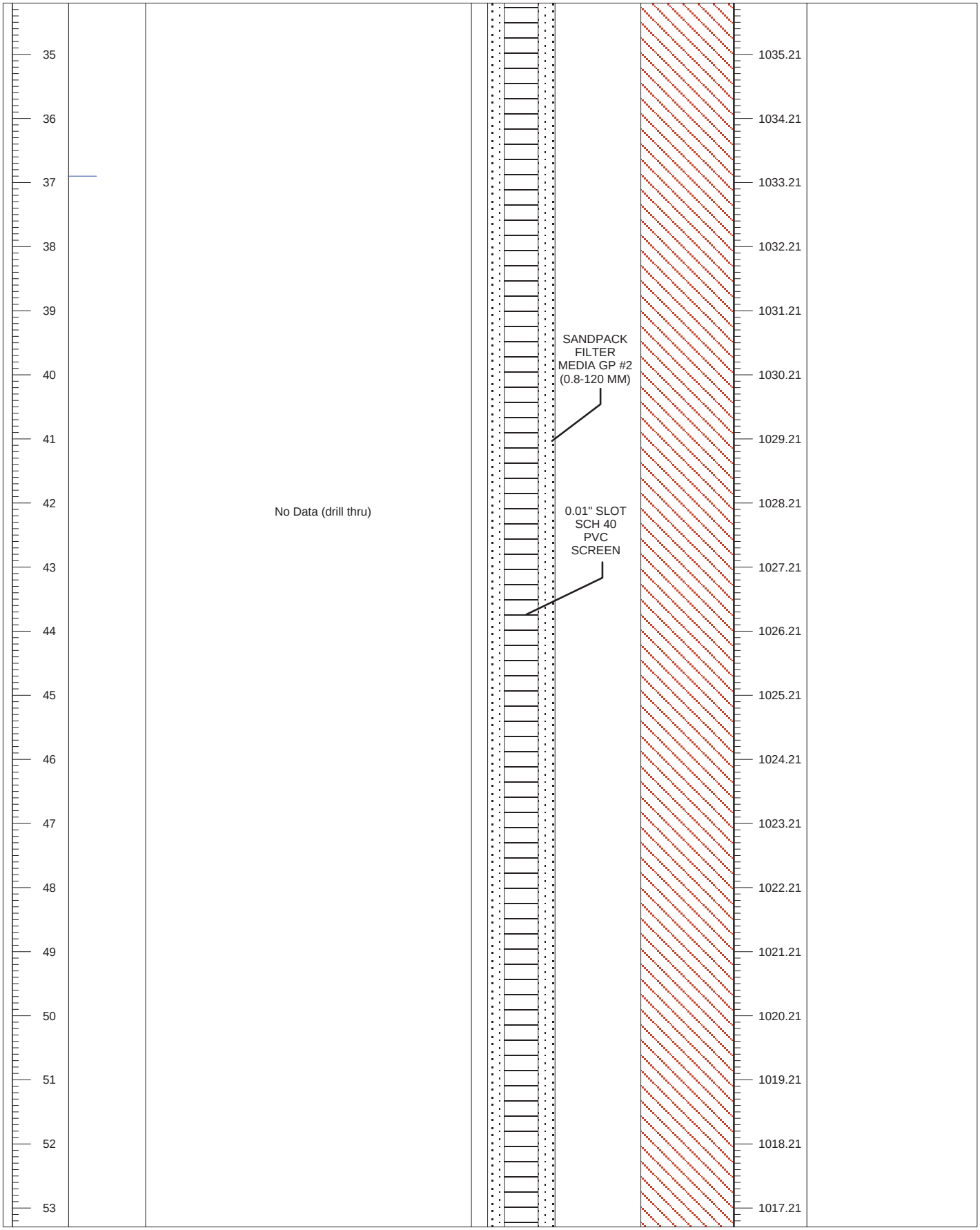
ELEVATION TOP OF HOLE: 1070.21 FT

TOTAL CORE RECOVERY: NOT APPLICABLE

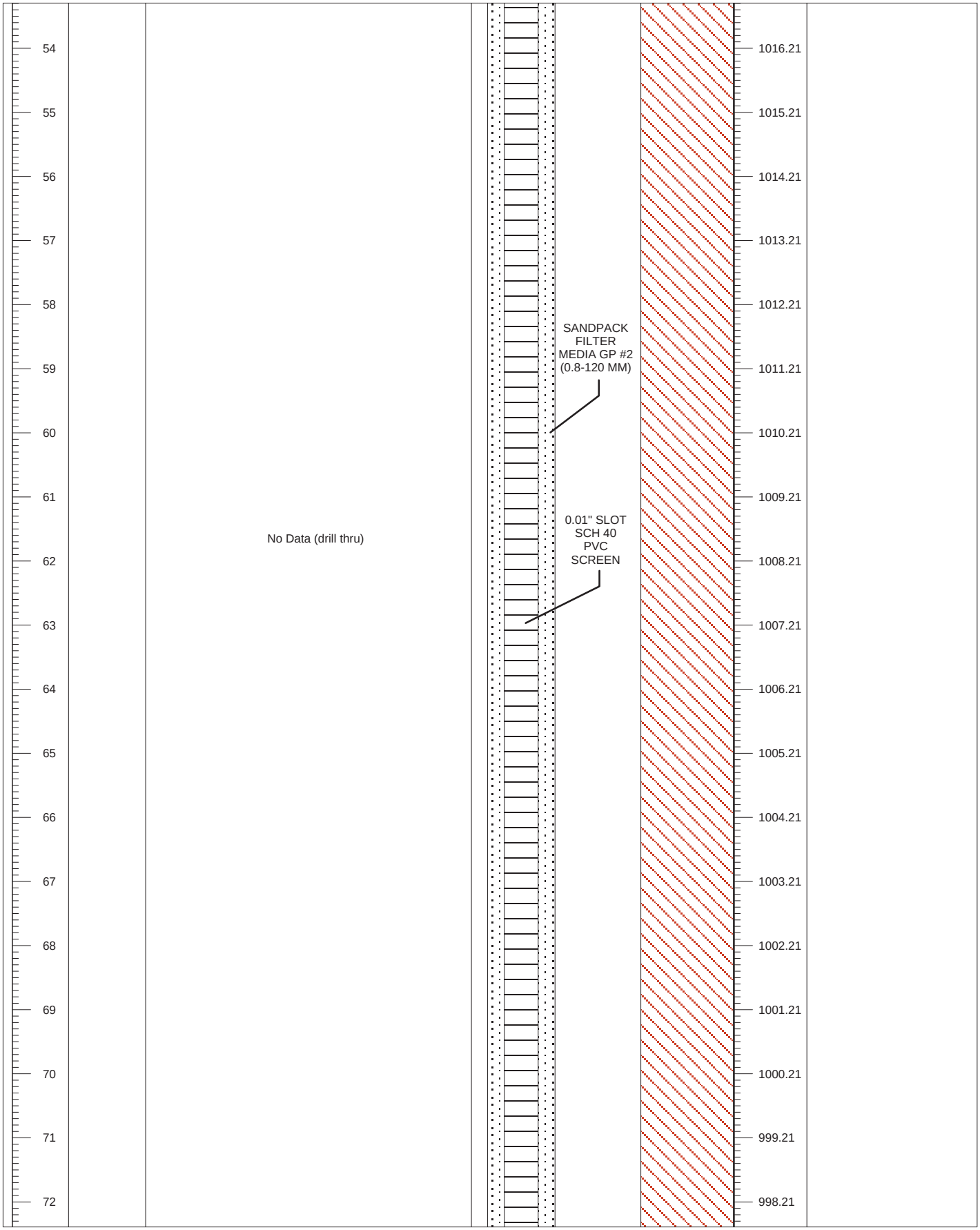



16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
1054.21
1053.21
1052.21
1051.21
1050.21
1049.21
1048.21
1047.21
1046.21
1045.21
1044.21
1043.21
1042.21
1041.21
1040.21
1039.21
1038.21
1037.21
1036.21
No Data (drill thru)
SANDPACK FILTER MEDIA GP #2 (0.8-120 MM)
0.01" SLOT SCH 40 PVC SCREEN

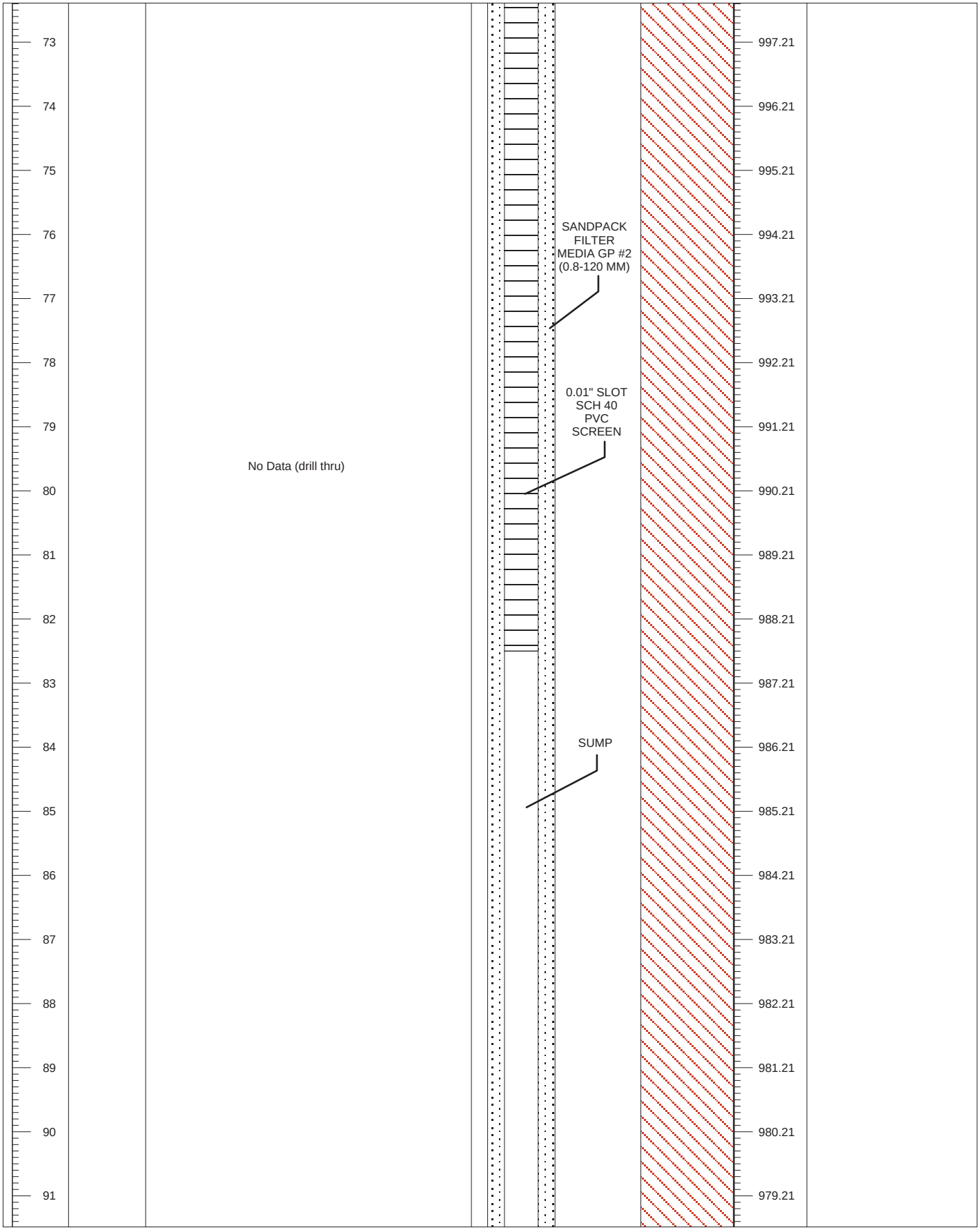
**GW-968** **2 of 6**


35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
1035.21
1034.21
1033.21
1032.21
1031.21
1030.21
1029.21
1028.21
1027.21
1026.21
1025.21
1024.21
1023.21
1022.21
1021.21
1020.21
1019.21
1018.21
1017.21
No Data (drill thru)
SANDPACK FILTER MEDIA GP #2 (0.8-120 MM)
0.01" SLOT SCH 40 PVC SCREEN

**GW-968** **3 of 6**


54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
1016.21
1015.21
1014.21
1013.21
1012.21
1011.21
1010.21
1009.21
1008.21
1007.21
1006.21
1005.21
1004.21
1003.21
1002.21
1001.21
1000.21
999.21
998.21
No Data (drill thru)
SANDPACK FILTER MEDIA GP #2 (0.8-120 MM)
0.01" SLOT SCH 40 PVC SCREEN

**GW-968** **4 of 6**


73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
997.21
996.21
995.21
994.21
993.21
992.21
991.21
990.21
989.21
988.21
987.21
986.21
985.21
984.21
983.21
982.21
981.21
980.21
979.21
No Data (drill thru)
SANDPACK FILTER MEDIA GP #2 (0.8-120 MM)
0.01" SLOT SCH 40 PVC SCREEN
SUMP

**GW-968** **5 of 6**

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 10 FT
DEPTH DRILLED INTO ROCK: 90 FT
TOTAL DEPTH OF HOLE: 100 FT

ALLIANT

# DRILLING LOG
# GW-968

DATE HOLE STARTED: 09-03-14
DATE HOLE COMPLETED: 09-10-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
3 DISTURBED 0 UNDISTURBED

TOTAL NO. OF CORE BOXES: 0

ELEVATION OF GROUNDWATER:
1065.41 FT ON 9/4/14 (OPEN BOREHOLE)

ELEVATION TOP OF HOLE: 1070.21 FT

TOTAL CORE RECOVERY: NOT APPLICABLE

| DEPTH (FT) | BLOWS | DESCRIPTION | WELL CONST. | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|---|
| 92 | | No Data (drill thru) | END CAP (92.6') | | 978.21 | |
| 93 | | | Total Well Depth 92.6 FT | | 977.21 | |
| 94 | | | Borehole Collapse @ 92.6-100' | | 976.21 | |
| 95 | | | | | 975.21 | |
| 96 | | | | | 974.21 | NOTE: BORING REAMED TO 10 FT BGS WITH AIR ROTARY (14" BIT) ON 9-8-14 @ 1324 TO SET 10" PVC CASING. HOLE DRILLED TO 100 FT BGS WITH 7 7/8" AIR ROTARY ON 9-10-14 @ 1500. INSTALLED PVC MONITORING WELL (DOUBLE-CASED) WITH 4", 70 FT SCREEN (12.5 TO 82.5 FT), 10 FT SUMP AND 0.1 FT END CAP TO A TOTAL DEPTH OF 92.6 FT BGS. WELL COMPLETED ON 12-23-2014 |
| 97 | | | | | 973.21 | |
| 98 | | | | | 972.21 | |
| 99 | | | | | 971.21 | |
| 100 | | | | | 970.21 | 100 FT |

## GW-968 LEGEND

- Clayey silt
- Silty sand/Sandy Silt
- Gravel
- Saprolite
- No data

1. HOLE NUMBER GW-968

| DRILLING LOG<br>For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 2. DIVISION<br>N/A | 3. INSTALLATION<br>Y-12 | SHEET 1<br>OF 2 SHEETS |
|---|---|---|---|
| 4. PROJECT<br>EMDF Phase 1 | | 13. SIZE AND TYPE OF BIT 4 1/4" ID H. Stem Auger; 7 7/8" A.Rotary | |
| | | 14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*<br>MSL | |
| 5. LOCATION *(Coordinates or Station)*<br>N 31535.57; E 48979.13 | | 15. MANUFACTURERS DESIGNATION OF DRILL<br>HSA - Diedrick 120; A. Rotary - Schramm T450 | |
| 6. DRILLING AGENCY<br>M&W Drilling | | 16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN<br>a. DISTURBED 3 / b. UNDISTURBED 0 | |
| 7. HOLE NUMBER *(as shown on drawing title and title number)*<br>GW-968 | | 17. TOTAL NUMBER CORE BOXES N/A | |
| 8. NAME OF DRILLER Garry Akins (H. Stem Auger)<br>George Akins (Air Rotary) | | 18. ELEVATION GROUND WATER 1065.41 ft on 9-4-14 | |
| 9. DIRECTION OF HOLE<br>[X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT. | | 19. DATE HOLE *(YYYYMMDD)*<br>a. STARTED 2014-09-03 / b. COMPLETED 2014-09-10 | |
| 10. THICKNESS OF OVERBURDEN 10 ft | | 20. ELEVATION TOP OF HOLE *(feet)* 1070.21 ft | |
| 11. DEPTH DRILLED INTO ROCK 90 ft | | 21. TOTAL CORE RECOVERY FOR BORING % N/A | |
| 12. TOTAL DEPTH OF HOLE 100 ft | | 22. SIGNATURE OF INSPECTOR<br>R.Stout / J. Strader | |

| 23. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | | Gravel (road base) 0.4' | % | | Note:Location as shown in Work Plan |
| | 3 | | Clayey Silt (ML) redish-brown (10yr4/4) to yellowish-orange (10yr6/2), very stiff, slightly damp to damp, silt, little clay, non-plastic (occasional saprolite)-weathered shale, siltstone, grades to silty sand (SM) last 0.4 ft of spoon | | Spoon 1 | Split-spoon 0-2 ft<br>Recovery = 1.6 ft<br>VOCs = 0.0<br>N=20 |
| | 5 | 1 | | % | | |
| | 15 | | | % | | |
| | 42 | 2 | | | | 2.0' |
| | | | | % | | |
| | | 3 | Silty sand (light brown) (from Cuttings) | % | | |
| | | | | % | | |
| | | 4 | | % | | |
| | | | Same as above (0.2 ft) 4.7' | | | DTW = 4.8' bgs in open hole on 9-4-14 @ 720 |
| | | 5 | | | | |

ENG FORM 1836, MAR 1971 PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)* PROJECT HOLE NUMBER GW-968 VERSION 1.0

| DRILLING LOG (Continuation Sheet) For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 1. ELEVATION TOP OF HOLE 1070.21 ft | 2. HOLE NUMBER GW-968 | SHEET 2 OF 2 SHEETS |
|---|---|---|---|
| 3. PROJECT EMDF Phase 1 | | 4. INSTALLATION Y-12 | |

| 5. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS (Description) | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS (Drilling Time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | 14<br>24<br>31<br>+50 | 6 | Sandy silt (ML), Olive-brown (10yr5/2), hard, slightly damp, silt, little sand, trace clay, non-plastic (saprolite)- weathered siltstone, sandstone, mudstone | % | Spoon 2 | Split-spoon 4.5-6.3 ft<br>Refused @ 6.3 ft<br>Recovery = 1.8 ft<br>VOCs = 0.0<br>N=+50<br>6.3' |
| | | 7 | Light brown sand silt (from cuttings) | | | |
| | | 8 | | | | |
| | | 9 | | | | |
| | +50 | 10 | Sandy silt (ML), dark grey (1Gley4/n), hard, saturated, grades to weathered sandstone and siltstone last 0.2 ft (damp)<br>BOH | 10.0' | Spoon 3 | Split-spoon 9.5-10.0 ft<br>Spoon Refused @ 10.0 ft<br>Recovery = 0.5 ft<br>VOCs = 0.0<br>N=+50 10.0'<br>Note: Boring reamed to 10 ft w/ Air Rotary (14" bit) on 9-8-14 @ 1324. Set 10" PVC Casing. Hole drilled to 100 ft with 7 7/8" Air Rotary on 9-10-14 @ 1500 |

| ENG FORM 1836A, JUN 1967 | PREVIOUS EDITIONS ARE OBSOLETE. (Translucent) | 6. PROJECT EMDF Phase 1 | 7. HOLE NUMBER GW-968 |
|---|---|---|---|

VERSION 1.0

1. HOLE NUMBER

**DRILLING LOG**
For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG.

| | |
|---|---|
| 2. DIVISION | |
| 3. INSTALLATION | Y-12 |
| SHEET | 1 |
| OF | 1 SHEETS |
| 4. PROJECT | EMDF Phase 1 |
| 5. LOCATION *(Coordinates or Station)* | N 31539.77; E 48968.13 |
| 6. DRILLING AGENCY | M&W DRILLING |
| 7. HOLE NUMBER *(as shown on drawing title and title number)* | GW-969 |
| 8. NAME OF DRILLER | M&W DRILLING GEORGE AKINS |
| 9. DIRECTION OF HOLE | [X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT. |
| 10. THICKNESS OF OVERBURDEN | 13.5 FT |
| 11. DEPTH DRILLED INTO ROCK | 0 |
| 12. TOTAL DEPTH OF HOLE | 13.5 FT |
| 13. SIZE AND TYPE OF BIT | 10" O.D. H.S.A. |
| 14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* | MSL |
| 15. MANUFACTURERS DESIGNATION OF DRILL | MOBILE B-59 |
| 16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN | a. DISTURBED 0 / b. UNDISTURBED 1 |
| 17. TOTAL NUMBER CORE BOXES | N/A |
| 18. ELEVATION GROUND WATER | 1068.48 FT on 2014-10-2 |
| 19. DATE HOLE *(YYYYMMDD)* | a. STARTED 2014-09-25 / b. COMPLETED 2014-09-25 |
| 20. ELEVATION TOP OF HOLE *(feet)* | 1070.45 FT |
| 21. TOTAL CORE RECOVERY FOR BORING % | N/A |
| 22. SIGNATURE OF INSPECTOR | JACK STRADER |

| 23. ELEVATION | a. DEPTH | b. LEGEND | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | 4 | } Gravel, Shelby Tube from 1-3 ft | % | | 66% recovery on Shelby tube |
| | | 8 | For soil description, see Drilling Log from GW-968 | % | | -Driller advised soil too hard for Shelby tube recovery deeper than 4 ft |
| | | 12 | 13.5' | % | | |
| | | 16 | BOH | % | | Terminated on weathered shale @ 13.5 FT (Auger refusal) |
| | | | | % | | |
| | | | | % | | |
| | | | | % | | |
| | | | | % | | |

**ENG FORM 1836, MAR 1971** PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

PROJECT: EMDF Phase 1 | HOLE NUMBER: GW-969

VERSION 1.0

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 25.6 FT
DEPTH DRILLED INTO ROCK: 75.4 FT
TOTAL DEPTH OF HOLE: 101 FT

# ALLIANT

# DRILLING LOG

# GW-970

DATE HOLE STARTED: 08-27-14
DATE HOLE COMPLETED: 09-16-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
6 DISTURBED 0 UNDISTURBED

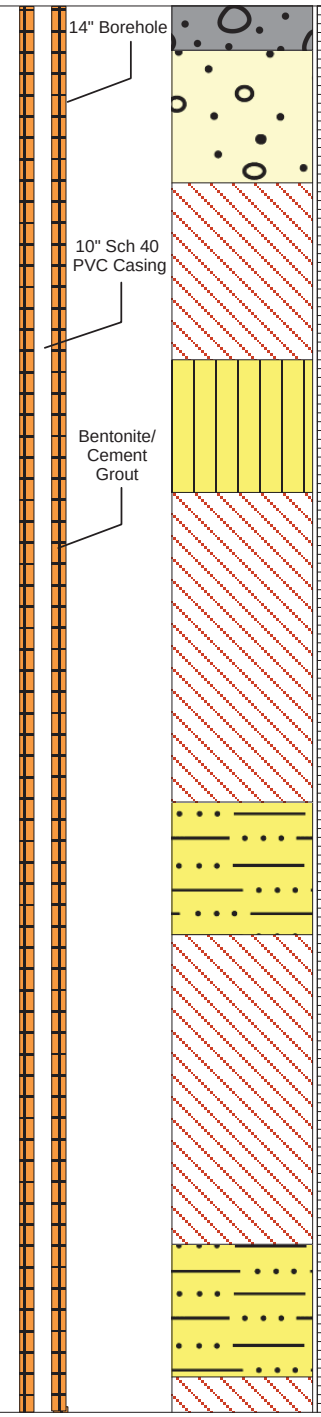
TOTAL NO. OF CORE BOXES: 0

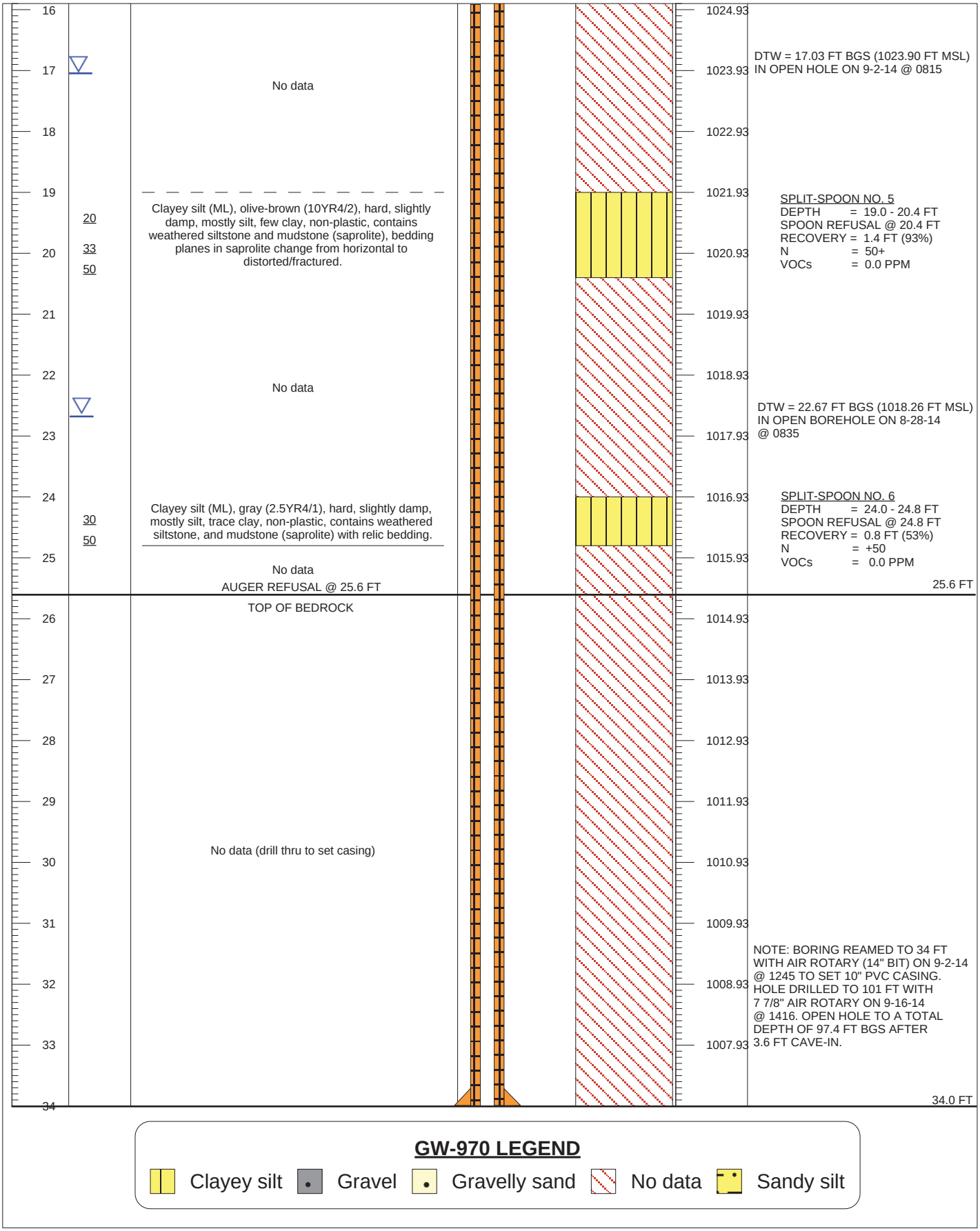
ELEVATION OF GROUNDWATER:
1018.26 FT ON 8/28/14 (OPEN BOREHOLE)

ELEVATION TOP OF HOLE: 1040.93 FT

TOTAL CORE RECOVERY: NOT APPLICABLE

| DEPTH (FT) | BLOWS | DESCRIPTION | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|
| 0 | | Gravel (Road Base) | 1040.93 | SPLIT-SPOON NO. 1<br>DEPTH = 0.5 - 2.0 FT<br>RECOVERY = 1.3 FT (87%)<br>N = 15<br>VOCs = 0.0 PPM |
| 1 | 5<br>7 | Gravelly sand (SP), yellow-orange (7.5YR5/6), stiff, damp, silt, trace medium sand, trace gravel, non-plastic | 1039.93 | |
| 2 | 8 | | 1038.93 | |
| 3 | | No data | 1037.93 | |
| 4 | 7 | Clayey silt (ML), red-brown (2.5YR5/2), very stiff, slightly damp, silt, little clay, trace coarse sand, trace medium sand, non-plastic, contains weathered mudstone, shale (saprolite) | 1036.93 | SPLIT-SPOON NO. 2<br>DEPTH = 4.0 - 5.5 FT<br>RECOVERY = 0.7 FT (47%)<br>N = 28<br>VOCs = 0.0 PPM |
| 5 | 14<br>14 | | 1035.93 | |
| 6 | | | 1034.93 | |
| 7 | | No data | 1033.93 | |
| 8 | | | 1032.93 | |
| 9 | 13 | Sandy silt (ML), gray-brown (10YR4/3), hard, damp, mostly silt, trace sand, trace fine gravel, non-plastic, weathered siltstone, shale, and sandstone (saprolite) | 1031.93 | SPLIT-SPOON NO. 3<br>DEPTH = 9.0 - 10.5 FT<br>RECOVERY = 1.5 FT (100%)<br>N = 58<br>VOCs = 0.0 PPM |
| 10 | 25<br>33 | | 1030.93 | |
| 11 | | | 1029.93 | |
| 12 | | No data | 1028.93 | |
| 13 | | | 1027.93 | |
| 14 | 12 | Sandy silt (ML), red-brown (10YR3/3), hard, damp, mostly silt, little fine sand, trace clay, non-plastic, weathered siltstone, mudstone, and sandstone (saprolite) | 1026.93 | SPLIT-SPOON NO. 4<br>DEPTH = 14.0 - 15.5 FT<br>RECOVERY = 1.5 FT (100%)<br>N = 64<br>VOCs = 0.0 PPM |
| 15 | 27<br>37 | | 1025.93 | |




16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
1024.93
1023.93
1022.93
1021.93
1020.93
1019.93
1018.93
1017.93
1016.93
1015.93
1014.93
1013.93
1012.93
1011.93
1010.93
1009.93
1008.93
1007.93
20
33
50
30
50
No data
Clayey silt (ML), olive-brown (10YR4/2), hard, slightly damp, mostly silt, few clay, non-plastic, contains weathered siltstone and mudstone (saprolite), bedding planes in saprolite change from horizontal to distorted/fractured.
No data
Clayey silt (ML), gray (2.5YR4/1), hard, slightly damp, mostly silt, trace clay, non-plastic, contains weathered siltstone, and mudstone (saprolite) with relic bedding.
No data
AUGER REFUSAL @ 25.6 FT
TOP OF BEDROCK
No data (drill thru to set casing)
DTW = 17.03 FT BGS (1023.90 FT MSL) IN OPEN HOLE ON 9-2-14 @ 0815
SPLIT-SPOON NO. 5
DEPTH = 19.0 - 20.4 FT
SPOON REFUSAL @ 20.4 FT
RECOVERY = 1.4 FT (93%)
N = 50+
VOCs = 0.0 PPM
DTW = 22.67 FT BGS (1018.26 FT MSL) IN OPEN BOREHOLE ON 8-28-14 @ 0835
SPLIT-SPOON NO. 6
DEPTH = 24.0 - 24.8 FT
SPOON REFUSAL @ 24.8 FT
RECOVERY = 0.8 FT (53%)
N = +50
VOCs = 0.0 PPM
25.6 FT
NOTE: BORING REAMED TO 34 FT WITH AIR ROTARY (14" BIT) ON 9-2-14 @ 1245 TO SET 10" PVC CASING. HOLE DRILLED TO 101 FT WITH 7 7/8" AIR ROTARY ON 9-16-14 @ 1416. OPEN HOLE TO A TOTAL DEPTH OF 97.4 FT BGS AFTER 3.6 FT CAVE-IN.
34.0 FT
GW-970 LEGEND
Clayey silt
Gravel
Gravelly sand
No data
Sandy silt

**GW-970** **2 of 2**

1. HOLE NUMBER GW-970

| DRILLING LOG<br>For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 2. DIVISION<br>N/A | 3. INSTALLATION<br>Y-12 | SHEET 1<br>OF 4 SHEETS |
|---|---|---|---|
| 4. PROJECT<br>EMDF Phase 1 | | 13. SIZE AND TYPE OF BIT 4 1/4" ID H. Stem Auger; 7 7/8" A.Rotary | |
| | | 14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*<br>MSL | |
| 5. LOCATION *(Coordinates or Station)*<br>N 31392.90; E 49568.45 | | 15. MANUFACTURERS DESIGNATION OF DRILL<br>HSA - Diedrick 120; A. Rotary - Schramm T450 | |
| 6. DRILLING AGENCY<br>M&W Drilling | | 16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN<br>a. DISTURBED 6 / b. UNDISTURBED 0 | |
| 7. HOLE NUMBER *(as shown on drawing title and title number)*<br>GW-970 | | 17. TOTAL NUMBER CORE BOXES N/A | |
| 8. NAME OF DRILLER Garry Akins (H. Stem Auger)<br>George Akins (Air Rotary) | | 18. ELEVATION GROUND WATER 1018.26 ft on 8-28-14 | |
| 9. DIRECTION OF HOLE<br>[X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT. | | 19. DATE HOLE *(YYYYMMDD)*<br>a. STARTED 2014-08-27 / b. COMPLETED 2014-09-16 | |
| 10. THICKNESS OF OVERBURDEN 25.6 ft | | 20. ELEVATION TOP OF HOLE *(feet)* 1040.93 ft | |
| 11. DEPTH DRILLED INTO ROCK 75.4 ft | | 21. TOTAL CORE RECOVERY FOR BORING % N/A | |
| 12. TOTAL DEPTH OF HOLE 101 ft | | 22. SIGNATURE OF INSPECTOR<br>R. Stout / J. Strader | |

| 23. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | | Gravel (road base) 0.5' | % | | Note:Location as shown in Work Plan |
| | 5<br>7<br>8 | 1<br>2 | Gravelly sand (SP) yellow-orange (7.5yr5/6), stiff, damp, trace medium sand, trace gravel, non-plastic | %<br>%<br>% | Spoon 1 | Split-spoon 0.5 - 2 ft<br>Recovery = 1.3 ft (87%)<br>VOCs = 0.0<br>N=15 |
| | | 3 | | % | | |
| | 7 | 4<br>5 | Clayey silt (ML), red-brown (2.5yr2.5/2), very stiff, slightly damp, silt, little clay, trace coarse sand, trace med sand, non-plastic, (saprolite) contains weathered mudstone, shale | %<br>% | Spoon 2 | Split-spoon 4 - 5.5 ft<br>Recovery = 0.7 ft (47%)<br>VOCs = 0.0<br>N=28 |

ENG FORM 1836, MAR 1971 PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)* | PROJECT | HOLE NUMBER GW-970 VERSION 1.0

| DRILLING LOG (Continuation Sheet) For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 1. ELEVATION TOP OF HOLE 1040.93 ft | 2. HOLE NUMBER GW-970 | SHEET 2 OF 4 SHEETS |
|---|---|---|---|
| 3. PROJECT EMDF Phase 1 | | 4. INSTALLATION Y-12 | |

| 5. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS (Description) | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS (Drilling Time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | 14 | | | % | | |
| | 14 | | | % | | |
| | | 6 | | % | | |
| | | | | % | | |
| | | 7 | | % | | |
| | | | | % | | |
| | | 8 | | % | | |
| | | | | % | | |
| | | 9 | Sandy silt (ML), gray-brown (10yr4/3), hard, damp, mostly silt, trace sand, trace fine gravel, non-plastic (saprolite)-weathered siltstone, shale, sandstone | % | Spoon 3 | Split-spoon 9-10.5 ft<br>Recovery = 1.5 ft (100%)<br>VOCs = 0.0<br>N=58 |
| | 13 | | | % | | |
| | 25 | 10 | | % | | |
| | 33 | | | % | | |
| | | 11 | | % | | |
| | | | | % | | |
| | | 12 | | % | | |

ENG FORM 1836A, JUN 1967 PREVIOUS EDITIONS ARE OBSOLETE. (Translucent)

6. PROJECT EMDF Phase 1

7. HOLE NUMBER GW-970

VERSION 1.0

| DRILLING LOG *(Continuation Sheet)* For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 1. ELEVATION TOP OF HOLE 1040.93 ft | 2. HOLE NUMBER GW-970 | SHEET 3 OF 4 SHEETS |
|---|---|---|---|
| 3. PROJECT | | 4. INSTALLATION | |

| 5. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | 13 | | % | | |
| | | | | % | | |
| | | 14 | Sandy silt (mL), red-brown (10yr3/3), hard, damp, mostly silt, little fine sand, trace clay, non-plastic (saprolite) contains weathered sandstone, siltstone, mudstone | % | Spoon 4 | Split-spoon 14-15.5 ft<br>Recovery = 1.5 ft (100%)<br>VOCs = 0.0<br>N=64 |
| | 12 | | | | | |
| | 27 | 15 | | % | | |
| | 37 | | | % | | |
| | | 16 | | % | | |
| | | | | % | | DTW= 17.03 ft bgs in open hole on 9-2-14 @ 0815 |
| | | 17 | | % | | |
| | | | | % | | |
| | | 18 | | % | | |
| | | | | % | | |
| | | 19 | Clayey silt (ML), olive-brown (10yr4/2), hard, slightly damp, mostly silt, few clay, non-plastic, (saprolite), contains weathered siltstone, mudstone, bedding planes change from horizontal to distorted/fractured. | % | Spoon 5 | Split-spoon 19-20.4 ft<br>Spoon Refusal @ 20.4 ft<br>Recovery = 1.4 ft (93%)<br>VOCs = 0.0<br>N=64 |
| | 20 | | | | | |
| | 33 | 20 | | % | | |

| ENG FORM 1836A, JUN 1967 | PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)* | 6. PROJECT EMDP Phase 1 | 7. HOLE NUMBER GW-970 |
|---|---|---|---|

VERSION 1.0

**DRILLING LOG** *(Continuation Sheet)*
For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG.

| 1. ELEVATION TOP OF HOLE | 2. HOLE NUMBER | SHEET |
|---|---|---|
| 1040.93 ft | GW-970 | 4 OF 4 SHEETS |

| 3. PROJECT | 4. INSTALLATION |
|---|---|
| EMDF Phase 1 | Y-12 |

| 5. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | 50 | | % | | |
| | | 21 | | % | | |
| | | | | % | | |
| | | 22 | | % | | Water level measured at 22.67 ft bgs on 8-28-14 |
| | | 23 | | % | | |
| | | | | % | | |
| | | 24 | Clayey Silt (ML), Gray (2.5yr4/1), hard slightly damp, mostly silt, trace clay, non-plastic, (saprolite), contains weathered siltstone and mudstone (relic bedding) | % | Spoon 6 | Split-spoon 24-24.8 ft<br>Auger refusal @ 24.8 ft<br>Recovery = 0.8 ft (53%)<br>VOCs = 0.0<br>N=50+ |
| | 30<br>50 | 25 | | % | | |
| | | | 25.6'<br>BOH | % | | Note: Boring reamed to 34 ft w/ Air Rotary (14" bit) on 9-2-14 @ 1245. Set 10" PVC Casing. Hole drilled to 101 ft with 7 7/8" Air Rotary on 9-16-14 @ 1416 |
| | | 26 | | % | | |
| | | | | % | | |
| | | 27 | | % | | |

**ENG FORM 1836A, JUN 1967** PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

| 6. PROJECT | 7. HOLE NUMBER |
|---|---|
| EMDF Phase 1 | GW-970 |

VERSION 1.0

1. HOLE NUMBER

**DRILLING LOG**
For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG.

2. DIVISION

3. INSTALLATION: Y-12

SHEET 1 OF 1 SHEETS

4. PROJECT: EMDF Phase 1

5. LOCATION *(Coordinates or Station)*: N 31392.01 E 49560.23

6. DRILLING AGENCY: M&W DRILLING

7. HOLE NUMBER *(as shown on drawing title and title number)*: GW-971

8. NAME OF DRILLER: GEORGE AKINS

9. DIRECTION OF HOLE: [X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT.

10. THICKNESS OF OVERBURDEN: 23.75

11. DEPTH DRILLED INTO ROCK: 0

12. TOTAL DEPTH OF HOLE: 23.75 FT

13. SIZE AND TYPE OF BIT: 10" O.D. HSA

14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: MSL

15. MANUFACTURERS DESIGNATION OF DRILL: MOBILE B-59

16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN: a. DISTURBED 0; b. UNDISTURBED 1

17. TOTAL NUMBER CORE BOXES: 0

18. ELEVATION GROUND WATER: 991.96 ft on 9-18-14

19. DATE HOLE *(YYYYMMDD)*: a. STARTED 2014/09/17; b. COMPLETED 2014/12/23

20. ELEVATION TOP OF HOLE *(feet)*: 1040.69 ft

21. TOTAL CORE RECOVERY FOR BORING %: N/A

22. SIGNATURE OF INSPECTOR: Richard Stout

| 23. ELEVATION | a. DEPTH | b. LEGEND | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | 4 | For soil description see drilling log for GW970 | % | | |
| | | 8 | | % | | |
| | | 12 | | % | | |
| | | 16 | } Shelby Tube from 17-19 ft | % | | 100% recovery on Shelby tube |
| | | 20 | 23.75' | | | |
| | | 24 | BOH | % | | Boring ended @ 23.75' on bedrock |
| | | 28 | | % | | |
| | | 32 | | % | | |
| | | 36 | | % | | |

**ENG FORM 1836, MAR 1971** PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

PROJECT: EMDF Phase 1 | HOLE NUMBER: GW-971

VERSION 1.0

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 24.2 FT
DEPTH DRILLED INTO ROCK: 75.3 FT
TOTAL DEPTH OF HOLE: 100.3 FT

ALLIANT

# DRILLING LOG
# GW-972

DATE HOLE STARTED: 09-02-14
DATE HOLE COMPLETED: 09-11-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
6 DISTURBED 0 UNDISTURBED

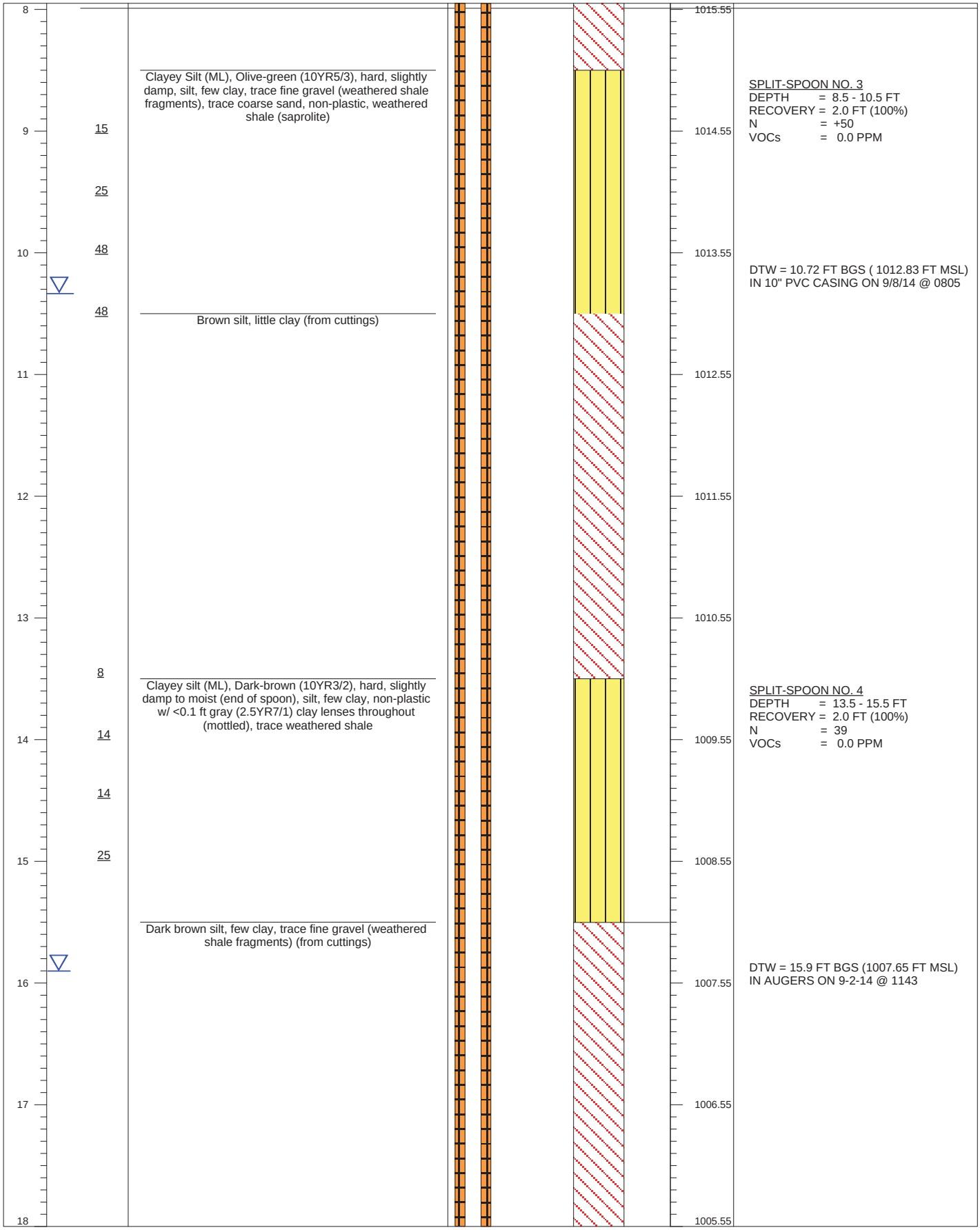
TOTAL NO. OF CORE BOXES: 6

ELEVATION OF GROUNDWATER:
1021.15 FT ON 9/3/14 (OPEN BOREHOLE)

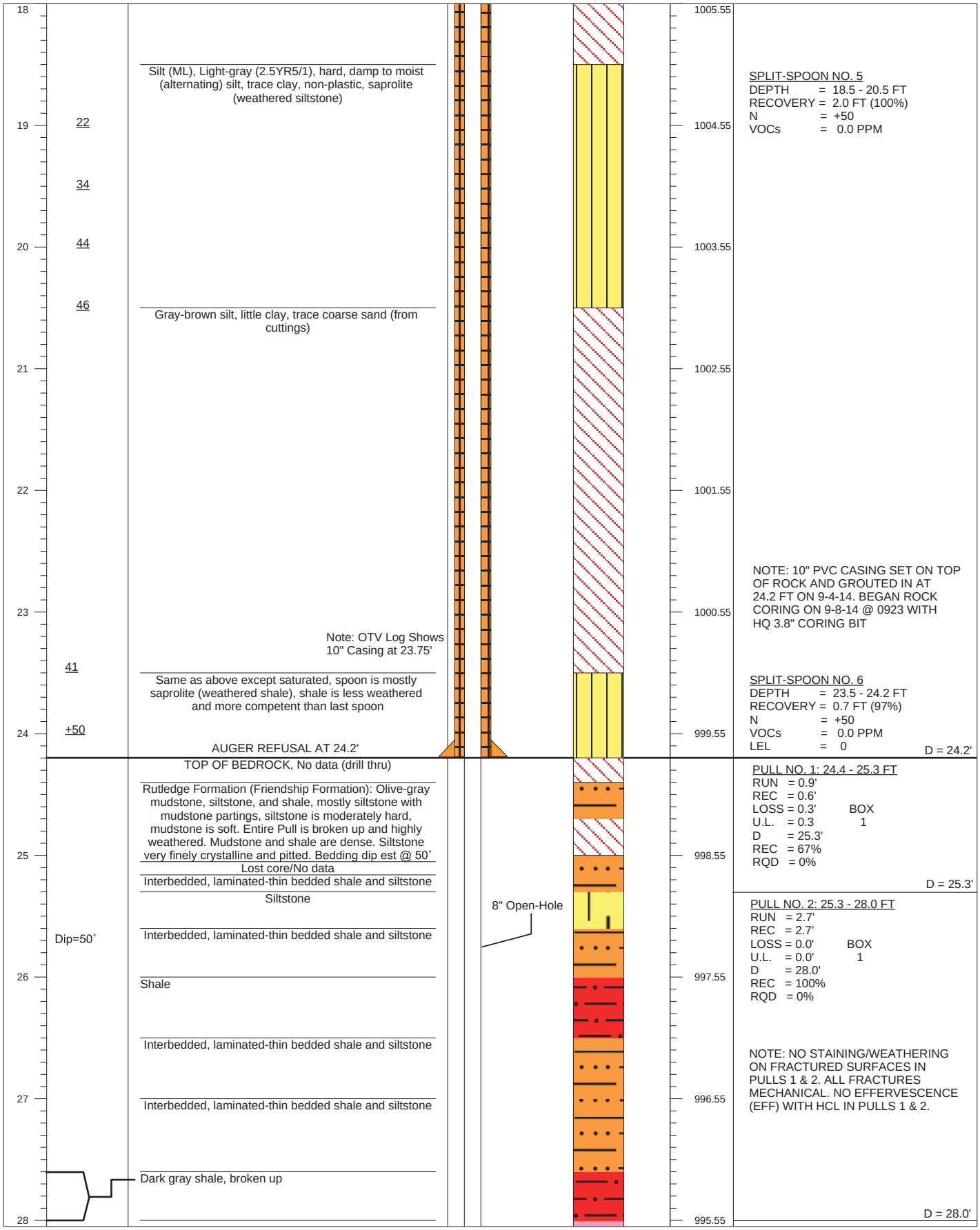
ELEVATION TOP OF HOLE: 1023.55 FT

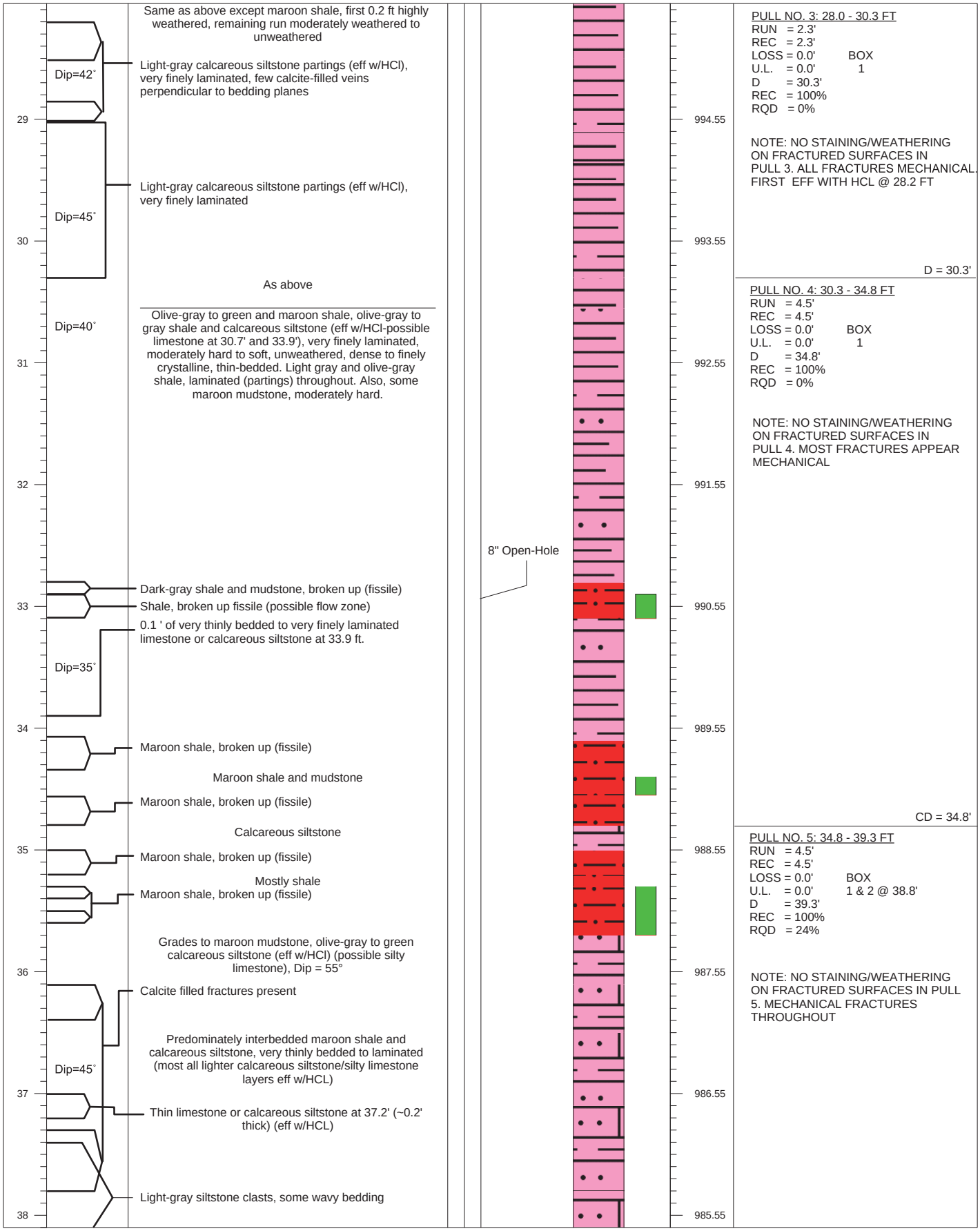
TOTAL CORE RECOVERY: 99 %

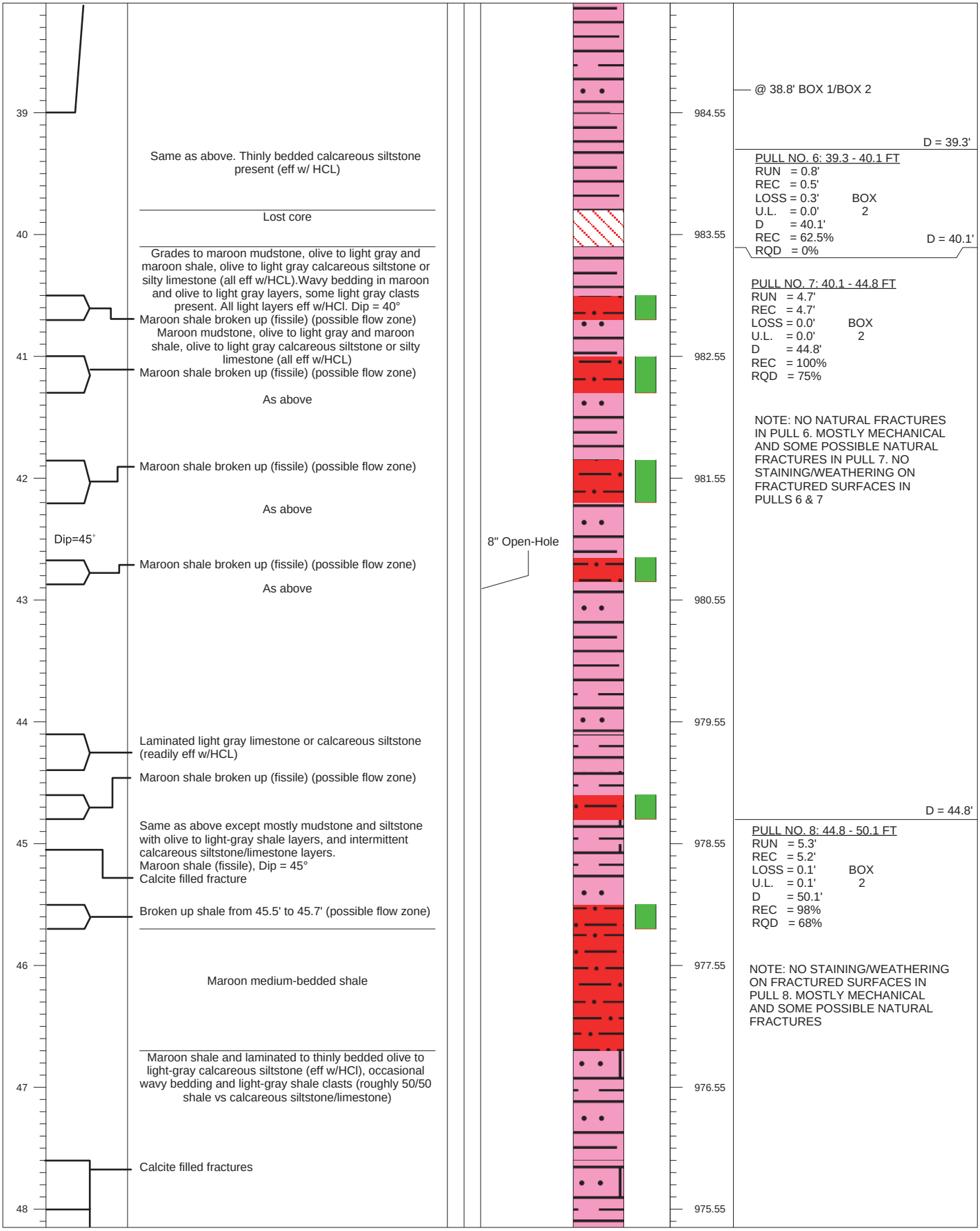
| DEPTH (FT) | NOTES/ OTHER | DESCRIPTION | WELL CONST. | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | Gravel (Road Base) | | | 1023.55 | |
| | Blows | Clayey Silt (ML), Light brown (10YR5/6), medium stiff, slightly damp, silt, some clay, trace fine gravel (weathered shale fragments), non-plastic | 14" Borehole | | | SPLIT-SPOON NO. 1<br>DEPTH = 0 - 2.0 FT<br>RECOVERY = 1.6 FT (80%)<br>N = 6<br>VOCs = 0.0 PPM |
| | 2 | | | | | |
| 1 | 3 | | 10" Sch 40 PVC Casing | | 1022.55 | |
| | 3 | | | | | |
| 2 | 4 | As above (from cuttings) | | | 1021.55 | DTW = 2.0 FT BGS (1021.55 FT MSL) ON 9/4/14 @ 0720 IN OPEN BOREHOLE<br>DTW = 2.4 FT BGS (1021.15 FT MSL) ON 9/3/14 @ 0738 IN OPEN BOREHOLE |
| | | | Bentonite/ Cement Grout | | | |
| 3 | | | | | 1020.55 | |
| | | As above | | | | |
| | | Clayey Silt (ML), Dark reddish-brown (7.5YR5/3), very stiff, slightly damp, silt, trace clay, non-plastic, weathered shale (saprolite) | | | | SPLIT-SPOON NO. 2<br>DEPTH = 3.5 - 5.5 FT<br>RECOVERY = 2.0 FT (100%)<br>N = 25<br>VOCs = 0.0 PPM |
| 4 | 9 | | | | 1019.55 | |
| | 12 | | | | | |
| 5 | 13 | | | | 1018.55 | |
| | 14 | Same as above, except trace gravel (weathered shale fragments) (from cuttings) | | | | |
| 6 | | | | | 1017.55 | |
| 7 | | | | | 1016.55 | DTW = 6.69 FT BGS (1016.86 FT MSL) IN 10" PVC CASING ON 9/9/14 @ 0738 |

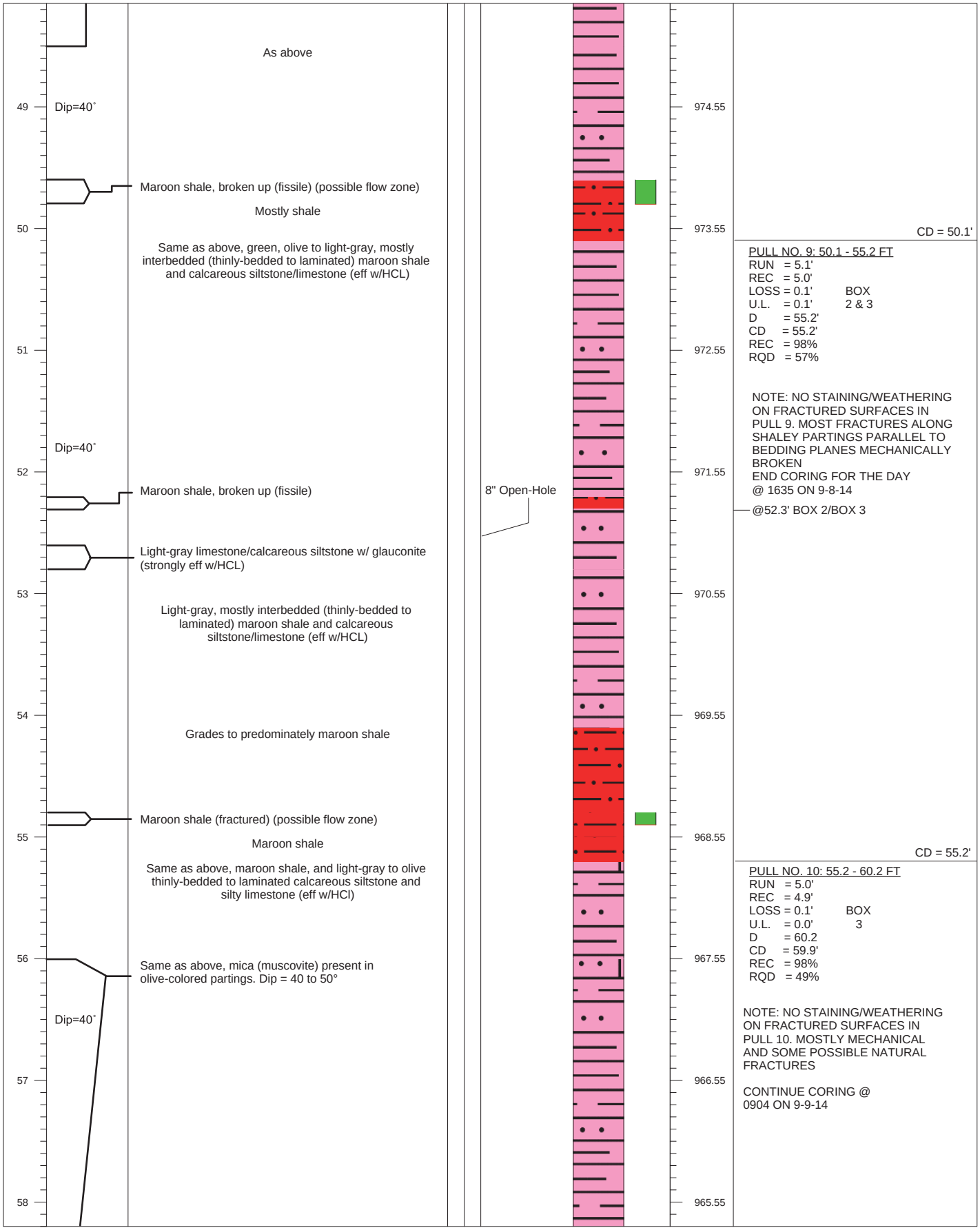

8
9
10
11
12
13
14
15
16
17
18
1015.55
1014.55
1013.55
1012.55
1011.55
1010.55
1009.55
1008.55
1007.55
1006.55
1005.55
15
25
48
48
8
14
14
25
Clayey Silt (ML), Olive-green (10YR5/3), hard, slightly damp, silt, few clay, trace fine gravel (weathered shale fragments), trace coarse sand, non-plastic, weathered shale (saprolite)
Brown silt, little clay (from cuttings)
Clayey silt (ML), Dark-brown (10YR3/2), hard, slightly damp to moist (end of spoon), silt, few clay, non-plastic w/ <0.1 ft gray (2.5YR7/1) clay lenses throughout (mottled), trace weathered shale
Dark brown silt, few clay, trace fine gravel (weathered shale fragments) (from cuttings)
SPLIT-SPOON NO. 3
DEPTH = 8.5 - 10.5 FT
RECOVERY = 2.0 FT (100%)
N = +50
VOCs = 0.0 PPM
DTW = 10.72 FT BGS ( 1012.83 FT MSL)
IN 10" PVC CASING ON 9/8/14 @ 0805
SPLIT-SPOON NO. 4
DEPTH = 13.5 - 15.5 FT
RECOVERY = 2.0 FT (100%)
N = 39
VOCs = 0.0 PPM
DTW = 15.9 FT BGS (1007.65 FT MSL)
IN AUGERS ON 9-2-14 @ 1143

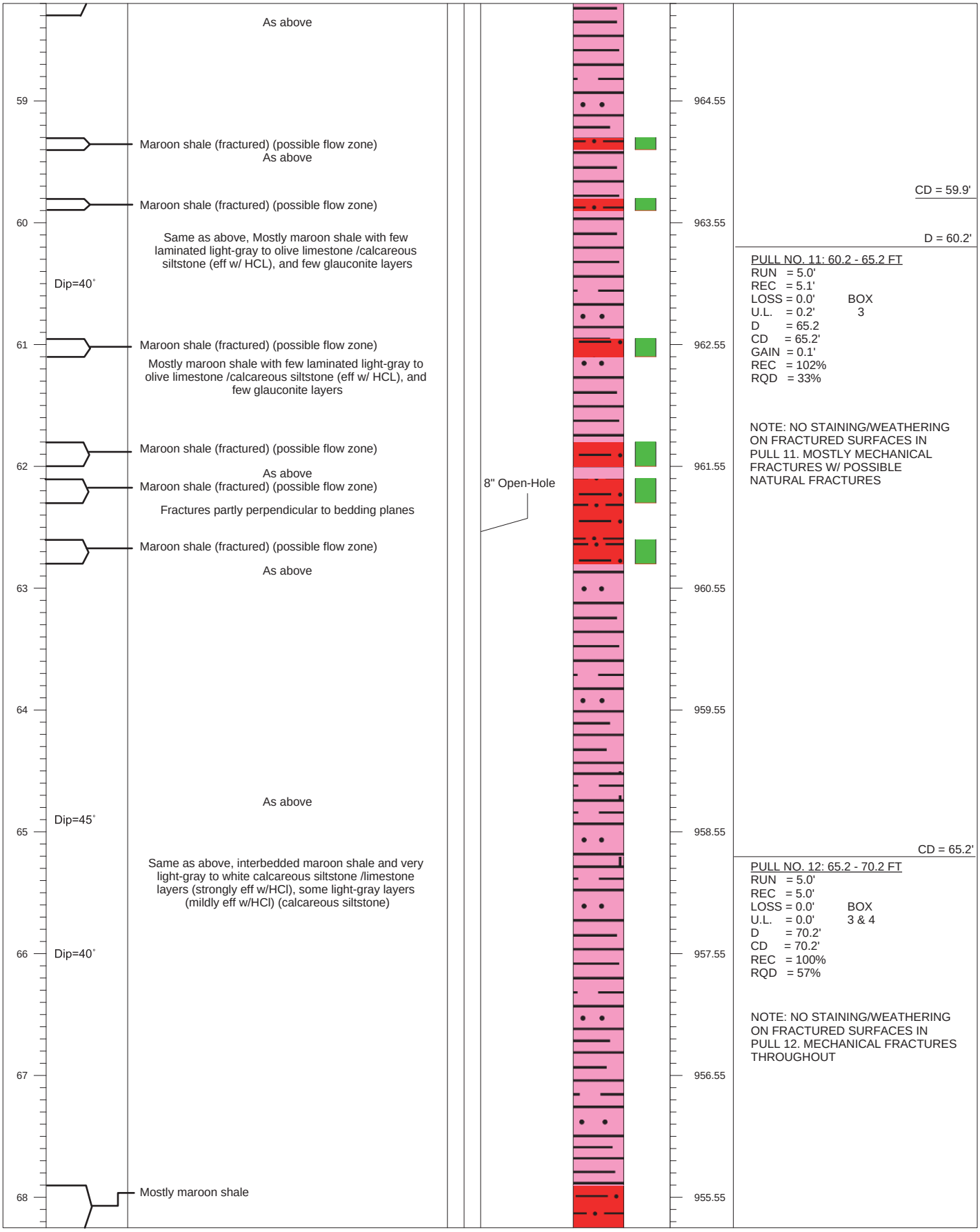
**GW-972** **2 of 11**

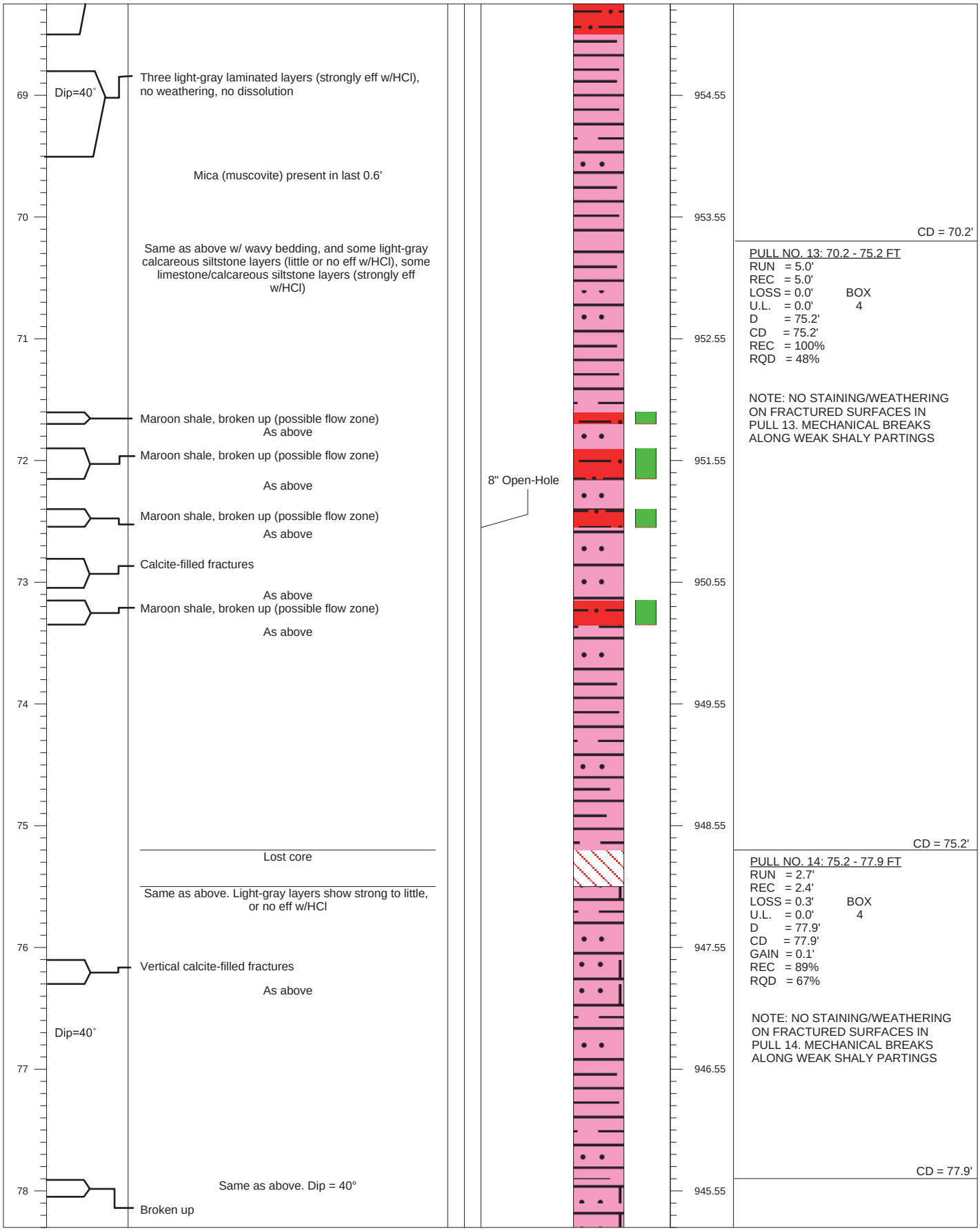

18
19
20
21
22
23
24
25
26
27
28
1005.55
1004.55
1003.55
1002.55
1001.55
1000.55
999.55
998.55
997.55
996.55
995.55
22
34
44
46
41
+50
Silt (ML), Light-gray (2.5YR5/1), hard, damp to moist (alternating) silt, trace clay, non-plastic, saprolite (weathered siltstone)
Gray-brown silt, little clay, trace coarse sand (from cuttings)
Note: OTV Log Shows 10" Casing at 23.75'
Same as above except saturated, spoon is mostly saprolite (weathered shale), shale is less weathered and more competent than last spoon
AUGER REFUSAL AT 24.2'
TOP OF BEDROCK, No data (drill thru)
Rutledge Formation (Friendship Formation): Olive-gray mudstone, siltstone, and shale, mostly siltstone with mudstone partings, siltstone is moderately hard, mudstone is soft. Entire Pull is broken up and highly weathered. Mudstone and shale are dense. Siltstone very finely crystalline and pitted. Bedding dip est @ 50˚
Lost core/No data
Interbedded, laminated-thin bedded shale and siltstone
Siltstone
Interbedded, laminated-thin bedded shale and siltstone
Dip=50˚
Shale
Interbedded, laminated-thin bedded shale and siltstone
Interbedded, laminated-thin bedded shale and siltstone
Dark gray shale, broken up
8" Open-Hole
SPLIT-SPOON NO. 5
DEPTH = 18.5 - 20.5 FT
RECOVERY = 2.0 FT (100%)
N = +50
VOCs = 0.0 PPM
NOTE: 10" PVC CASING SET ON TOP OF ROCK AND GROUTED IN AT 24.2 FT ON 9-4-14. BEGAN ROCK CORING ON 9-8-14 @ 0923 WITH HQ 3.8" CORING BIT
SPLIT-SPOON NO. 6
DEPTH = 23.5 - 24.2 FT
RECOVERY = 0.7 FT (97%)
N = +50
VOCs = 0.0 PPM
LEL = 0
D = 24.2'
PULL NO. 1: 24.4 - 25.3 FT
RUN = 0.9'
REC = 0.6'
LOSS = 0.3' BOX
U.L. = 0.3 1
D = 25.3'
REC = 67%
RQD = 0%
D = 25.3'
PULL NO. 2: 25.3 - 28.0 FT
RUN = 2.7'
REC = 2.7'
LOSS = 0.0' BOX
U.L. = 0.0' 1
D = 28.0'
REC = 100%
RQD = 0%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULLS 1 & 2. ALL FRACTURES MECHANICAL. NO EFFERVESCENCE (EFF) WITH HCL IN PULLS 1 & 2.
D = 28.0'

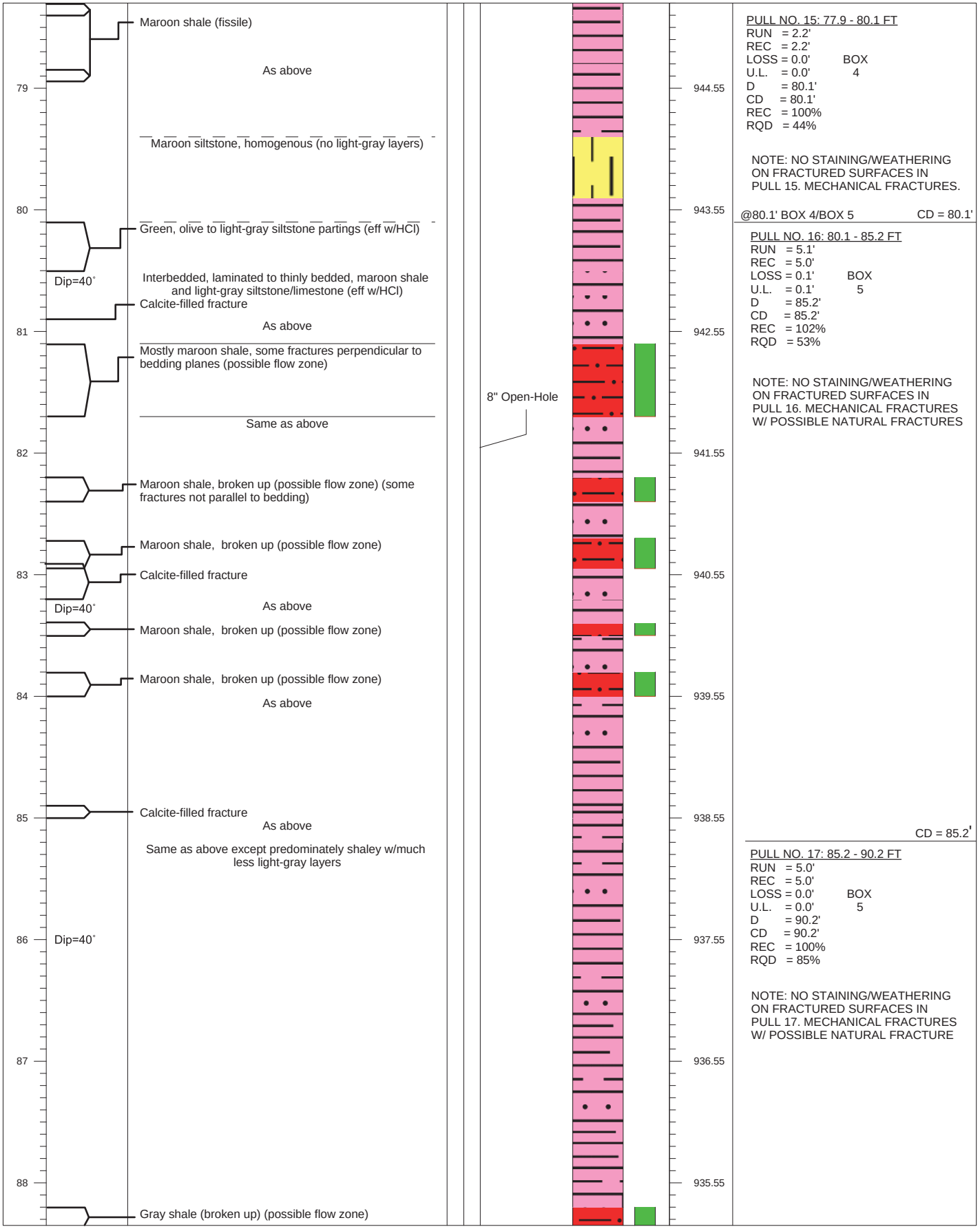

Same as above except maroon shale, first 0.2 ft highly weathered, remaining run moderately weathered to unweathered
Light-gray calcareous siltstone partings (eff w/HCl), very finely laminated, few calcite-filled veins perpendicular to bedding planes
Dip=42˚
Light-gray calcareous siltstone partings (eff w/HCl), very finely laminated
Dip=45˚
As above
Olive-gray to green and maroon shale, olive-gray to gray shale and calcareous siltstone (eff w/HCl-possible limestone at 30.7' and 33.9'), very finely laminated, moderately hard to soft, unweathered, dense to finely crystalline, thin-bedded. Light gray and olive-gray shale, laminated (partings) throughout. Also, some maroon mudstone, moderately hard.
Dip=40˚
Dark-gray shale and mudstone, broken up (fissile)
Shale, broken up fissile (possible flow zone)
0.1 ' of very thinly bedded to very finely laminated limestone or calcareous siltstone at 33.9 ft.
Dip=35˚
Maroon shale, broken up (fissile)
Maroon shale and mudstone
Maroon shale, broken up (fissile)
Calcareous siltstone
Maroon shale, broken up (fissile)
Mostly shale
Maroon shale, broken up (fissile)
Grades to maroon mudstone, olive-gray to green calcareous siltstone (eff w/HCl) (possible silty limestone), Dip = 55°
Calcite filled fractures present
Predominately interbedded maroon shale and calcareous siltstone, very thinly bedded to laminated (most all lighter calcareous siltstone/silty limestone layers eff w/HCL)
Dip=45˚
Thin limestone or calcareous siltstone at 37.2' (~0.2' thick) (eff w/HCL)
Light-gray siltstone clasts, some wavy bedding
29
30
31
32
33
34
35
36
37
38
8" Open-Hole
994.55
993.55
992.55
991.55
990.55
989.55
988.55
987.55
986.55
985.55
PULL NO. 3: 28.0 - 30.3 FT
RUN = 2.3'
REC = 2.3'
LOSS = 0.0' BOX
U.L. = 0.0' 1
D = 30.3'
REC = 100%
RQD = 0%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 3. ALL FRACTURES MECHANICAL. FIRST EFF WITH HCL @ 28.2 FT
D = 30.3'
PULL NO. 4: 30.3 - 34.8 FT
RUN = 4.5'
REC = 4.5'
LOSS = 0.0' BOX
U.L. = 0.0' 1
D = 34.8'
REC = 100%
RQD = 0%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 4. MOST FRACTURES APPEAR MECHANICAL
CD = 34.8'
PULL NO. 5: 34.8 - 39.3 FT
RUN = 4.5'
REC = 4.5'
LOSS = 0.0' BOX
U.L. = 0.0' 1 & 2 @ 38.8'
D = 39.3'
REC = 100%
RQD = 24%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 5. MECHANICAL FRACTURES THROUGHOUT


39
40
41
42
43
44
45
46
47
48
984.55
983.55
982.55
981.55
980.55
979.55
978.55
977.55
976.55
975.55
Same as above. Thinly bedded calcareous siltstone present (eff w/ HCL)
Lost core
Grades to maroon mudstone, olive to light gray and maroon shale, olive to light gray calcareous siltstone or silty limestone (all eff w/HCL).Wavy bedding in maroon and olive to light gray layers, some light gray clasts present. All light layers eff w/HCl. Dip = 40°
Maroon shale broken up (fissile) (possible flow zone)
Maroon mudstone, olive to light gray and maroon shale, olive to light gray calcareous siltstone or silty limestone (all eff w/HCL)
Maroon shale broken up (fissile) (possible flow zone)
As above
Maroon shale broken up (fissile) (possible flow zone)
As above
Dip=45°
Maroon shale broken up (fissile) (possible flow zone)
As above
Laminated light gray limestone or calcareous siltstone (readily eff w/HCL)
Maroon shale broken up (fissile) (possible flow zone)
Same as above except mostly mudstone and siltstone with olive to light-gray shale layers, and intermittent calcareous siltstone/limestone layers.
Maroon shale (fissile), Dip = 45°
Calcite filled fracture
Broken up shale from 45.5' to 45.7' (possible flow zone)
Maroon medium-bedded shale
Maroon shale and laminated to thinly bedded olive to light-gray calcareous siltstone (eff w/HCl), occasional wavy bedding and light-gray shale clasts (roughly 50/50 shale vs calcareous siltstone/limestone)
Calcite filled fractures
8" Open-Hole
@ 38.8' BOX 1/BOX 2
D = 39.3'
PULL NO. 6: 39.3 - 40.1 FT
RUN = 0.8'
REC = 0.5'
LOSS = 0.3' BOX
U.L. = 0.0' 2
D = 40.1'
REC = 62.5%
RQD = 0%
D = 40.1'
PULL NO. 7: 40.1 - 44.8 FT
RUN = 4.7'
REC = 4.7'
LOSS = 0.0' BOX
U.L. = 0.0' 2
D = 44.8'
REC = 100%
RQD = 75%
NOTE: NO NATURAL FRACTURES IN PULL 6. MOSTLY MECHANICAL AND SOME POSSIBLE NATURAL FRACTURES IN PULL 7. NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULLS 6 & 7
D = 44.8'
PULL NO. 8: 44.8 - 50.1 FT
RUN = 5.3'
REC = 5.2'
LOSS = 0.1' BOX
U.L. = 0.1' 2
D = 50.1'
REC = 98%
RQD = 68%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 8. MOSTLY MECHANICAL AND SOME POSSIBLE NATURAL FRACTURES


As above
49
Dip=40°
974.55
Maroon shale, broken up (fissile) (possible flow zone)
Mostly shale
50
973.55
CD = 50.1'
Same as above, green, olive to light-gray, mostly interbedded (thinly-bedded to laminated) maroon shale and calcareous siltstone/limestone (eff w/HCL)
PULL NO. 9: 50.1 - 55.2 FT
RUN = 5.1'
REC = 5.0'
LOSS = 0.1' BOX
U.L. = 0.1' 2 & 3
D = 55.2'
CD = 55.2'
REC = 98%
RQD = 57%
51
972.55
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 9. MOST FRACTURES ALONG SHALEY PARTINGS PARALLEL TO BEDDING PLANES MECHANICALLY BROKEN
END CORING FOR THE DAY @ 1635 ON 9-8-14
Dip=40°
52
971.55
Maroon shale, broken up (fissile)
8" Open-Hole
@52.3' BOX 2/BOX 3
Light-gray limestone/calcareous siltstone w/ glauconite (strongly eff w/HCL)
53
970.55
Light-gray, mostly interbedded (thinly-bedded to laminated) maroon shale and calcareous siltstone/limestone (eff w/HCL)
54
969.55
Grades to predominately maroon shale
Maroon shale (fractured) (possible flow zone)
55
968.55
CD = 55.2'
Maroon shale
Same as above, maroon shale, and light-gray to olive thinly-bedded to laminated calcareous siltstone and silty limestone (eff w/HCl)
PULL NO. 10: 55.2 - 60.2 FT
RUN = 5.0'
REC = 4.9'
LOSS = 0.1' BOX
U.L. = 0.0' 3
D = 60.2
CD = 59.9'
REC = 98%
RQD = 49%
56
967.55
Same as above, mica (muscovite) present in olive-colored partings. Dip = 40 to 50°
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 10. MOSTLY MECHANICAL AND SOME POSSIBLE NATURAL FRACTURES
Dip=40°
CONTINUE CORING @ 0904 ON 9-9-14
57
966.55
58
965.55


As above
59
964.55
Maroon shale (fractured) (possible flow zone)
As above
Maroon shale (fractured) (possible flow zone)
60
963.55
Same as above, Mostly maroon shale with few laminated light-gray to olive limestone /calcareous siltstone (eff w/ HCL), and few glauconite layers
Dip=40˚
61
962.55
Maroon shale (fractured) (possible flow zone)
Mostly maroon shale with few laminated light-gray to olive limestone /calcareous siltstone (eff w/ HCL), and few glauconite layers
Maroon shale (fractured) (possible flow zone)
62
961.55
As above
Maroon shale (fractured) (possible flow zone)
8" Open-Hole
Fractures partly perpendicular to bedding planes
Maroon shale (fractured) (possible flow zone)
As above
63
960.55
64
959.55
As above
Dip=45˚
65
958.55
Same as above, interbedded maroon shale and very light-gray to white calcareous siltstone /limestone layers (strongly eff w/HCl), some light-gray layers (mildly eff w/HCl) (calcareous siltstone)
66
957.55
Dip=40˚
67
956.55
68
955.55
Mostly maroon shale
CD = 59.9'
D = 60.2'
PULL NO. 11: 60.2 - 65.2 FT
RUN = 5.0'
REC = 5.1'
LOSS = 0.0'
BOX
U.L. = 0.2'
3
D = 65.2
CD = 65.2'
GAIN = 0.1'
REC = 102%
RQD = 33%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 11. MOSTLY MECHANICAL FRACTURES W/ POSSIBLE NATURAL FRACTURES
CD = 65.2'
PULL NO. 12: 65.2 - 70.2 FT
RUN = 5.0'
REC = 5.0'
LOSS = 0.0'
BOX
U.L. = 0.0'
3 & 4
D = 70.2'
CD = 70.2'
REC = 100%
RQD = 57%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 12. MECHANICAL FRACTURES THROUGHOUT


69
70
71
72
73
74
75
76
77
78
954.55
953.55
952.55
951.55
950.55
949.55
948.55
947.55
946.55
945.55
Dip=40°
Three light-gray laminated layers (strongly eff w/HCl), no weathering, no dissolution
Mica (muscovite) present in last 0.6'
Same as above w/ wavy bedding, and some light-gray calcareous siltstone layers (little or no eff w/HCl), some limestone/calcareous siltstone layers (strongly eff w/HCl)
Maroon shale, broken up (possible flow zone)
As above
Maroon shale, broken up (possible flow zone)
As above
Maroon shale, broken up (possible flow zone)
As above
Calcite-filled fractures
As above
Maroon shale, broken up (possible flow zone)
As above
Lost core
Same as above. Light-gray layers show strong to little, or no eff w/HCl
Vertical calcite-filled fractures
As above
Dip=40°
Same as above. Dip = 40°
Broken up
8" Open-Hole
CD = 70.2'
PULL NO. 13: 70.2 - 75.2 FT
RUN = 5.0'
REC = 5.0'
LOSS = 0.0' BOX
U.L. = 0.0' 4
D = 75.2'
CD = 75.2'
REC = 100%
RQD = 48%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 13. MECHANICAL BREAKS ALONG WEAK SHALY PARTINGS
CD = 75.2'
PULL NO. 14: 75.2 - 77.9 FT
RUN = 2.7'
REC = 2.4'
LOSS = 0.3' BOX
U.L. = 0.0' 4
D = 77.9'
CD = 77.9'
GAIN = 0.1'
REC = 89%
RQD = 67%
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 14. MECHANICAL BREAKS ALONG WEAK SHALY PARTINGS
CD = 77.9'




PULL NO. 15: 77.9 - 80.1 FT
RUN = 2.2'
REC = 2.2'
LOSS = 0.0' BOX
U.L. = 0.0' 4
D = 80.1'
CD = 80.1'
REC = 100%
RQD = 44%

NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 15. MECHANICAL FRACTURES.

@80.1' BOX 4/BOX 5 CD = 80.1'

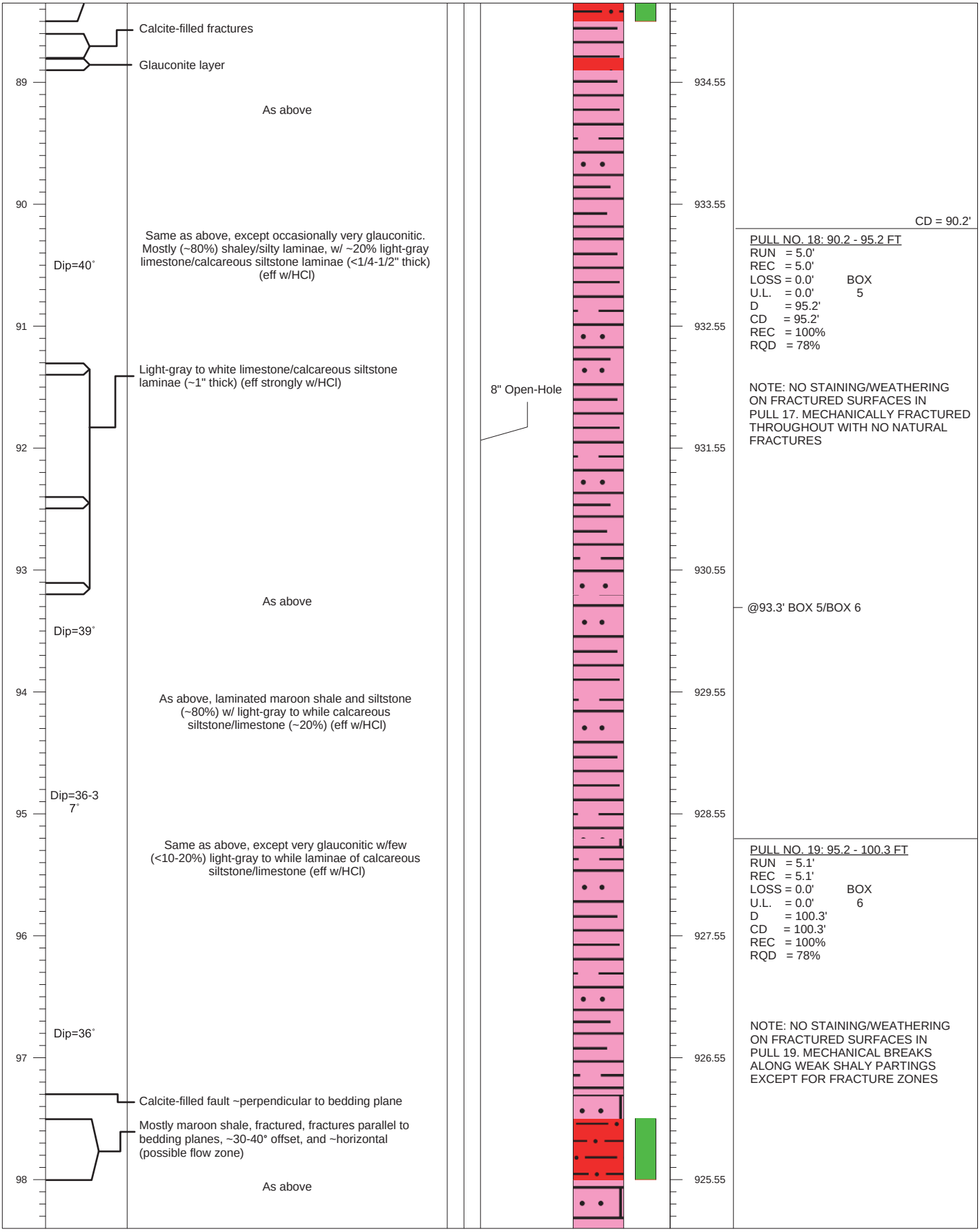
PULL NO. 16: 80.1 - 85.2 FT
RUN = 5.1'
REC = 5.0'
LOSS = 0.1' BOX
U.L. = 0.1' 5
D = 85.2'
CD = 85.2'
REC = 102%
RQD = 53%

NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 16. MECHANICAL FRACTURES W/ POSSIBLE NATURAL FRACTURES

CD = 85.2'

PULL NO. 17: 85.2 - 90.2 FT
RUN = 5.0'
REC = 5.0'
LOSS = 0.0' BOX
U.L. = 0.0' 5
D = 90.2'
CD = 90.2'
REC = 100%
RQD = 85%

NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 17. MECHANICAL FRACTURES W/ POSSIBLE NATURAL FRACTURE


Calcite-filled fractures
Glauconite layer
As above
Same as above, except occasionally very glauconitic. Mostly (~80%) shaley/silty laminae, w/ ~20% light-gray limestone/calcareous siltstone laminae (<1/4-1/2" thick) (eff w/HCl)
Dip=40˚
Light-gray to white limestone/calcareous siltstone laminae (~1" thick) (eff strongly w/HCl)
8" Open-Hole
As above
Dip=39˚
As above, laminated maroon shale and siltstone (~80%) w/ light-gray to while calcareous siltstone/limestone (~20%) (eff w/HCl)
Dip=36-37˚
Same as above, except very glauconitic w/few (<10-20%) light-gray to while laminae of calcareous siltstone/limestone (eff w/HCl)
Dip=36˚
Calcite-filled fault ~perpendicular to bedding plane
Mostly maroon shale, fractured, fractures parallel to bedding planes, ~30-40° offset, and ~horizontal (possible flow zone)
As above
89
90
91
92
93
94
95
96
97
98
934.55
933.55
932.55
931.55
930.55
929.55
928.55
927.55
926.55
925.55
CD = 90.2'
PULL NO. 18: 90.2 - 95.2 FT
RUN = 5.0'
REC = 5.0'
LOSS = 0.0'
U.L. = 0.0'
D = 95.2'
CD = 95.2'
REC = 100%
RQD = 78%
BOX 5
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 17. MECHANICALLY FRACTURED THROUGHOUT WITH NO NATURAL FRACTURES
@93.3' BOX 5/BOX 6
PULL NO. 19: 95.2 - 100.3 FT
RUN = 5.1'
REC = 5.1'
LOSS = 0.0'
U.L. = 0.0'
D = 100.3'
CD = 100.3'
REC = 100%
RQD = 78%
BOX 6
NOTE: NO STAINING/WEATHERING ON FRACTURED SURFACES IN PULL 19. MECHANICAL BREAKS ALONG WEAK SHALY PARTINGS EXCEPT FOR FRACTURE ZONES

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 24.2 FT
DEPTH DRILLED INTO ROCK: 75.3 FT
TOTAL DEPTH OF HOLE: 100.3 FT

ALLIANT

# DRILLING LOG
# GW-972

DATE HOLE STARTED: 09-02-14
DATE HOLE COMPLETED: 09-11-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
6 DISTURBED 0 UNDISTURBED

TOTAL NO. OF CORE BOXES: 6

ELEVATION OF GROUNDWATER:
1021.15 FT ON 9/3/14 (OPEN BOREHOLE)

ELEVATION TOP OF HOLE: 1023.55 FT

TOTAL CORE RECOVERY: 99 %

| DEPTH (FT) | NOTES/ OTHER | DESCRIPTION | WELL CONST. | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|---|
| | | As above | | | | |
| | | Maroon shale, fractured (possible flow zone) | | | | |
| 99 | Dip=40˚ | As above, shale zone | Total Borehole Depth 99.6 FT | | 924.55 | NOTE: COMPLETED ROCK CORING AT GW-972 @ 0920 ON 9-9-14. HOLE REAMED TO 100.3 FT VIA AIR ROTARY @ 1400 ON 9-11-2014 (8-INCH HOLE). OPEN HOLE TO 99.6 FT AFTER SLIGHT 0.7 FT CAVE-IN |
| | | Mostly maroon shale, fractured parallel to bedding planes and ~horizontal (possible flow zone) | | | | |
| 100 | | As above, shale zone | Borehole Collapse @ 99.6-100.3' | | 923.55 | |
| | | 100.3 FT | | | 923.25 FT | 100.3 FT |
| | | BOTTOM OF HOLE | | | | |

## GW-972 Legend

- Silt/Clayey Silt
- Gravel
- Lost core/No data
- Shale
- Interbedded, mostly laminated shale and calcareous siltstone/limestone
- Possible flow zone?
- Siltstone
- Interbedded, laminated-thin bedded shale and siltstone

1. HOLE NUMBER

**DRILLING LOG**
For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG.

2. DIVISION

3. INSTALLATION: Y-12

SHEET 1 OF 1 SHEETS

4. PROJECT: EMDF Phase 1

5. LOCATION *(Coordinates or Station)*: N 31268.37; E 49092.12

6. DRILLING AGENCY: M&W DRILLING

7. HOLE NUMBER *(as shown on drawing title and title number)*: GW-973

8. NAME OF DRILLER: GEORGE AKINS

9. DIRECTION OF HOLE: [X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT.

10. THICKNESS OF OVERBURDEN: 23 FT

11. DEPTH DRILLED INTO ROCK: 0

12. TOTAL DEPTH OF HOLE: 23 FT

13. SIZE AND TYPE OF BIT: 10 inch H.S.A.

14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: MSL

15. MANUFACTURERS DESIGNATION OF DRILL: MOBILE B-59 H.S.A. Rig

16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN: a. DISTURBED 0; b. UNDISTURBED 1

17. TOTAL NUMBER CORE BOXES: N/A

18. ELEVATION GROUND WATER: 1013.86 FT on 10-2-2014

19. DATE HOLE *(YYYYMMDD)*: a. STARTED 2014-09-25; b. COMPLETED 2014-09-25

20. ELEVATION TOP OF HOLE *(feet)*: 1024.46 FT

21. TOTAL CORE RECOVERY FOR BORING %: N/A

22. SIGNATURE OF INSPECTOR: Jack Strader

| 23. ELEVATION | a. DEPTH | b. LEGEND | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | 4 | Shelby tube From 2-4' | % | | 85% Recovery on Shelby tube |
| | | 8 | Gravel Clayey Silt (mL) | % | | |
| | | 12 | For soil description see drilling log from GW-972 | % | | |
| | | 16 | | % | | |
| | | 20 | | % | | |
| | | 23' | BOH | % | | Terminated on weathered shale @ 23.0 FT (Auger refusal) |
| | | 24 | | % | | |
| | | 28 | | % | | |
| | | 32 | | % | | |
| | | 36 | | % | | |

**ENG FORM 1836, MAR 1971** PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

PROJECT: EMDF Phase 1

HOLE NUMBER: GW-973

VERSION 1.0

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 12.5 FT
DEPTH DRILLED INTO ROCK: 88.5 FT
TOTAL DEPTH OF HOLE: 101 FT

ALLIANT

# DRILLING LOG
# GW-974

DATE HOLE STARTED: 09-02-14
DATE HOLE COMPLETED: 09-15-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
3 DISTURBED 0 UNDISTURBED

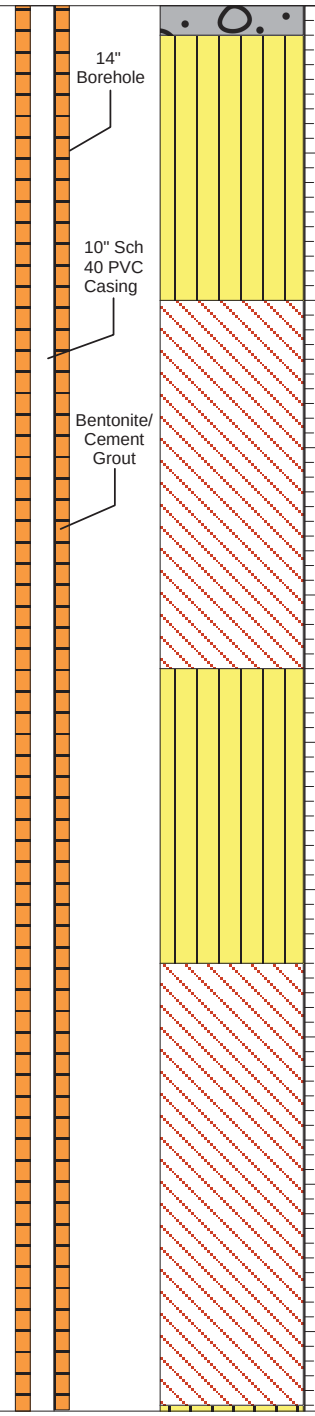
TOTAL NO. OF CORE BOXES: 0

ELEVATION OF GROUNDWATER:
996.10 FT ON 9/3/14 (OPEN BOREHOLE)

ELEVATION TOP OF HOLE: 1002.80 FT

TOTAL CORE RECOVERY: NOT APPLICABLE

| DEPTH (FT) | BLOWS | DESCRIPTION | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|
| 0 | 4 | Gravel (Road Base) | | 1002.8 | SPLIT-SPOON NO. 1<br>DEPTH = 0.0 - 2.0 FT<br>RECOVERY = 2.0 FT (100%)<br>N = 12<br>VOCs = 6.2 PPM |
| 1 | 5 | Clayey silt (ML), orange-yellow (10YR5/8), stiff, slightly damp, silt, few clay, non-plastic occasional saprolite (weathered shale), plant roots, dark-brown stains, slight odor (septic like) | | 1001.8 | |
| | 7 | | | | |
| 2 | 12 | | | 1000.8 | |
| 3 | | No data | | 999.8 | |
| 4 | | | | 998.8 | |
| 5 | 9 | Same as above (no roots) | | 997.8 | SPLIT-SPOON NO. 2<br>DEPTH = 4.5 - 6.5 FT<br>RECOVERY = 2.0 FT (100%)<br>N = 38<br>VOCs = 5.9 PPM |
| | 15 | | | | |
| 6 | 23 | Clayey silt (ML), yellowish-orange (2.5YR7/3), hard, slightly damp, silt, few clay, non-plastic, weathered shale, mudstone, shale (saprolite) | | 996.8 | DTW = 6.7 FT BGS (996.10 FT MSL) IN OPEN BOREHOLE ON 9-3-14 @ 0754 |
| | 34 | | | | DTW = 6.4 FT BGS (996.40 FT MSL) IN OPEN BOREHOLE ON 9-4-14 @ 0720 |
| 7 | | | | 995.8 | |
| 8 | | Same as above (from cuttings) | | 994.8 | DTW = 8.15 FT BGS (994.65 FT MSL) IN 10" PVC CASING ON 9-18-14 @ 0754 |
| 9 | | | | 993.8 | |



PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 12.5 FT
DEPTH DRILLED INTO ROCK: 88.5 FT
TOTAL DEPTH OF HOLE: 101 FT

ALLIANT

# DRILLING LOG
# GW-974

DATE HOLE STARTED: 09-02-14
DATE HOLE COMPLETED: 09-15-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
3 DISTURBED 0 UNDISTURBED

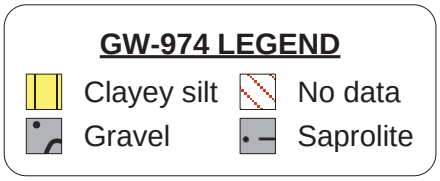
TOTAL NO. OF CORE BOXES: 0

ELEVATION OF GROUNDWATER:
996.10 FT ON 9/3/14 (OPEN BOREHOLE)

ELEVATION TOP OF HOLE: 1002.80 FT

TOTAL CORE RECOVERY: NOT APPLICABLE

| DEPTH (FT) | BLOWS | DESCRIPTION | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|
| 10 | 15 | Sames as above, except damp mid spoon (10.2 ft) | | 992.8 | SPLIT-SPOON NO. 3<br>DEPTH = 9.5 - 10.8 FT<br>SPOON REFUSAL @ 10.8 FT<br>RECOVERY = 1.3 FT (100%)<br>N = +50<br>VOCs = 0.0 PPM |
| | 26 | Weathered siltstone, mudstone, and sandstone | | | |
| 11 | 50 | No data (drill thru) | | 991.8 | |
| 12 | | AUGER REFUSAL @ 12.5 FT 12.5 FT | | 990.8 | 12.5 FT |
| | | TOP OF BEDROCK | | | |
| 13 | | | | 989.8 | |
| 14 | | No data (overdrilled to install 8" PVC casing) | | 988.8 | NOTE: BORING REAMED TO 14" AND 10" PVC CASING SET TO 12.5 FT ON 9-18-2014 @ 0930. 10" CASING BROKEN BY DRILLERS ON 9-9-14. BORING REAMED TO 15.5 FT ON 9-11-14 @ 0720 AND 8" CASING SET. BORING DRILLED TO 101 FT @ 1445 ON 9-15-14 USING 8" AIR ROTARY. OPEN HOLE TO 97.9 FT AFTER 3.1 FT CAVE-IN |
| 15 | | Note: OTV Log Shows 8" Casing @ 15.0 ft BGS | | 987.8 | |
| | | 15.5 FT | | | 15.5 FT |



1. HOLE NUMBER GW-974

| DRILLING LOG<br>For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 2. DIVISION<br>N/A | 3. INSTALLATION<br>Y-12 | SHEET 1<br>OF 2 SHEETS |
|---|---|---|---|
| 4. PROJECT<br>EMDF Phase 1 | | 13. SIZE AND TYPE OF BIT<br>4 1/4" ID H. Stem Auger; 7 7/8" A.Rotary | |
| 5. LOCATION *(Coordinates or Station)*<br>N 31105.66; E 48798.68 | | 14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*<br>MSL | |
| 6. DRILLING AGENCY<br>M&W Drilling | | 15. MANUFACTURERS DESIGNATION OF DRILL<br>HSA - Diedrick 120; A. Rotary - Schramm T450 | |
| 7. HOLE NUMBER *(as shown on drawing title and title number)*<br>GW-974 | | 16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN<br>a. DISTURBED: 3<br>b. UNDISTURBED: 0 | |
| 8. NAME OF DRILLER<br>Garry Akins (H. Stem Auger)<br>George Akins (Air Rotary) | | 17. TOTAL NUMBER CORE BOXES<br>N/A | |
| 9. DIRECTION OF HOLE<br>[X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT. | | 18. ELEVATION GROUND WATER<br>996.10 ft on 9-3-14 | |
| 10. THICKNESS OF OVERBURDEN<br>12.5 ft | | 19. DATE HOLE *(YYYYMMDD)*<br>a. STARTED: 2014-09-02<br>b. COMPLETED: 2014-09-15 | |
| 11. DEPTH DRILLED INTO ROCK<br>88.5 ft | | 20. ELEVATION TOP OF HOLE *(feet)*<br>1002.80 ft | |
| 12. TOTAL DEPTH OF HOLE<br>101 ft | | 21. TOTAL CORE RECOVERY FOR BORING %<br>N/A | |
| | | 22. SIGNATURE OF INSPECTOR<br>R. Stout / J. Strader | |

| 23. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | | Gravel (road base) | 0.2' | | Note:Location as shown in Work Plan |
| | 4 | | Clayey silt (ML), orange-yellow (10yr5/8), stiff, slightly damp, silt, few clay, non-plastic occasional saprolite (weathered shale), plant roots, dark-brown stains, slight odor (spetic-like) | % | Spoon 1 | Split-spoon 0 - 2 ft<br>Recovery = 2.0 ft (100%)<br>VOCs = 6.2ppm |
| | 5 | 1 | | % | | N=12 |
| | 7 | | | % | | |
| | 12 | 2 | | % | | |
| | | 3 | | % | | |
| | | | | % | | |
| | | 4 | | % | | |
| | – | | Same as above (no roots) | % | Spoon 2 | Split-spoon 4.5 - 6.5 ft<br>Recovery = 2.0 ft (100%) |
| | | 5 | | | | |

ENG FORM 1836, MAR 1971 PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

PROJECT: EMDF Phase 1 | HOLE NUMBER: GW-974

VERSION 1.0

**DRILLING LOG** *(Continuation Sheet)*
For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG.

| 1. ELEVATION TOP OF HOLE | 2. HOLE NUMBER | SHEET |
|---|---|---|
| 1002.80 ft | GW-974 | 2 OF 2 SHEETS |

| 3. PROJECT | 4. INSTALLATION |
|---|---|
| EMDF Phase 1 | Y-12 |

| 5. ELEVATION | a. BLOWS | b. DEPTH (ft) | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | 9 | | 5.3' | | | VOCs = 5.9 ppm<br>N = 38 |
| | 15 | | Clayey silt (ML), Yellowish-orange (2.5yr7/3), hard, slightly damp, silt, few clay, few fine gravel, non-plastic (saprolite)-weathered shale, mudstone, siltstone | % | | |
| | 23 | 6 | | % | | |
| | 24 | | | % | | DTW = 6.7 ft bgs in open hole on 9-3-14 @ 0754. DTW = 6.4 ft bgs in open hole on 9-4-14 @ 0720 |
| | | 7 | Same as above (from cuttings) | % | | |
| | | 8 | | % | | |
| | | | | % | | |
| | | 9 | | % | Spoon 3 | Split-spoon 9.5 -10.8 ft<br>Split-spoon refusal @ 10.8 ft<br>Recovery = 1.3 ft (100%)<br>VOCs = 0.0<br>N=+50 |
| | 15 | 10 | Same as above , except damp mid-spoon (10.2 ft) | % | | |
| | 26 | | | % | | |
| | 50 | | Weathered siltstone, mudstone, sandstone 10.8' | | | |
| | | 11 | | % | | |
| | | | | % | | Note: Boring reamed to 14" and 10" PVC casing set on 9-18-14 at 0930. 10" casing broken by drillers on 9-9-14. Boring overdrilled on 9-11-14 at 0720 and 8" casing set. On 9-15-14 at 1445, boring was drilled to 101 ft using an 8" air rotary |
| | | 12 | 12.5' | % | | |
| | | | BOH | | | Auger Refusal @ 12.5' |

**ENG FORM 1836A, JUN 1967** PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

| 6. PROJECT | 7. HOLE NUMBER |
|---|---|
| EMDF Phase 1 | GW-974 |

VERSION 1.0

1. HOLE NUMBER GW-975

| DRILLING LOG<br>For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 2. DIVISION | 3. INSTALLATION<br>Y-12 | SHEET 1 OF 1 SHEETS |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 4. PROJECT<br>EMDF Phase 1 | | 13. SIZE AND TYPE OF BIT<br>6 1/4" ID HSA (10" OD) | |
| | | 14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*<br>Y-12 | |
| 5. LOCATION *(Coordinates or Station)*<br>N 31112.08; E 48789.94 | | 15. MANUFACTURERS DESIGNATION OF DRILL<br>Mobile B59 HSA Rig | |
| 6. DRILLING AGENCY<br>M&W DRILLING | | 16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN | a. DISTURBED<br>0 / b. UNDISTURBED<br>1 |
| 7. HOLE NUMBER *(as shown on drawing title and title number)*<br>GW-975 | | 17. TOTAL NUMBER CORE BOXES<br>N/A | |
| 8. NAME OF DRILLER<br>George Akins<br>Shadoe Anderson (helper) | | 18. ELEVATION GROUND WATER<br>993.72 FT on 10-2-2014 | |
| 9. DIRECTION OF HOLE<br>[X] a. VERTICAL [ ] b. INCLINED c. DEG. FROM VERT. | | 19. DATE HOLE *(YYYYMMDD)* | a. STARTED<br>2014-09-29 / b. COMPLETED<br>2014-12-23 |
| | | 20. ELEVATION TOP OF HOLE *(feet)*<br>1002.52 FT | |
| 10. THICKNESS OF OVERBURDEN<br>10.0 FT | | 21. TOTAL CORE RECOVERY FOR BORING %<br>N/A | |
| 11. DEPTH DRILLED INTO ROCK<br>N/A | | 22. SIGNATURE OF INSPECTOR<br>Richard Stout | |
| 12. TOTAL DEPTH OF HOLE<br>10.0 FT | | | |

| 23. ELEVATION | a. DEPTH | b. LEGEND | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | 2<br>4<br>6<br>8<br>10 | | For soil description see drilling log for GW-974<br><br>} Shelby Tube From 7-8.5 ft<br><br>BOH | %<br>%<br>%<br>%<br>%<br>%<br>%<br>% | | 75% Recovery on Shelby tube |

0 2 4 6 8 10

ENG FORM 1836, MAR 1971 PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

PROJECT EMDF Phase 1 | HOLE NUMBER GW-975

VERSION 1.0

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 24.4 FT
DEPTH DRILLED INTO ROCK: 75.7 FT
TOTAL DEPTH OF HOLE: 100.1 FT

ALLIANT

# DRILLING LOG

# GW-976

DATE HOLE STARTED: 08-27-14
DATE HOLE COMPLETED: 09-17-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
6 DISTURBED 0 UNDISTURBED

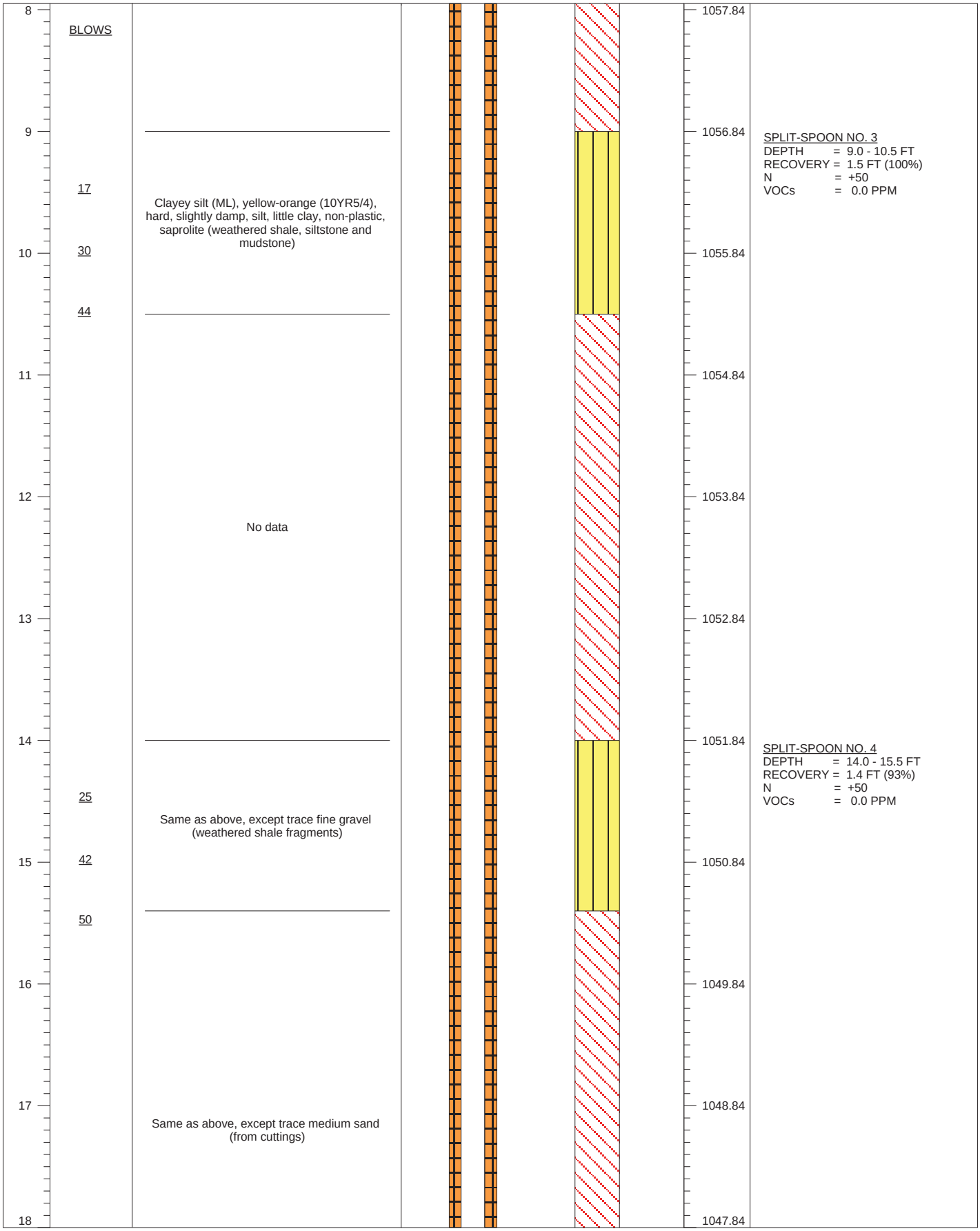
TOTAL NO. OF CORE BOXES: 5

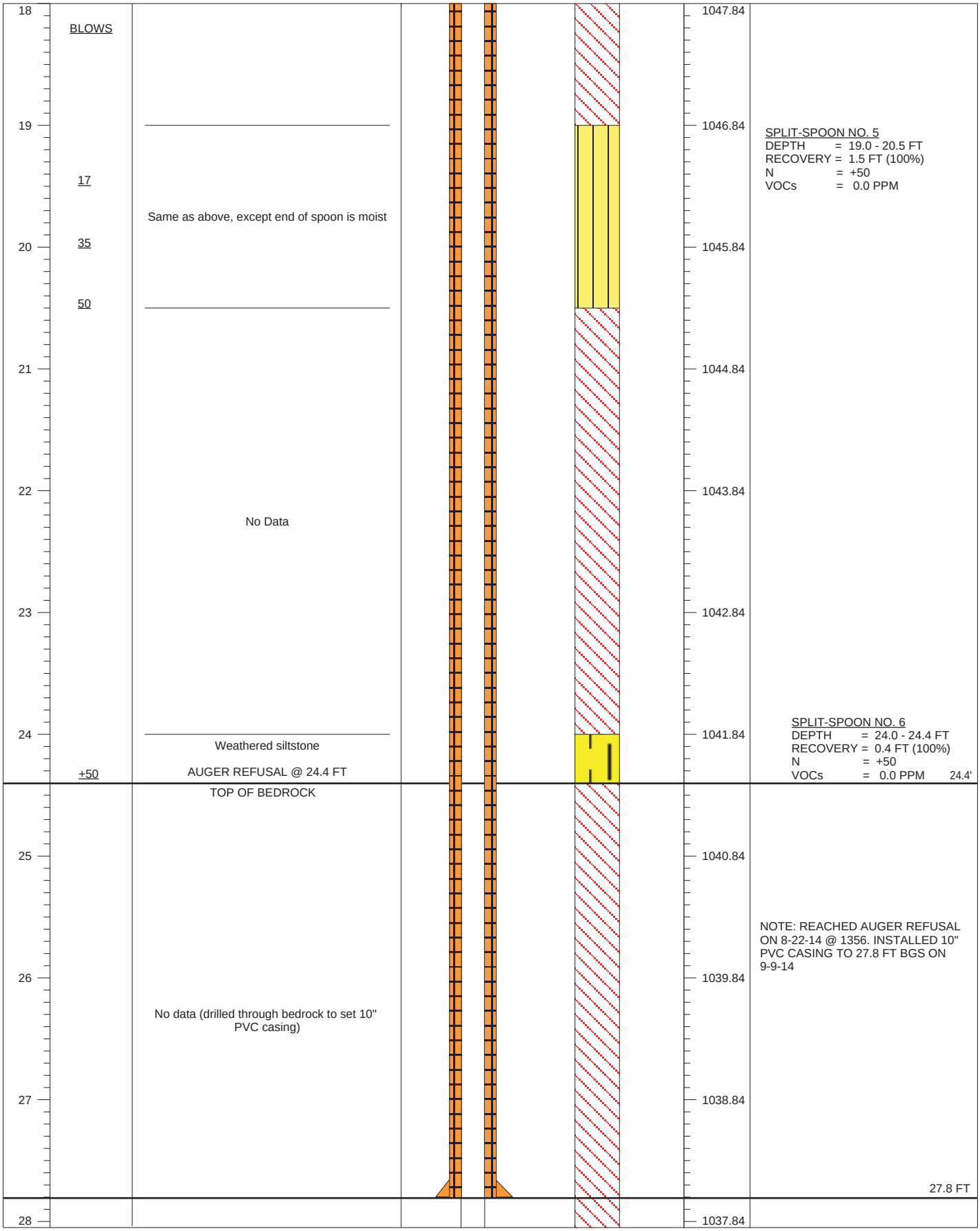
ELEVATION OF GROUNDWATER:
1014.33 FT ON 9/18/14 (10" PVC CASING)

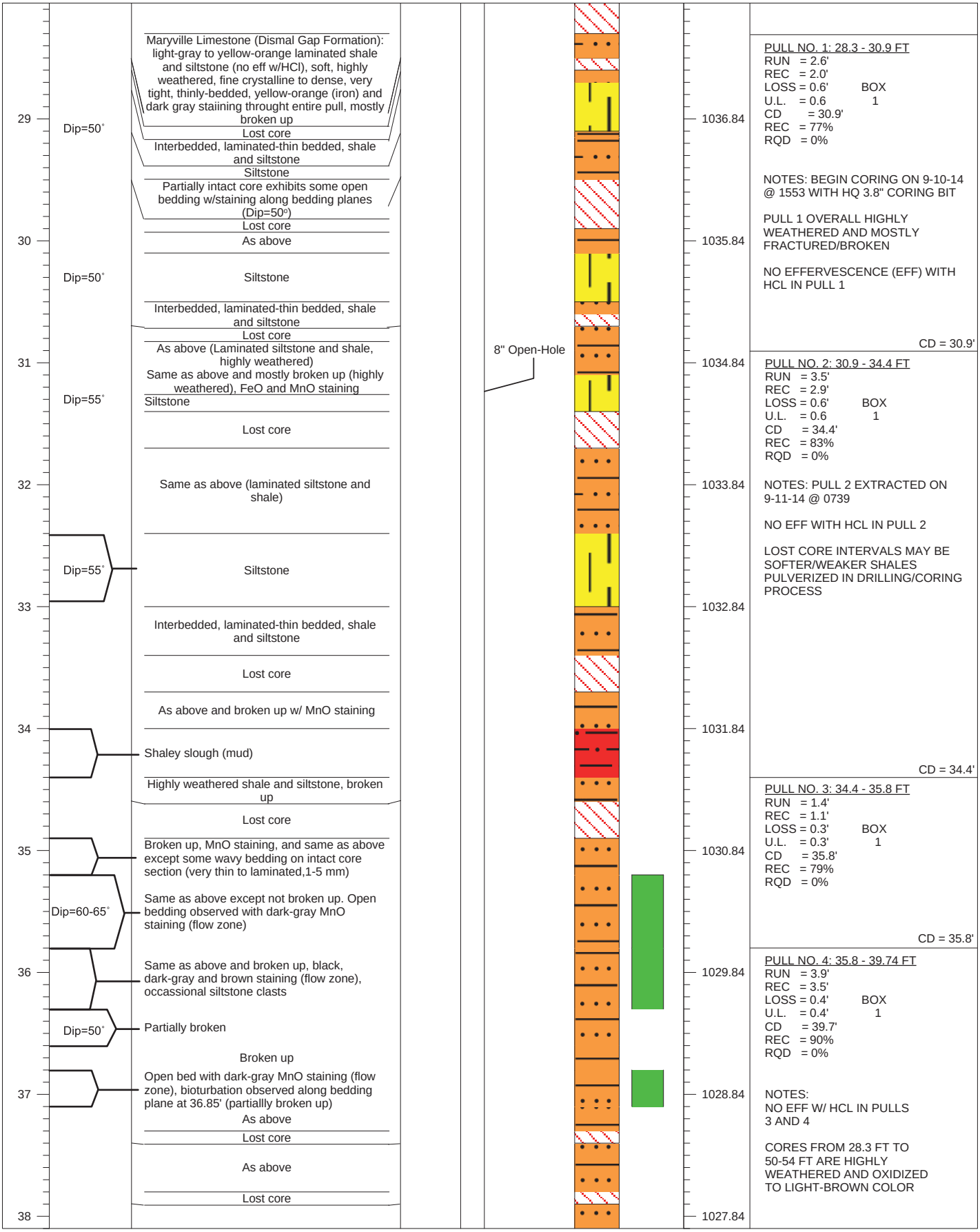
ELEVATION TOP OF HOLE: 1065.84 FT

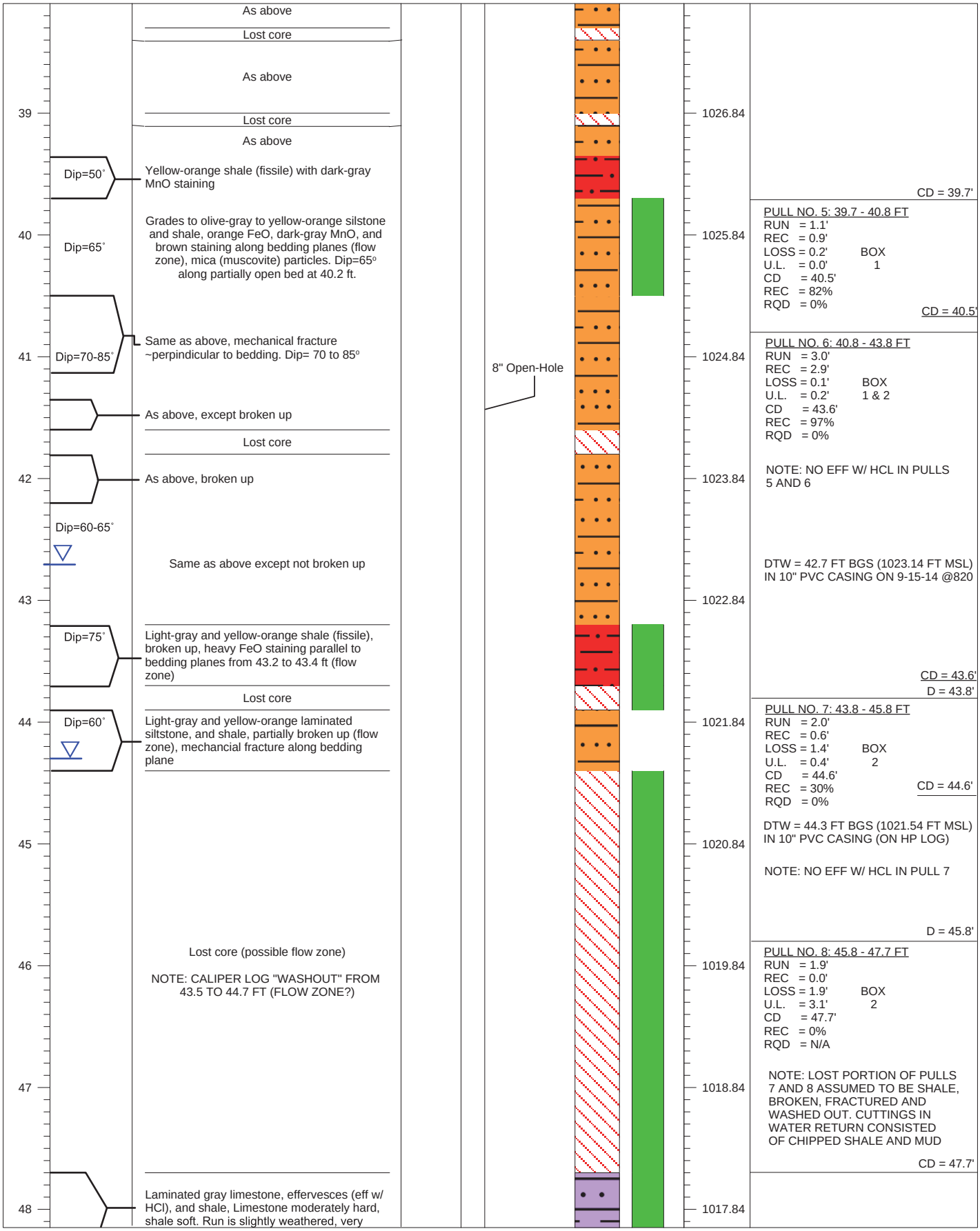
TOTAL CORE RECOVERY: 78 %

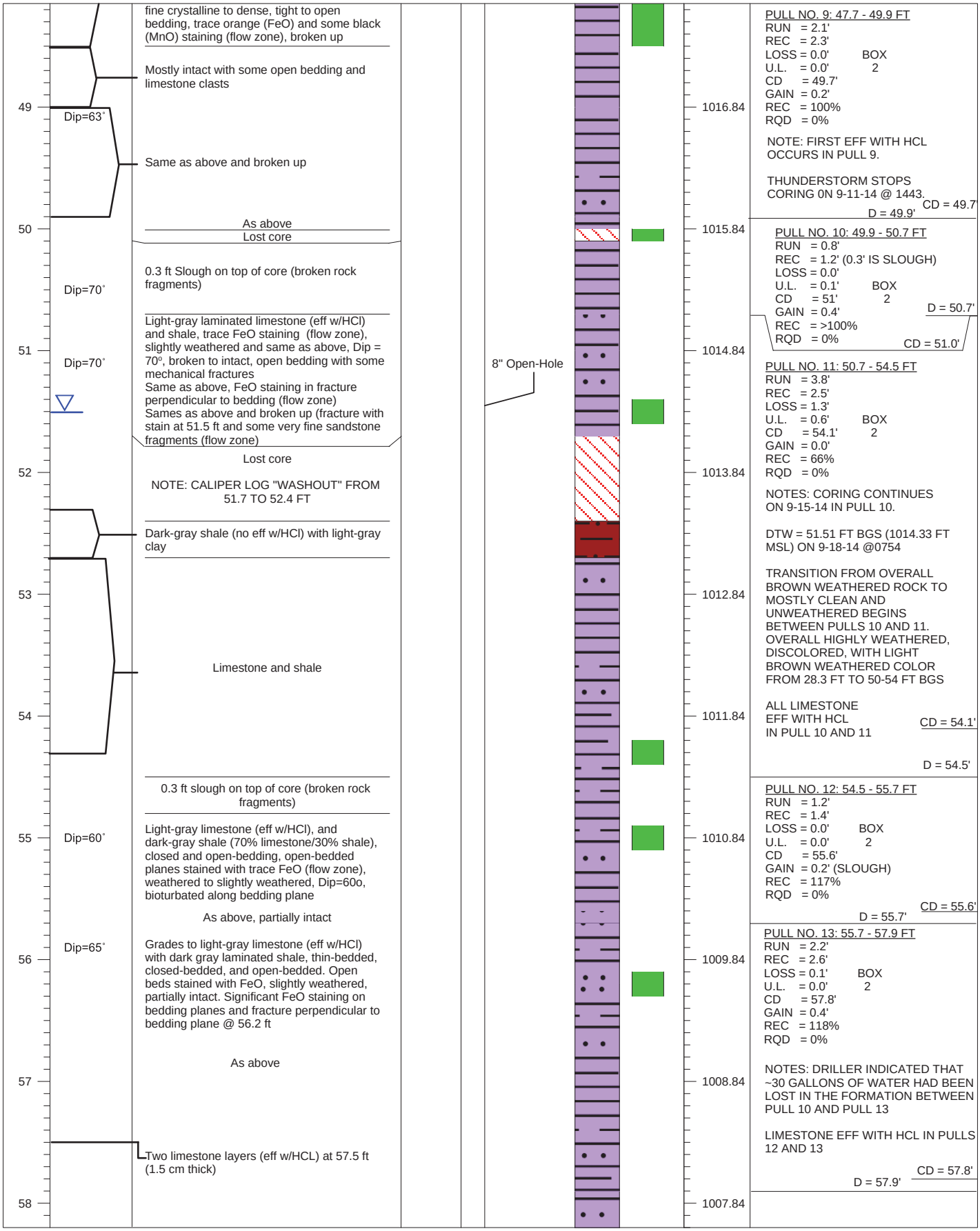
| DEPTH (FT) | NOTES/ OTHER | DESCRIPTION | WELL CONST. | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|---|
| 0 | BLOWS | Gravel (Road Base) | 14" Borehole | | | SPLIT-SPOON NO. 1<br>DEPTH = 0.5 - 2.0 FT<br>RECOVERY = 1.3 FT (87%)<br>N = 16<br>VOCs = 0.0 PPM |
| 1 | 4 | Clayey silt (ML), yellow-orange (7.5YR5/6), very stiff, slightly damp, silt, some clay, non-plastic | | | 1064.84 | |
| | 6 | Grades to same as above with little clay | 10" Sch 40 PVC Casing | | | |
| 2 | 10 | | | | 1063.84 | |
| | | | Bentonite/ Cement Grout | | | |
| 3 | | No Data | | | 1062.84 | |
| 4 | | | | | 1061.84 | |
| 5 | 14 | Clayey silt (ML), yellow-orange (10YR6/4), hard, slightly damp, silt, few clay, non-plastic | | | 1060.84 | SPLIT-SPOON NO. 2<br>DEPTH = 4.5 - 6.0 FT<br>RECOVERY = 1.5 FT (100%)<br>N = +50<br>VOCs = 0.0 PPM |
| | 28 | | | | | |
| 6 | 42 | | | | 1059.84 | |
| 7 | | No Data | | | 1058.84 | |

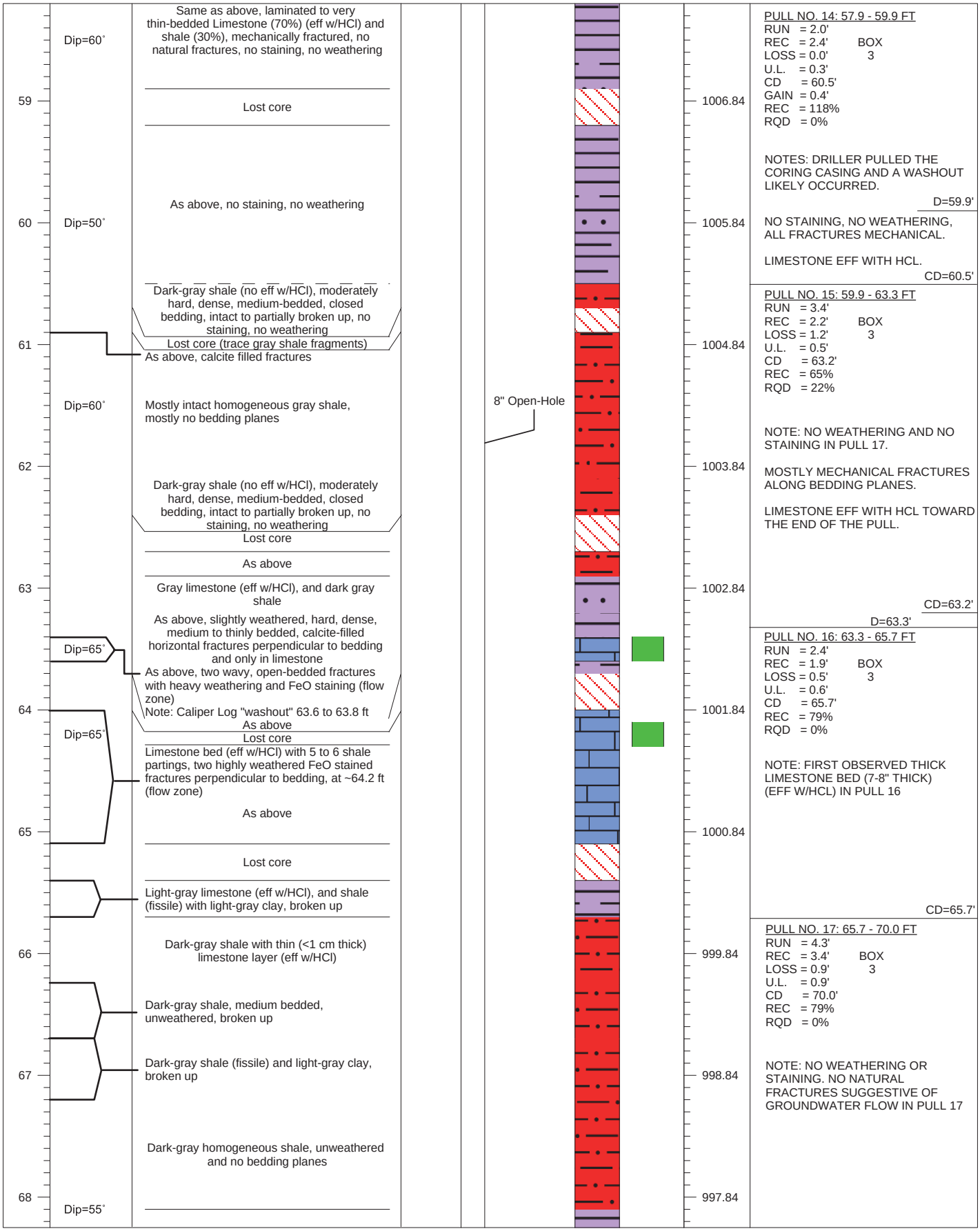

BLOWS
17
30
44
25
42
50
Clayey silt (ML), yellow-orange (10YR5/4), hard, slightly damp, silt, little clay, non-plastic, saprolite (weathered shale, siltstone and mudstone)
No data
Same as above, except trace fine gravel (weathered shale fragments)
Same as above, except trace medium sand (from cuttings)
8
9
10
11
12
13
14
15
16
17
18
1057.84
1056.84
1055.84
1054.84
1053.84
1052.84
1051.84
1050.84
1049.84
1048.84
1047.84
SPLIT-SPOON NO. 3
DEPTH = 9.0 - 10.5 FT
RECOVERY = 1.5 FT (100%)
N = +50
VOCs = 0.0 PPM
SPLIT-SPOON NO. 4
DEPTH = 14.0 - 15.5 FT
RECOVERY = 1.4 FT (93%)
N = +50
VOCs = 0.0 PPM

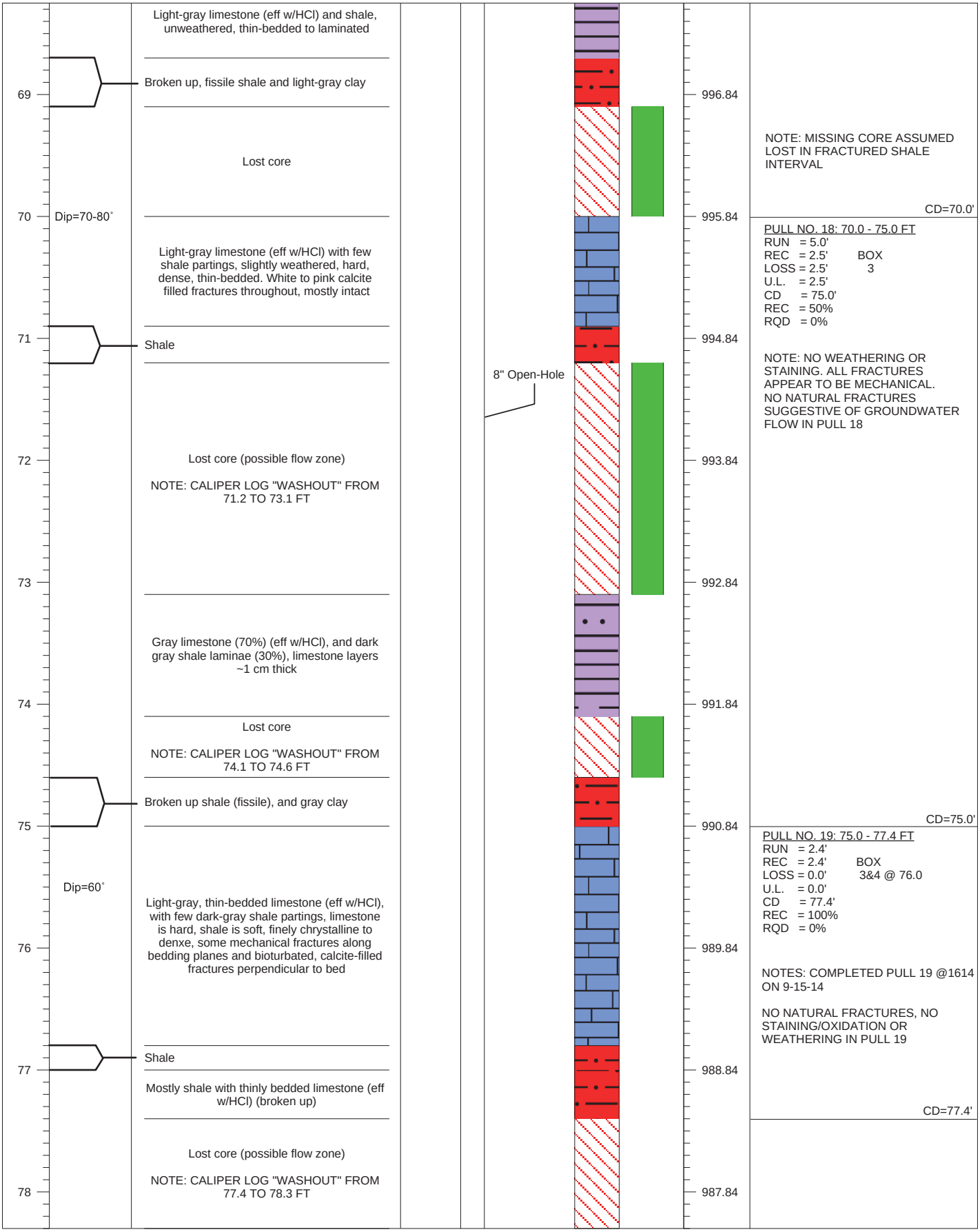

BLOWS
17
35
50
+50
Same as above, except end of spoon is moist
No Data
Weathered siltstone
AUGER REFUSAL @ 24.4 FT
TOP OF BEDROCK
No data (drilled through bedrock to set 10" PVC casing)
18
19
20
21
22
23
24
25
26
27
28
1047.84
1046.84
1045.84
1044.84
1043.84
1042.84
1041.84
1040.84
1039.84
1038.84
1037.84
SPLIT-SPOON NO. 5
DEPTH = 19.0 - 20.5 FT
RECOVERY = 1.5 FT (100%)
N = +50
VOCs = 0.0 PPM
SPLIT-SPOON NO. 6
DEPTH = 24.0 - 24.4 FT
RECOVERY = 0.4 FT (100%)
N = +50
VOCs = 0.0 PPM
24.4'
NOTE: REACHED AUGER REFUSAL ON 8-22-14 @ 1356. INSTALLED 10" PVC CASING TO 27.8 FT BGS ON 9-9-14
27.8 FT

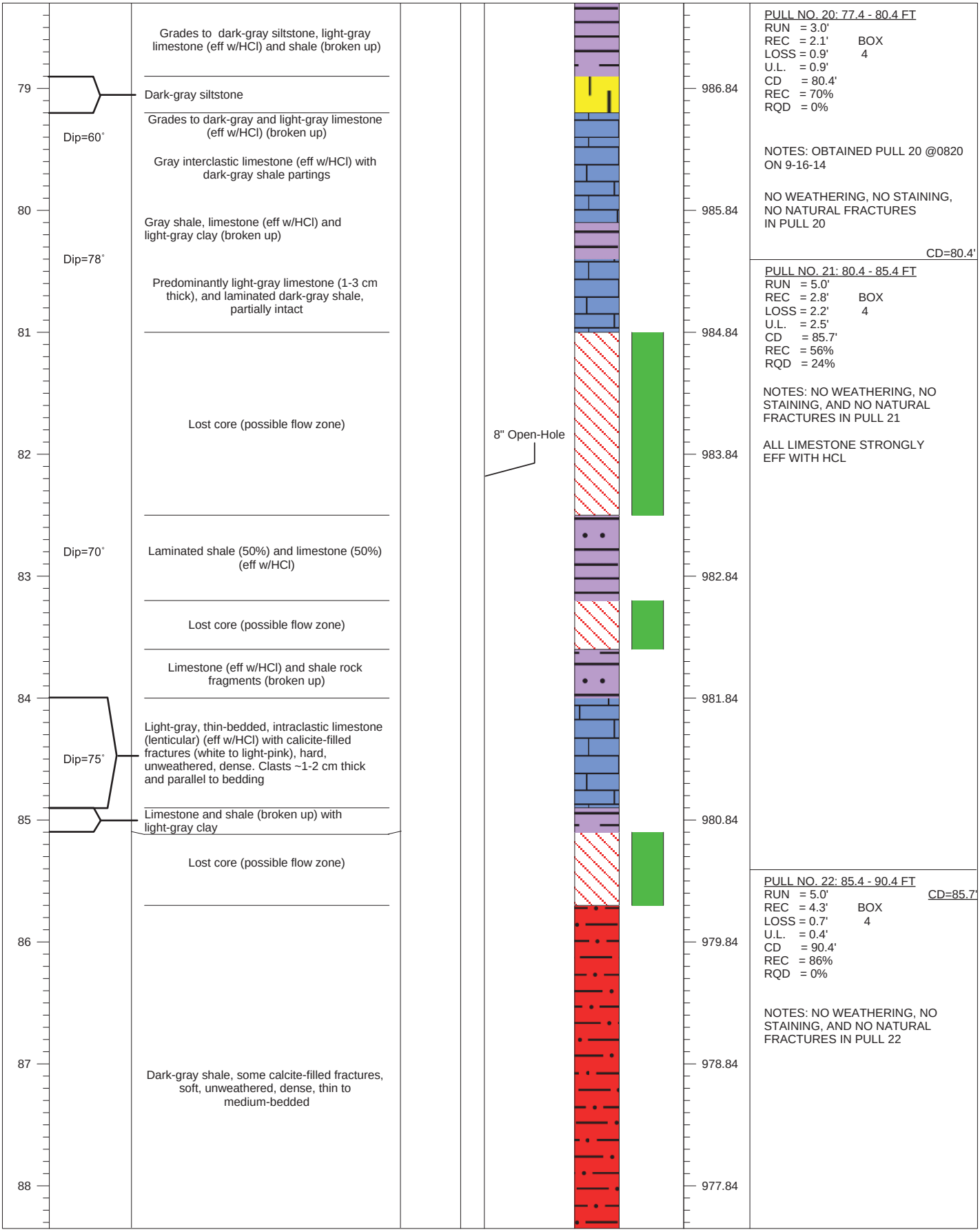

29
30
31
32
33
34
35
36
37
38
Dip=50˚
Dip=50˚
Dip=55˚
Dip=55˚
Dip=60-65˚
Dip=50˚
Maryville Limestone (Dismal Gap Formation): light-gray to yellow-orange laminated shale and siltstone (no eff w/HCl), soft, highly weathered, fine crystalline to dense, very tight, thinly-bedded, yellow-orange (iron) and dark gray staiining throught entire pull, mostly broken up
Lost core
Interbedded, laminated-thin bedded, shale and siltstone
Siltstone
Partially intact core exhibits some open bedding w/staining along bedding planes (Dip=50º)
Lost core
As above
Siltstone
Interbedded, laminated-thin bedded, shale and siltstone
Lost core
As above (Laminated siltstone and shale, highly weathered)
Same as above and mostly broken up (highly weathered), FeO and MnO staining
Siltstone
Lost core
Same as above (laminated siltstone and shale)
Siltstone
Interbedded, laminated-thin bedded, shale and siltstone
Lost core
As above and broken up w/ MnO staining
Shaley slough (mud)
Highly weathered shale and siltstone, broken up
Lost core
Broken up, MnO staining, and same as above except some wavy bedding on intact core section (very thin to laminated,1-5 mm)
Same as above except not broken up. Open bedding observed with dark-gray MnO staining (flow zone)
Same as above and broken up, black, dark-gray and brown staining (flow zone), occassional siltstone clasts
Partially broken
Broken up
Open bed with dark-gray MnO staining (flow zone), bioturbation observed along bedding plane at 36.85' (partiallly broken up)
As above
Lost core
As above
Lost core
8" Open-Hole
1036.84
1035.84
1034.84
1033.84
1032.84
1031.84
1030.84
1029.84
1028.84
1027.84
PULL NO. 1: 28.3 - 30.9 FT
RUN = 2.6'
REC = 2.0'
LOSS = 0.6' BOX
U.L. = 0.6 1
CD = 30.9'
REC = 77%
RQD = 0%
NOTES: BEGIN CORING ON 9-10-14 @ 1553 WITH HQ 3.8" CORING BIT
PULL 1 OVERALL HIGHLY WEATHERED AND MOSTLY FRACTURED/BROKEN
NO EFFERVESCENCE (EFF) WITH HCL IN PULL 1
CD = 30.9'
PULL NO. 2: 30.9 - 34.4 FT
RUN = 3.5'
REC = 2.9'
LOSS = 0.6' BOX
U.L. = 0.6 1
CD = 34.4'
REC = 83%
RQD = 0%
NOTES: PULL 2 EXTRACTED ON 9-11-14 @ 0739
NO EFF WITH HCL IN PULL 2
LOST CORE INTERVALS MAY BE SOFTER/WEAKER SHALES PULVERIZED IN DRILLING/CORING PROCESS
CD = 34.4'
PULL NO. 3: 34.4 - 35.8 FT
RUN = 1.4'
REC = 1.1'
LOSS = 0.3' BOX
U.L. = 0.3' 1
CD = 35.8'
REC = 79%
RQD = 0%
CD = 35.8'
PULL NO. 4: 35.8 - 39.74 FT
RUN = 3.9'
REC = 3.5'
LOSS = 0.4' BOX
U.L. = 0.4' 1
CD = 39.7'
REC = 90%
RQD = 0%
NOTES:
NO EFF W/ HCL IN PULLS 3 AND 4
CORES FROM 28.3 FT TO 50-54 FT ARE HIGHLY WEATHERED AND OXIDIZED TO LIGHT-BROWN COLOR


As above
Lost core
As above
Lost core
As above
Dip=50°
Yellow-orange shale (fissile) with dark-gray MnO staining
Grades to olive-gray to yellow-orange silstone and shale, orange FeO, dark-gray MnO, and brown staining along bedding planes (flow zone), mica (muscovite) particles. Dip=65° along partially open bed at 40.2 ft.
Dip=65°
Dip=70-85°
Same as above, mechanical fracture ~perpindicular to bedding. Dip= 70 to 85°
As above, except broken up
Lost core
As above, broken up
Dip=60-65°
Same as above except not broken up
Dip=75°
Light-gray and yellow-orange shale (fissile), broken up, heavy FeO staining parallel to bedding planes from 43.2 to 43.4 ft (flow zone)
Lost core
Dip=60°
Light-gray and yellow-orange laminated siltstone, and shale, partially broken up (flow zone), mechancial fracture along bedding plane
Lost core (possible flow zone)
NOTE: CALIPER LOG "WASHOUT" FROM 43.5 TO 44.7 FT (FLOW ZONE?)
Laminated gray limestone, effervesces (eff w/ HCl), and shale, Limestone moderately hard, shale soft. Run is slightly weathered, very
39
40
41
42
43
44
45
46
47
48
8" Open-Hole
1026.84
1025.84
1024.84
1023.84
1022.84
1021.84
1020.84
1019.84
1018.84
1017.84
CD = 39.7'
PULL NO. 5: 39.7 - 40.8 FT
RUN = 1.1'
REC = 0.9'
LOSS = 0.2' BOX
U.L. = 0.0' 1
CD = 40.5'
REC = 82%
RQD = 0%
CD = 40.5'
PULL NO. 6: 40.8 - 43.8 FT
RUN = 3.0'
REC = 2.9'
LOSS = 0.1' BOX
U.L. = 0.2' 1 & 2
CD = 43.6'
REC = 97%
RQD = 0%
NOTE: NO EFF W/ HCL IN PULLS 5 AND 6
DTW = 42.7 FT BGS (1023.14 FT MSL) IN 10" PVC CASING ON 9-15-14 @820
CD = 43.6'
D = 43.8'
PULL NO. 7: 43.8 - 45.8 FT
RUN = 2.0'
REC = 0.6'
LOSS = 1.4' BOX
U.L. = 0.4' 2
CD = 44.6'
REC = 30%
RQD = 0%
CD = 44.6'
DTW = 44.3 FT BGS (1021.54 FT MSL) IN 10" PVC CASING (ON HP LOG)
NOTE: NO EFF W/ HCL IN PULL 7
D = 45.8'
PULL NO. 8: 45.8 - 47.7 FT
RUN = 1.9'
REC = 0.0'
LOSS = 1.9' BOX
U.L. = 3.1' 2
CD = 47.7'
REC = 0%
RQD = N/A
NOTE: LOST PORTION OF PULLS 7 AND 8 ASSUMED TO BE SHALE, BROKEN, FRACTURED AND WASHED OUT. CUTTINGS IN WATER RETURN CONSISTED OF CHIPPED SHALE AND MUD
CD = 47.7'


fine crystalline to dense, tight to open bedding, trace orange (FeO) and some black (MnO) staining (flow zone), broken up
Mostly intact with some open bedding and limestone clasts
Same as above and broken up
As above
Lost core
0.3 ft Slough on top of core (broken rock fragments)
Light-gray laminated limestone (eff w/HCl) and shale, trace FeO staining (flow zone), slightly weathered and same as above, Dip = 70°, broken to intact, open bedding with some mechanical fractures
Same as above, FeO staining in fracture perpendicular to bedding (flow zone)
Sames as above and broken up (fracture with stain at 51.5 ft and some very fine sandstone fragments (flow zone)
Lost core
NOTE: CALIPER LOG "WASHOUT" FROM 51.7 TO 52.4 FT
Dark-gray shale (no eff w/HCl) with light-gray clay
Limestone and shale
0.3 ft slough on top of core (broken rock fragments)
Light-gray limestone (eff w/HCl), and dark-gray shale (70% limestone/30% shale), closed and open-bedding, open-bedded planes stained with trace FeO (flow zone), weathered to slightly weathered, Dip=60o, bioturbated along bedding plane
As above, partially intact
Grades to light-gray limestone (eff w/HCl) with dark gray laminated shale, thin-bedded, closed-bedded, and open-bedded. Open beds stained with FeO, slightly weathered, partially intact. Significant FeO staining on bedding planes and fracture perpendicular to bedding plane @ 56.2 ft
As above
Two limestone layers (eff w/HCL) at 57.5 ft (1.5 cm thick)
49
50
51
52
53
54
55
56
57
58
Dip=63°
Dip=70°
Dip=70°
Dip=60°
Dip=65°
8" Open-Hole
1016.84
1015.84
1014.84
1013.84
1012.84
1011.84
1010.84
1009.84
1008.84
1007.84
PULL NO. 9: 47.7 - 49.9 FT
RUN = 2.1'
REC = 2.3'
LOSS = 0.0' BOX
U.L. = 0.0' 2
CD = 49.7'
GAIN = 0.2'
REC = 100%
RQD = 0%
NOTE: FIRST EFF WITH HCL OCCURS IN PULL 9.
THUNDERSTORM STOPS CORING 0N 9-11-14 @ 1443.
CD = 49.7'
D = 49.9'
PULL NO. 10: 49.9 - 50.7 FT
RUN = 0.8'
REC = 1.2' (0.3' IS SLOUGH)
LOSS = 0.0'
U.L. = 0.1' BOX
CD = 51' 2
GAIN = 0.4'
REC = >100%
RQD = 0%
D = 50.7'
CD = 51.0'
PULL NO. 11: 50.7 - 54.5 FT
RUN = 3.8'
REC = 2.5'
LOSS = 1.3'
U.L. = 0.6' BOX
CD = 54.1' 2
GAIN = 0.0'
REC = 66%
RQD = 0%
NOTES: CORING CONTINUES ON 9-15-14 IN PULL 10.
DTW = 51.51 FT BGS (1014.33 FT MSL) ON 9-18-14 @0754
TRANSITION FROM OVERALL BROWN WEATHERED ROCK TO MOSTLY CLEAN AND UNWEATHERED BEGINS BETWEEN PULLS 10 AND 11. OVERALL HIGHLY WEATHERED, DISCOLORED, WITH LIGHT BROWN WEATHERED COLOR FROM 28.3 FT TO 50-54 FT BGS
ALL LIMESTONE EFF WITH HCL IN PULL 10 AND 11
CD = 54.1'
D = 54.5'
PULL NO. 12: 54.5 - 55.7 FT
RUN = 1.2'
REC = 1.4'
LOSS = 0.0' BOX
U.L. = 0.0' 2
CD = 55.6'
GAIN = 0.2' (SLOUGH)
REC = 117%
RQD = 0%
CD = 55.6'
D = 55.7'
PULL NO. 13: 55.7 - 57.9 FT
RUN = 2.2'
REC = 2.6'
LOSS = 0.1' BOX
U.L. = 0.0' 2
CD = 57.8'
GAIN = 0.4'
REC = 118%
RQD = 0%
NOTES: DRILLER INDICATED THAT ~30 GALLONS OF WATER HAD BEEN LOST IN THE FORMATION BETWEEN PULL 10 AND PULL 13
LIMESTONE EFF WITH HCL IN PULLS 12 AND 13
CD = 57.8'
D = 57.9'


Same as above, laminated to very thin-bedded Limestone (70%) (eff w/HCl) and shale (30%), mechanically fractured, no natural fractures, no staining, no weathering
Dip=60˚
59
Lost core
As above, no staining, no weathering
60
Dip=50˚
Dark-gray shale (no eff w/HCl), moderately hard, dense, medium-bedded, closed bedding, intact to partially broken up, no staining, no weathering
Lost core (trace gray shale fragments)
61
As above, calcite filled fractures
Dip=60˚
Mostly intact homogeneous gray shale, mostly no bedding planes
62
Dark-gray shale (no eff w/HCl), moderately hard, dense, medium-bedded, closed bedding, intact to partially broken up, no staining, no weathering
Lost core
As above
63
Gray limestone (eff w/HCl), and dark gray shale
As above, slightly weathered, hard, dense, medium to thinly bedded, calcite-filled horizontal fractures perpendicular to bedding and only in limestone
Dip=65˚
As above, two wavy, open-bedded fractures with heavy weathering and FeO staining (flow zone)
Note: Caliper Log "washout" 63.6 to 63.8 ft
64
As above
Lost core
Dip=65˚
Limestone bed (eff w/HCl) with 5 to 6 shale partings, two highly weathered FeO stained fractures perpendicular to bedding, at ~64.2 ft (flow zone)
As above
65
Lost core
Light-gray limestone (eff w/HCl), and shale (fissile) with light-gray clay, broken up
Dark-gray shale with thin (<1 cm thick) limestone layer (eff w/HCl)
66
Dark-gray shale, medium bedded, unweathered, broken up
Dark-gray shale (fissile) and light-gray clay, broken up
67
Dark-gray homogeneous shale, unweathered and no bedding planes
68
Dip=55˚
8" Open-Hole
1006.84
1005.84
1004.84
1003.84
1002.84
1001.84
1000.84
999.84
998.84
997.84
PULL NO. 14: 57.9 - 59.9 FT
RUN = 2.0'
REC = 2.4' BOX
LOSS = 0.0' 3
U.L. = 0.3'
CD = 60.5'
GAIN = 0.4'
REC = 118%
RQD = 0%
NOTES: DRILLER PULLED THE CORING CASING AND A WASHOUT LIKELY OCCURRED.
D=59.9'
NO STAINING, NO WEATHERING, ALL FRACTURES MECHANICAL.
LIMESTONE EFF WITH HCL.
CD=60.5'
PULL NO. 15: 59.9 - 63.3 FT
RUN = 3.4'
REC = 2.2' BOX
LOSS = 1.2' 3
U.L. = 0.5'
CD = 63.2'
REC = 65%
RQD = 22%
NOTE: NO WEATHERING AND NO STAINING IN PULL 17.
MOSTLY MECHANICAL FRACTURES ALONG BEDDING PLANES.
LIMESTONE EFF WITH HCL TOWARD THE END OF THE PULL.
CD=63.2'
D=63.3'
PULL NO. 16: 63.3 - 65.7 FT
RUN = 2.4'
REC = 1.9' BOX
LOSS = 0.5' 3
U.L. = 0.6'
CD = 65.7'
REC = 79%
RQD = 0%
NOTE: FIRST OBSERVED THICK LIMESTONE BED (7-8" THICK) (EFF W/HCL) IN PULL 16
CD=65.7'
PULL NO. 17: 65.7 - 70.0 FT
RUN = 4.3'
REC = 3.4' BOX
LOSS = 0.9' 3
U.L. = 0.9'
CD = 70.0'
REC = 79%
RQD = 0%
NOTE: NO WEATHERING OR STAINING. NO NATURAL FRACTURES SUGGESTIVE OF GROUNDWATER FLOW IN PULL 17


Light-gray limestone (eff w/HCl) and shale, unweathered, thin-bedded to laminated
Broken up, fissile shale and light-gray clay
Lost core
Dip=70-80˚
Light-gray limestone (eff w/HCl) with few shale partings, slightly weathered, hard, dense, thin-bedded. White to pink calcite filled fractures throughout, mostly intact
Shale
Lost core (possible flow zone)
NOTE: CALIPER LOG "WASHOUT" FROM 71.2 TO 73.1 FT
Gray limestone (70%) (eff w/HCl), and dark gray shale laminae (30%), limestone layers ~1 cm thick
Lost core
NOTE: CALIPER LOG "WASHOUT" FROM 74.1 TO 74.6 FT
Broken up shale (fissile), and gray clay
Dip=60˚
Light-gray, thin-bedded limestone (eff w/HCl), with few dark-gray shale partings, limestone is hard, shale is soft, finely chrystalline to denxe, some mechanical fractures along bedding planes and bioturbated, calcite-filled fractures perpendicular to bed
Shale
Mostly shale with thinly bedded limestone (eff w/HCl) (broken up)
Lost core (possible flow zone)
NOTE: CALIPER LOG "WASHOUT" FROM 77.4 TO 78.3 FT
69
70
71
72
73
74
75
76
77
78
8" Open-Hole
996.84
995.84
994.84
993.84
992.84
991.84
990.84
989.84
988.84
987.84
NOTE: MISSING CORE ASSUMED LOST IN FRACTURED SHALE INTERVAL
CD=70.0'
PULL NO. 18: 70.0 - 75.0 FT
RUN = 5.0'
REC = 2.5' BOX
LOSS = 2.5' 3
U.L. = 2.5'
CD = 75.0'
REC = 50%
RQD = 0%
NOTE: NO WEATHERING OR STAINING. ALL FRACTURES APPEAR TO BE MECHANICAL. NO NATURAL FRACTURES SUGGESTIVE OF GROUNDWATER FLOW IN PULL 18
CD=75.0'
PULL NO. 19: 75.0 - 77.4 FT
RUN = 2.4'
REC = 2.4' BOX
LOSS = 0.0' 3&4 @ 76.0
U.L. = 0.0'
CD = 77.4'
REC = 100%
RQD = 0%
NOTES: COMPLETED PULL 19 @1614 ON 9-15-14
NO NATURAL FRACTURES, NO STAINING/OXIDATION OR WEATHERING IN PULL 19
CD=77.4'




PULL NO. 20: 77.4 - 80.4 FT
RUN = 3.0'
REC = 2.1' BOX
LOSS = 0.9' 4
U.L. = 0.9'
CD = 80.4'
REC = 70%
RQD = 0%

NOTES: OBTAINED PULL 20 @0820 ON 9-16-14

NO WEATHERING, NO STAINING, NO NATURAL FRACTURES IN PULL 20

CD=80.4'

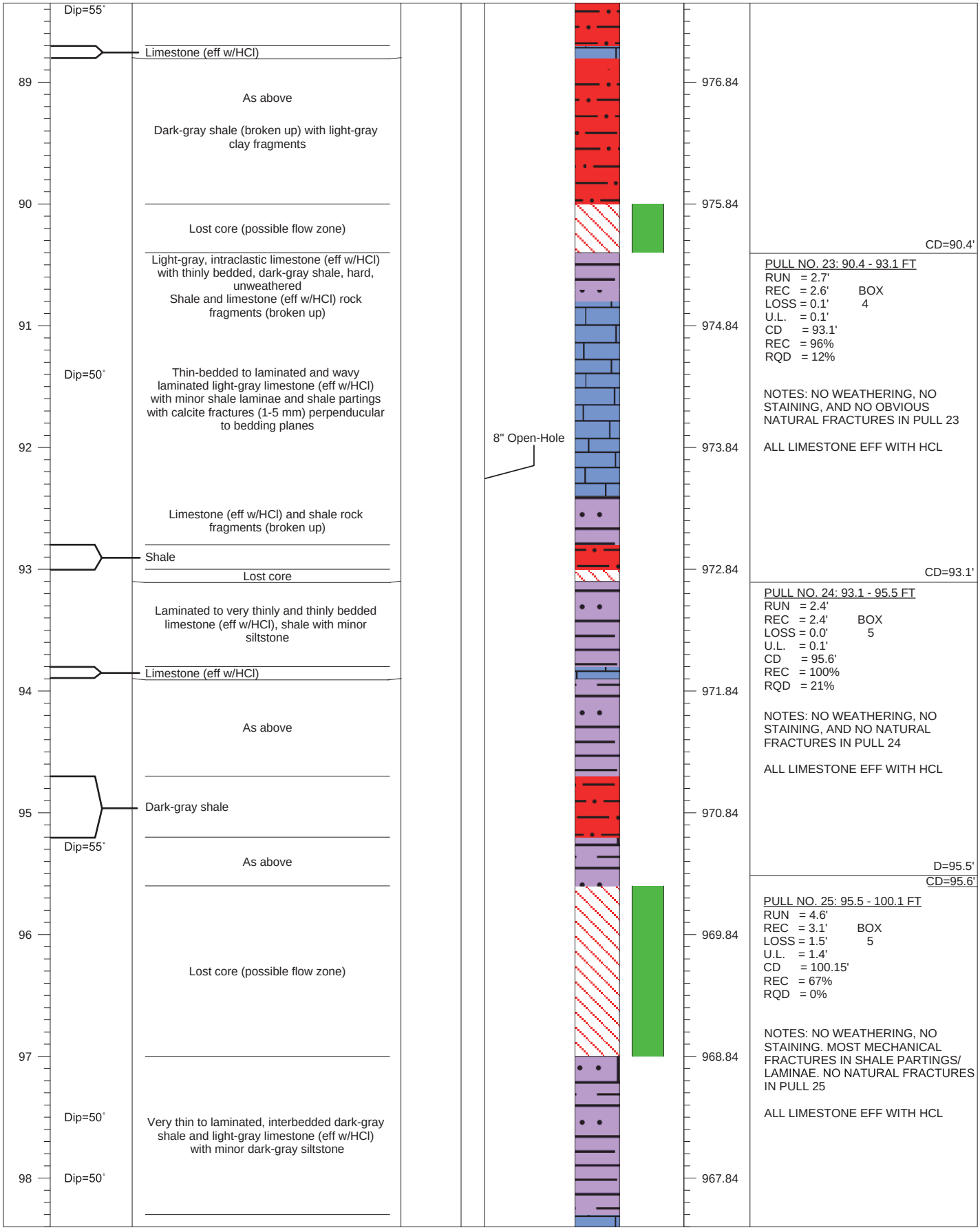
PULL NO. 21: 80.4 - 85.4 FT
RUN = 5.0'
REC = 2.8' BOX
LOSS = 2.2' 4
U.L. = 2.5'
CD = 85.7'
REC = 56%
RQD = 24%

NOTES: NO WEATHERING, NO STAINING, AND NO NATURAL FRACTURES IN PULL 21

ALL LIMESTONE STRONGLY EFF WITH HCL

PULL NO. 22: 85.4 - 90.4 FT
RUN = 5.0' CD=85.7'
REC = 4.3' BOX
LOSS = 0.7' 4
U.L. = 0.4'
CD = 90.4'
REC = 86%
RQD = 0%

NOTES: NO WEATHERING, NO STAINING, AND NO NATURAL FRACTURES IN PULL 22


Dip=55˚
Limestone (eff w/HCl)
89
As above
Dark-gray shale (broken up) with light-gray clay fragments
90
Lost core (possible flow zone)
Light-gray, intraclastic limestone (eff w/HCl) with thinly bedded, dark-gray shale, hard, unweathered
Shale and limestone (eff w/HCl) rock fragments (broken up)
91
Dip=50˚
Thin-bedded to laminated and wavy laminated light-gray limestone (eff w/HCl) with minor shale laminae and shale partings with calcite fractures (1-5 mm) perpendicular to bedding planes
92
Limestone (eff w/HCl) and shale rock fragments (broken up)
Shale
93
Lost core
Laminated to very thinly and thinly bedded limestone (eff w/HCl), shale with minor siltstone
Limestone (eff w/HCl)
94
As above
Dark-gray shale
95
Dip=55˚
As above
96
Lost core (possible flow zone)
97
Dip=50˚
Very thin to laminated, interbedded dark-gray shale and light-gray limestone (eff w/HCl) with minor dark-gray siltstone
98
Dip=50˚
8" Open-Hole
976.84
975.84
974.84
973.84
972.84
971.84
970.84
969.84
968.84
967.84
CD=90.4'
PULL NO. 23: 90.4 - 93.1 FT
RUN = 2.7'
REC = 2.6' BOX
LOSS = 0.1' 4
U.L. = 0.1'
CD = 93.1'
REC = 96%
RQD = 12%
NOTES: NO WEATHERING, NO STAINING, AND NO OBVIOUS NATURAL FRACTURES IN PULL 23
ALL LIMESTONE EFF WITH HCL
CD=93.1'
PULL NO. 24: 93.1 - 95.5 FT
RUN = 2.4'
REC = 2.4' BOX
LOSS = 0.0' 5
U.L. = 0.1'
CD = 95.6'
REC = 100%
RQD = 21%
NOTES: NO WEATHERING, NO STAINING, AND NO NATURAL FRACTURES IN PULL 24
ALL LIMESTONE EFF WITH HCL
D=95.5'
CD=95.6'
PULL NO. 25: 95.5 - 100.1 FT
RUN = 4.6'
REC = 3.1' BOX
LOSS = 1.5' 5
U.L. = 1.4'
CD = 100.15'
REC = 67%
RQD = 0%
NOTES: NO WEATHERING, NO STAINING. MOST MECHANICAL FRACTURES IN SHALE PARTINGS/ LAMINAE. NO NATURAL FRACTURES IN PULL 25
ALL LIMESTONE EFF WITH HCL

PROJECT: EMDF PHASE 1 SITE CHARACTERIZATION

INSTALLATION:
Y-12 NATIONAL SECURITY COMPLEX

DRILLING AGENCY: M&W DRILLING
NAME OF DRILLER:
GARRY AKINS (HOLLOW STEM AUGER)
GEORGE AKINS (AIR ROTARY)
LOGGED BY:
RICHARD STOUT, PG (ALLIANT CORPORATION)

THICKNESS OF OVERBURDEN: 24.4 FT
DEPTH DRILLED INTO ROCK: 75.7 FT
TOTAL DEPTH OF HOLE: 100.1 FT

ALLIANT

# DRILLING LOG

# GW-976

DATE HOLE STARTED: 08-27-14
DATE HOLE COMPLETED: 09-17-14

SIZE AND TYPE OF BIT:
6 1/4" HOLLOW STEM AUGER
14" ROLLER CONE; 7 7/8" AIR ROTARY

TOTAL NO. OF OVERBURDEN SAMPLES:
6 DISTURBED 0 UNDISTURBED

TOTAL NO. OF CORE BOXES: 5

ELEVATION OF GROUNDWATER:
1014.33 FT ON 9/18/14 (10" PVC CASING)

ELEVATION TOP OF HOLE: 1065.84 FT

TOTAL CORE RECOVERY: 78 %

| DEPTH (FT) | NOTES/ OTHER | DESCRIPTION | WELL CONST. | LITHOLOGY | ELEVATION (FT MSL) | REMARKS |
|---|---|---|---|---|---|---|
| 99 | Dip=50˚ | Light-gray limestone, medium-bedded with 2 shale partings (4-inch or 10 cm thick) parallel to bedding | Total Borehole Depth 100.3 FT | | 966.84 | |
| | | Dark-gray siltstone, hard | | | | |
| | Dip=40˚ | Very thin to laminated, interbedded dark-gray shale and light-gray limestone (eff w/HCl) with minor dark-gray siltstone | | | | |
| 100 | | Limestone and shale rock fragments (broken up). Bottom of rock coring @ 100.1 ft | | | 965.84 | D=100.1' |
| | | 100.1 FT | | | | NOTE: COMPLETED ROCK CORING TO 100.1 FT AT GW-976 @ 1231 ON 9-16-14. HOLE REAMED TO 101 FT VIA AIR ROTARY @ 0949 ON 9-17-2014 (8-INCH HOLE). OPEN HOLE TO 100.3 FT AFTER SLIGHT CAVE-IN |
| | | No data (drill thru) | Borehole Collapse @ 100.3-101' | | | |
| | | 101 FT | | | 964.84 | 101 FT |

BOTTOM OF HOLE

## GW-976 Legend

- Clayey silt
- Gravel
- Possible flow zone?
- Limestone
- Interbedded, mostly laminated limestone and shale
- Lost core/No data
- Shale
- Interbedded, laminated-thin bedded shale and siltstone
- Siltstone

GW-977

1. HOLE NUMBER

| DRILLING LOG<br>For use of this form, see EM 1110-1-1804; the proponent agency is CECW-EG. | 2. DIVISION | 3. INSTALLATION<br>Y-12 | SHEET 1 of<br>OF 1 SHEETS |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 4. PROJECT<br>EMDF Phase 1 | | 13. SIZE AND TYPE OF BIT<br>10" O.D. HSA | |
| | | 14. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*<br>MSL | |
| 5. LOCATION *(Coordinates or Station)*<br>N 30831.10; E 49397.44 | | 15. MANUFACTURERS DESIGNATION OF DRILL<br>MOBILE B-59 Hollow Stem Auger Rig | |
| 6. DRILLING AGENCY<br>M&W DRILLING | | 16. TOTAL NO. OF OVER BURDEN SAMPLES TAKEN | a. DISTURBED<br>0 / b. UNDISTURBED<br>1 |
| 7. HOLE NUMBER *(as shown on drawing title and title number)*<br>GW-977 | | 17. TOTAL NUMBER CORE BOXES<br>N/A | |
| | | 18. ELEVATION GROUND WATER<br>Well is Dry | |
| 8. NAME OF DRILLER<br>George Akins | | 19. DATE HOLE *(YYYYMMDD)* | a. STARTED<br>2014-09-24 / b. COMPLETED<br>2014-09-24 |
| 9. DIRECTION OF HOLE<br>☒ a. VERTICAL ☐ b. INCLINED | c. DEG. FROM VERT. | 20. ELEVATION TOP OF HOLE *(feet)*<br>1065.63 FT | |
| 10. THICKNESS OF OVERBURDEN<br>24.4' | | 21. TOTAL CORE RECOVERY FOR BORING %<br>N/A | |
| 11. DEPTH DRILLED INTO ROCK<br>0 | | 22. SIGNATURE OF INSPECTOR<br>Jack Strader | |
| 12. TOTAL DEPTH OF HOLE<br>24.4' | | | |

| 23. ELEVATION | a. DEPTH | b. LEGEND | c. CLASSIFICATION OF MATERIALS *(Description)* | d. % CORE RECOVERY | e. BOX OR SAMPLE NUMBER | f. REMARKS *(Drilling Time, water loss, depth of weathering, etc., if significant)* |
|---|---|---|---|---|---|---|
| | | 4<br>8<br>12<br>16<br>20<br>24<br>28 | GRAVEL<br>Clayey Silt (mc) yellow-orange<br>Shelby tube from 10-10.7 FT<br>For soil description see drilling log for GW-976<br>25.5'<br>BOH | %<br>%<br>%<br>%<br>%<br>%<br>% | | 28% Recovery on Shelby tube<br>Auger Refusal @ 25.50' on bedrock<br>Note: No groundwater detected in soil boring or completed well. |

ENG FORM 1836, MAR 1971 PREVIOUS EDITIONS ARE OBSOLETE. *(Translucent)*

PROJECT: EMDF Phase 1 | HOLE NUMBER: GW-977

VERSION 1.0

This page intentionally left blank.

# EXHIBIT A.5:
# PHOTOGRAPHS OF SPLIT-TUBE SAMPLES OF REGOLITH MATERIALS

This page intentionally left blank.

# GW-968

Split-spoon (0-2 ft) at GW-968

2nd Split-spoon (4.5-6.3 ft) at GW-968 (split-spoon refusal)

3rd Split-spoon (9.5-10 ft) at GW-968 showing saturation on top of damp siltstone

# GW-970

Note: Photos are not available for split-spoons at 0.5-2 ft and 4.0-5.5 ft at GW-970

3rd Split-spoon upper section close up of 9-10.5 ft interval at GW-970

4th Split-spoon (14-15.5 ft) at GW-970

4th Split-spoon close up of 14-15.5 ft interval (GW-970)

# GW-970 continued

5th Split-spoon (19-21.3 ft) at GW-970 showing horizontal bedding at top of sample

5th Split-spoon (19-21.3 ft) at GW-970 showing distorted/ fractured bedding, reddish iron and black mineral stains

6th Split-spoon (24-24.8 ft) at GW-970

# GW-972

1st Split-spoon (0-2 ft) at GW-972

2nd Split-spoon (3.5-5.5 ft) at GW-972 (weathered shale)

3rd Split-spoon (8.5-10.5 ft) at GW-972

Note: Photos are not available for split-spoons at 13.5-15.5 ft, 18.5-20.5 ft, & 23.5-24.2 ft

# GW-974

1st Split-spoon (0-2 ft) at GW-974

Scanning 2nd split-spoon (4.5-6.5 ft)

3rd Split-spoon (9.5-10.8 ft) at GW-974 - split-spoon refusal (auger refusal at 12.5 ft)

# GW-976

1st Split-spoon (0.5-2 ft) at GW-976

2nd Split-spoon (4.5-6 ft) at GW-976

Top of 3rd Split-spoon (9-10.5 ft) at GW-976

# GW-976 continued

4th Split-spoon (14-15.5 ft) Relic bedding at GW-976

Relic bedding in 5th Split-spoon (19-20.5 ft) at GW-976

6th Split-spoon (24.0-24.4 ft) at GW-976. Spoon and auger refusal at 24.4ft.

This page intentionally left blank.

# EXHIBIT A.6:
# WELL DRILLING AND CONSTRUCTION ACTIVITY/PROGRESS REPORTS

This page intentionally left blank.

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

**WELL NO.** GW-968

**PAGE** 1 **of 1**

| | | | |
|---|---|---|---|
| **LOCATION:** | EMDF | **DATE: START:** | 9-3-14 @ 0938 |
| **OPERATOR:** | M&W DRILLING | **FINISH:** | 12-23-14 @ 1020 |
| **HELPER:** | Michael Moss<br>Vince Amburn | **DRILLING METHODS:** | Air Rotary<br>HSA |
| **DRILLER:** | Garry Akins / George Akins | **LOGGED BY:** | Richard Stout |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-3-14 | 0938 | 1030 | Soil sampling (split-spoon) and augering to ~10' |
| 9-8-14 | 1145 | 1518 | Ream to 14", set 10" PVC casing to 10' |
| 9-10-14 | 0942 | 1500 | Air Rotary 8" to 100 ft |
| 11-03-14 | 1045 | 1410 | Install 4" PVC casing and screen w/ 5 ft stainless-steel riser |
| 11-04-14 | 0725 | 0732 | Add bentonite pellets to top of sandpack |
| 11-04-14 | 1425 | 1428 | Add grout and install 4" protective casing |
| 11-05-14 | 0740 | 1159 | Develop well by surging and pumping (370-gal) |
| 11-06-14 | 0838 | 1407 | Install form, pour 4' x 4' x 0.5' concrete pad, drill weep hole |
| 12-23-14 | 0810 | 1020 | Install additional 5 ft of stainless-steel (ss) riser, install ID tag |
| 2-9-2015 | 1000 | 1100 | Install additional 5.04 ft ss riser (10.04 ft total) (1082.56 ft MSL) |
| 2-11-2015 | 1300 | 1400 | Re-set and re-seal riser due to leak from bottom joint |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

**WELL NO.** GW-969

**PAGE** 1 **of 1**

**LOCATION:** EMDF Y-12
**OPERATOR:** George Akins
**HELPER:** Shadoe Anderson
**DRILLER:** M&W Drilling

**DATE: START:** 9-25-14 @ 1230
**FINISH:** 12-23-14 @ 1427
**DRILLING METHODS:** HSA
**LOGGED BY:** Jack Strader

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-25-14 | 1230 | 1510 | Auger, take Shelby tube, set well (13.5 FT) |
| 9-29-14 | 1330 | 1345 | Grout well, add 0.2' to riser, set protective casing |
| 9-30-14 | 1230 | 1300 | Begin developing & pumped dry (~8 gal) |
| 10-1-14 | 0730 | 1430 | Build pad (4' x 4' x 0.5') |
| 10-1-14 | 1400 | 1430 | Continue developing & pumped dry (~12 gal) |
| 10-7-14 | 0910 | 0924 | Complete development & pumped dry 2x (~14 gal) |
| 12-23-14 | 0810 | 1427 | Install ID tag |
| 2-9-15 | 1000 | 1100 | Install additional 5 ft of PVC casing |
| 2-11-15 | 1400 | 1600 | Install another 5 ft of PVC casing (10 ft total) (1082.98 ft MSL) |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

**WELL NO.** GW-970

**PAGE** 1 **of** 1

| | | | |
|---|---|---|---|
| **LOCATION:** | EMDF | **DATE: START:** | 8-27-14 @ 1034 |
| **OPERATOR:** | M&W DRILLING | **FINISH:** | 12-23-14 @ 1327 |
| **HELPER:** | Michael Moss, Vince Amburn<br>Gary Akins (Auger - M&W) | **DRILLING METHODS:** | Hollow Stem Auger<br>Air Rotary |
| **DRILLER:** | Geoge Akins (Air.R. - M&W) | **LOGGED BY:** | Jack Strader / Richard Stout |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 8-27-14 | 1034 | 1356 | Auger, split spoon @ 5' Interv. Refusal @ 26.5' |
| 9-2-14 | 0940 | 1230 | Ream, set 10" casing @ 34' |
| 9-2-14 | 1330 | 1630 | Began tremmie of grout in annular space |
| 9-9-14 | 1430 | 1530 | Completed tremmie of grout at GW-970 |
| 9-16-14 | 0830 | 1416 | Drilled to 101 ft bgs using 8" bit (Air Rotary) |
| 11-4-14 | 1043 | 1215 | Install collar and PVC riser extension |
| 11-6-14 | 1013 | 1407 | Install Protective Casing, 4' x 4' x 0.5' pad, drill weep hole |
| 12-23-14 | 0810 | 1327 | Install lanyard for vented well cap, and install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

**WELL NO.** GW-971

**PAGE** 1 **of** 1

| | | | |
|---|---|---|---|
| **LOCATION:** | EMDF | **DATE: START:** | 9-18-14 @ 0800 |
| **OPERATOR:** | M&W DRILLING | **FINISH:** | 12-23-14 @ 1427 |
| **HELPER:** | Michael Moss | **DRILLING METHODS:** | HSA |
| **DRILLER:** | George Akins | **LOGGED BY:** | R. Stout / J. Strader |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-17-14 | 0800 | 1450 | Auger, Shelby tubes, set well |
| 9-18-14 | 0754 | 1200 | Tremmie Grout, installed protective steel casing |
| 9-18-14 | 1400 | 1430 | Build concrete pad (4' x 4' x 0.5') |
| 9-22-14 | 1330 | 1345 | Begin developing and pump dry (~15.5 gal) |
| 9-23-14 | 0725 | 0745 | Continue developing and pump dry (7.5 gal) |
| 9-29-14 | 1535 | 1552 | Continue developing and pump dry (~3.5 gal) |
| 9-30-14 | 1520 | 1533 | Complete development, pump dry (~10 gal) |
| 12-23-14 | 0810 | 1327 | Install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

**WELL NO.** GW-972

**PAGE** 1 **of** 1

| | | | |
|---|---|---|---|
| **LOCATION:** | EMDF Site | **DATE: START:** | 9-2-14 |
| **OPERATOR:** | M&W Drilling | **FINISH:** | 12-23-14 |
| **HELPER:** | Michael Mass / Vince Amburn | **DRILLING METHODS:** | Air Rotary<br>H. Stem Auger |
| **DRILLER:** | George Akins (Air Rotary) Gary Akins (H. Stem Auger) | **LOGGED BY:** | J. Strader, R. Stout |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-2-14 | 0830 | 1130 | Soil Samp. & Augering, Refusal @ 24.2' bgs |
| 9-3-14 | 0926 | 1630 | Set Air Rig in Prep for Over Reaming |
| 9-4-14 | 0730 | 0939 | Over Reaming & Setting of 24.6' Casing |
| 9-4-14 | 0939 | 1057 | Tremmie Grout in Annular Space |
| 9-8-14 | 0923 | 1635 | Core rock to ~55 FT |
| 9-9-14 | 0904 | 1632 | Core rock to ~90 FT |
| 9-10-14 | 0731 | 0920 | Finish coring rock to 100.3 FT bgs |
| 9-11-14 | 0930 | 1400 | Air Rotary 8" to 101 FT |
| 11-04-14 | 1215 | 1400 | Install collar and PVC riser extension |
| 11-06-14 | 0801 | 0830 | Install Protective Casing, 4' x 4' x 0.5' pad, drill weep hole |
| 12-23-14 | 1124 | 1327 | Install lanyard for vented well cap, and install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT | WELL NO. GW-973<br>PAGE 1 of 1 |
|---|---|

| | | | |
|---|---|---|---|
| **LOCATION:** | EMDF Y-12 | **DATE: START:** | 9-25-14 |
| **OPERATOR:** | George Akins | **FINISH:** | 12-23-14 |
| **HELPER:** | Shadoe Anderson | **DRILLING METHODS:** | HSA |
| **DRILLER:** | M&W Drilling | **LOGGED BY:** | J. Strader |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-25-14 | 0745 | 0921 | Auger, Shelby tube, set well at 23' BGS |
| 9-29-14 | 1404 | 1426 | Grout well, set protective casing |
| 9-30-14 | 1420 | 1500 | Begin developing & pumped well dry (~24 gal) |
| 10-1-14 | 0730 | 1400 | Build pad (4' x 4' x 0.5') |
| 10-1-14 | 1400 | 1430 | Continue developing & pumped well dry (~20 gal) |
| 10-2-14 | 1042 | 1052 | Complete development & pumped well dry (~19 gal) |
| 12-23-14 | 1124 | 1421 | Install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

WELL NO. GW-974

PAGE 1 of 1

| | | | |
|---|---|---|---|
| LOCATION: | EMDF Site | DATE: START: | 9-2-14 |
| OPERATOR: | M&W Drilling | FINISH: | 12-23-14 |
| HELPER: | Michael Moss / Shadoe Anderson | DRILLING METHODS: | H. Stem Auger<br>Air Rotary |
| DRILLER: | Garry Akins (H. Stem Auger)<br>George Akins (Air Rotatry) | LOGGED BY: | R. Stout, Jack Strader |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-2-14 | 1446 | 1559 | Soil Sampling (split spoon) and augering |
| 9-8-14 | 0730 | 0930 | Ream hole to 14" and set 10" PVC casing w/ air rotary |
| 9-11-14 | 0720 | 0903 | Overdrill & install 8" casing |
| 9-15-14 | 1300 | 1445 | Drilled to 101 ft using 8" Air Rotary |
| 11-06-14 | 1215 | 1300 | Installed form, pour 4' x 4' x 0.5' concrete pad, drill weep hole |
| 12-23-14 | 1305 | 1327 | Install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

WELL NO. GW-975

PAGE 1 of 1

| | | | |
|---|---|---|---|
| LOCATION: | EMDF | DATE: START: | 9-29-14 |
| OPERATOR: | M&W Drilling | FINISH: | 12-23-14 |
| HELPER: | Shadoe Anderson | DRILLING METHODS: | H. Stem Auger |
| DRILLER: | George Akins | LOGGED BY: | R. Stout |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-29-14 | 0826 | 1129 | HSA drilling, Collect Shelby tube, set well (10 FT) |
| 9-30-14 | 1158 | 1205 | Begin developing, well pumped dry (~2 gal) |
| 10-1-14 | 0730 | 1430 | Build pad (4'x4'), fill last 1.9' w/ cement. Install protective casing |
| 10-1-14 | 1002 | 1008 | Continue developing, bailed dry (~1.5 gal) |
| 10-6-14 | 0930 | 0936 | Complete development, bailed dry (~2.0 gal) |
| 12-23-14 | 1305 | 1427 | Install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT

**WELL NO.** GW-976

**PAGE** 1 **of** 1

| | | | |
|---|---|---|---|
| **LOCATION:** | EMDF | **DATE: START:** | 8-27-14 |
| **OPERATOR:** | M&W Drilling | **FINISH:** | 12-23-14 |
| **HELPER:** | Michael Moss (H. Stem Auger)<br>Vince Amburn (Air Rotary) | **DRILLING METHODS:** | H. Stem Auger<br>Air Rotary |
| **DRILLER:** | Gary Akins (H. Stem Auger)<br>George Akins (Air Rotary) | **LOGGED BY:** | J. Strader, R. Stout |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 8-27-14 | 1600 | 1638 | Set Auger Rig in Prep for Soil Sampling |
| 8-28-14 | 0814 | 1050 | Soil Sampling, Auger Refusal @ 24.4 FT BGS |
| 9-9-14 | 1200 | 1249 | Install 10" casing (PVC) |
| 9-10-14 | 1553 | 1647 | Core Rock to ~35 FT |
| 9-11-14 | 0736 | 1443 | Core rock (Thunderstorm at ~1440) @ ~50 FT |
| 9-15-14 | 0837 | 1645 | Core rock to ~77 FT |
| 9-16-14 | 0754 | 1231 | Core rock to 100.1 FT |
| 9-17-14 | 0830 | 0949 | Air Rotary 8" to 101 FT |
| 11-4-14 | 1007 | 1017 | Install Colllar and PVC riser extension |
| 11-6-14 | 0944 | 1153 | Install Protective casing, 4' x4' x 0.5' pad, drill weep hole |
| 12-23-14 | 0810 | 1327 | Install lanyard for vented well cap, and install ID tag |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| WELL DRILLING & CONSTRUCTION ACTIVITY/PROGRESS REPORT | WELL NO. GW-977<br>PAGE 1 of 1 |
|---|---|

| | | | |
|---|---|---|---|
| LOCATION: | EMDF | DATE: START: | 9-24-14 |
| OPERATOR: | M&W Drilling | FINISH: | 12-23-14 |
| HELPER: | Shadoe Anderson | DRILLING METHODS: | HSA |
| DRILLER: | George Akins | LOGGED BY: | J. Strader |

| DATE | TIME | | ACTIVITY/COMMENTS |
|---|---|---|---|
| | START | FINISH | |
| 9-24-14 | 0800 | 1500 | Auger, push Shelby tube, set casing |
| 9-29-14 | 1225 | 1250 | Grout well, set protective casing |
| 10-1-14 | 0730 | 1430 | Build concrete pad (4' x 4' x 0.5') |
| 12-23-14 | 1020 | 1327 | Install ID tag |
| | | | |
| | | | Well is dry and was not developed |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# EXHIBIT A.7:
# ROCK CORE PHOTOGRAPHS

This page intentionally left blank.

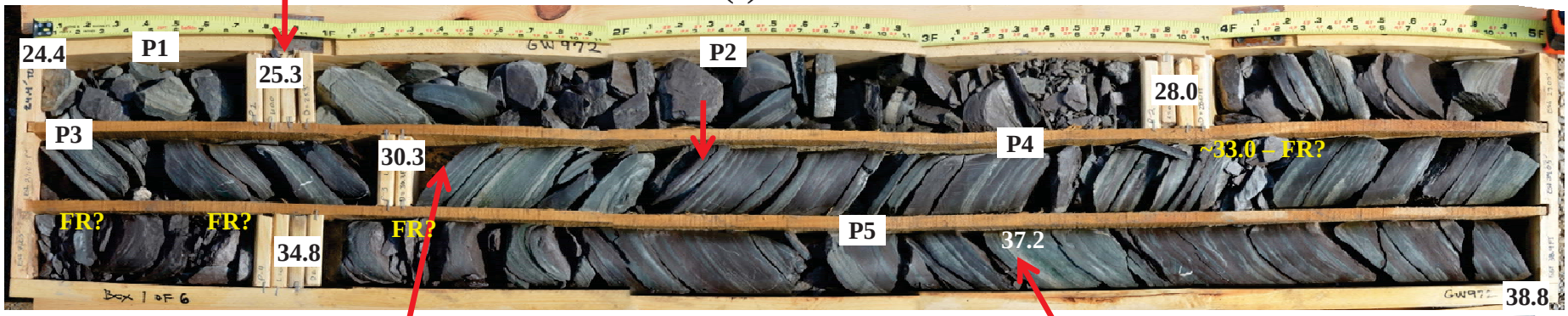
# Rock Core Photos – GW-972(I)
# Rutledge Limestone (Friendship Formation)

- Depths below ground surface (bgs) are shown in black and white at points along core boxes for reference to detailed boring logs
- Core runs or “Pulls” are indicated by P1, P2, etc., located near the center of each pull; pull blocks are located at the base of each core run
- Fracture intervals are indicated by “FR” at approximate midpoint of fracture interval. FR? indicates uncertainty regarding whether fractures are natural or mechanically induced
- Most breaks in relatively intact sections of cores occur along weak bedding plane partings and are mechanical breaks and likely not indicative of natural in-situ fractures
- True in-situ fracture conditions cannot be discerned from intervals with disaggregated broken up sections of core; intact core sections provide the most reliable indications of naturally occurring fracture conditions
- Boring logs should be referenced for detailed comparison of log photos with pull data, rock core descriptions, and measured maximum bedding plane dip angles

**Note:** **Pull blocks located at base of each Core Barrel Pull**

## GW-972(I) – Box 1 of 6

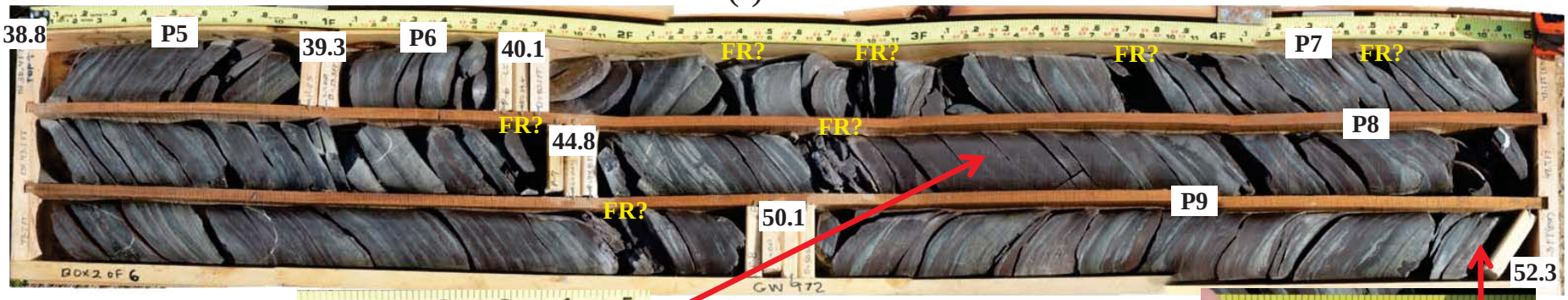
**Note: Entire rock core is within the saturated zone of ground water**

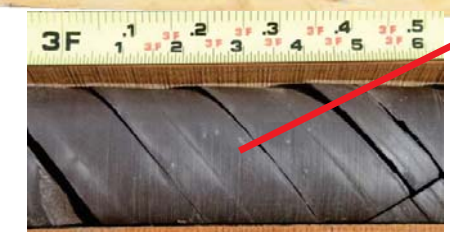


Finely laminated shale/mudstone & limestone/calcareous siltstone (white lamina) w/HCL effervescence

Interbedded & finely laminated shale (maroon) /mudstone & limestone/calcareous siltstone (white layer) w/HCL effervescence (Note green glauconitic layer)

## GW-972(I) – Box 2 of 6

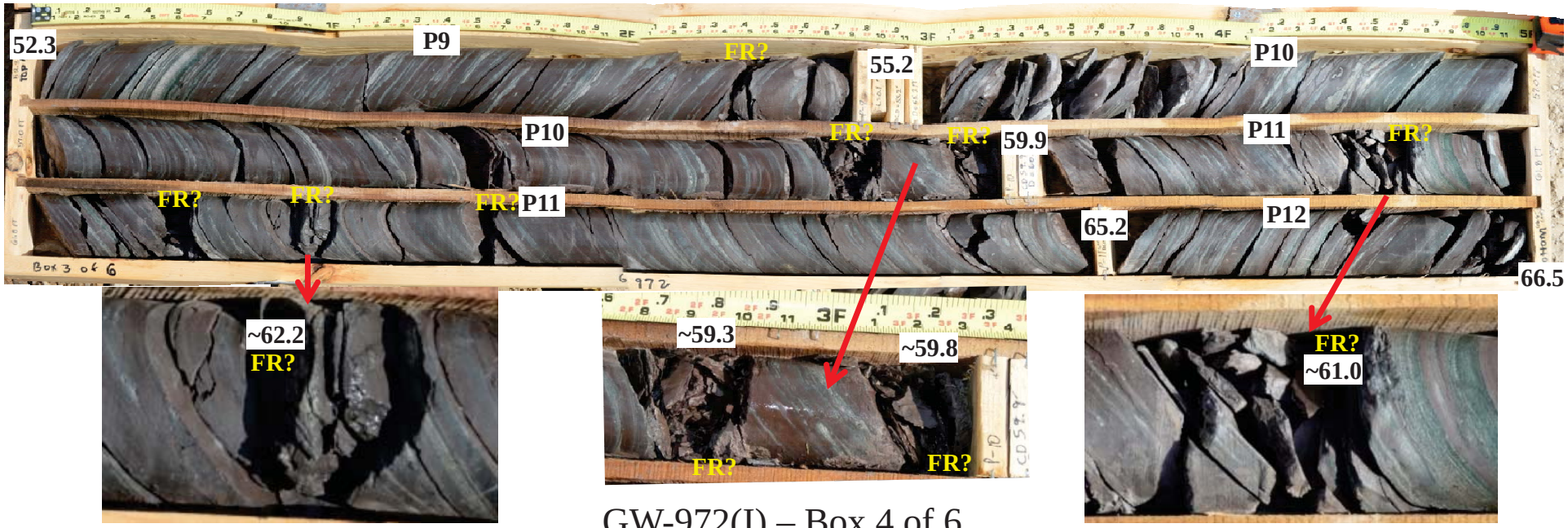


Homogeneous maroon shale bed ~ 1 ft thick; most fractures throughout core appear to be all mechanical breaks

Laminated limestone/calc. siltstone bed (~0.15 ft thick – HCL effervescence) interbedded w/ maroon shale

# GW-972(I) – Box 3 of 6





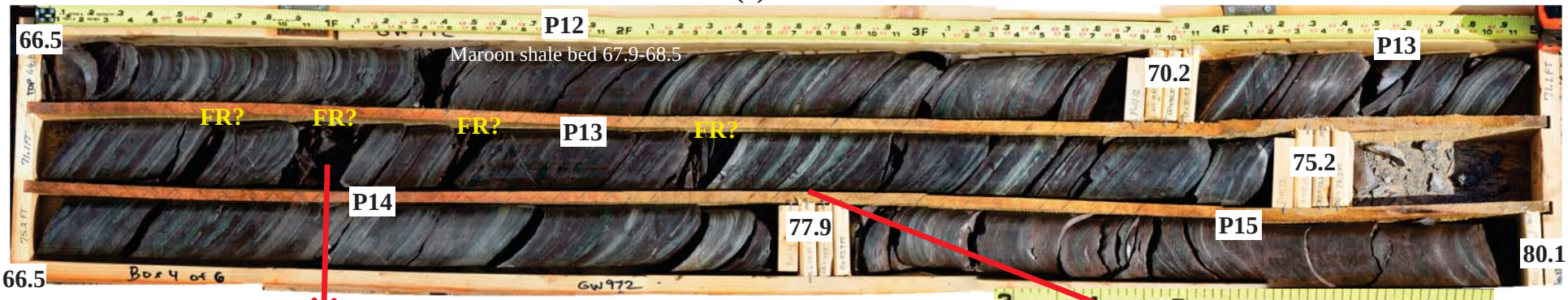




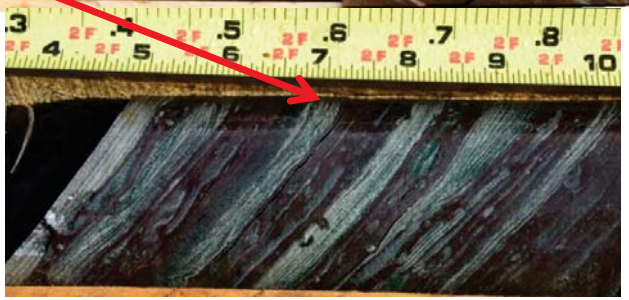




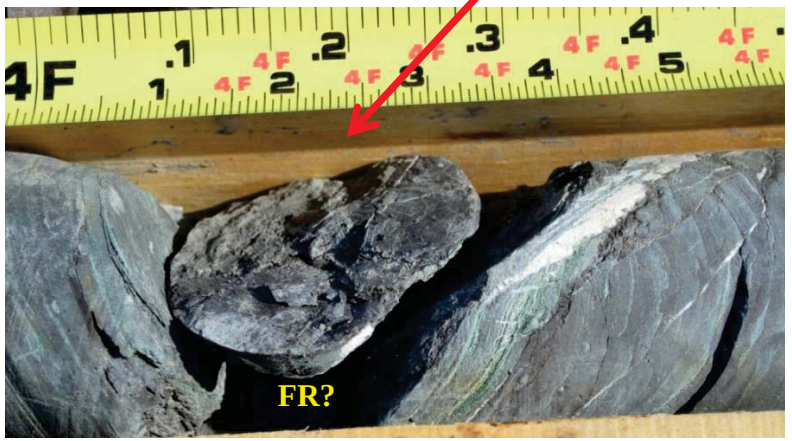
# GW-972(I) – Box 4 of 6

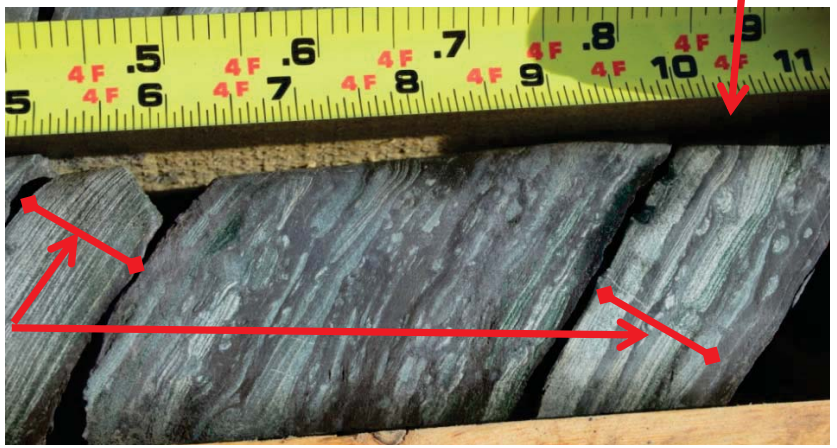


Interbedded laminated maroon shale and light gray calcareous siltstone/limestone with no evidence of dissolution

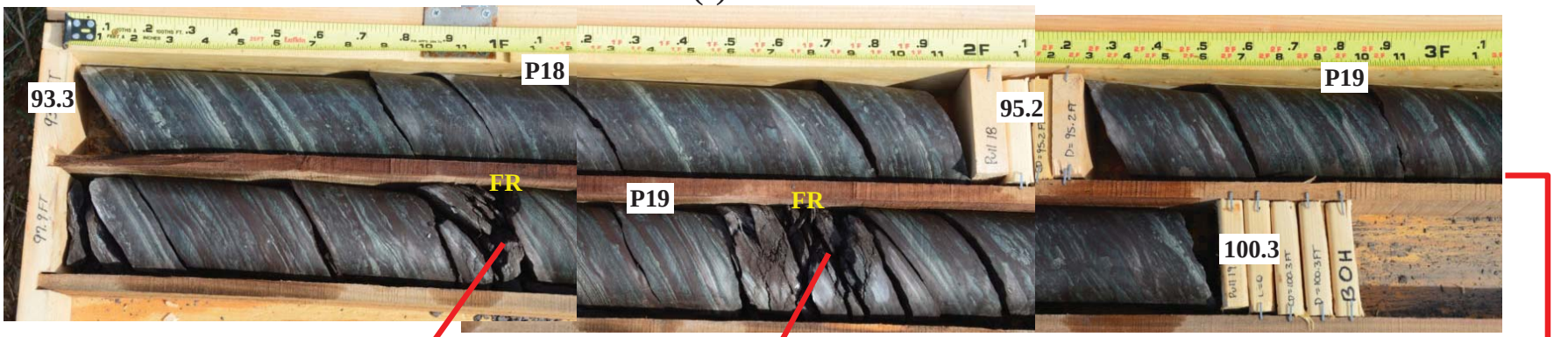


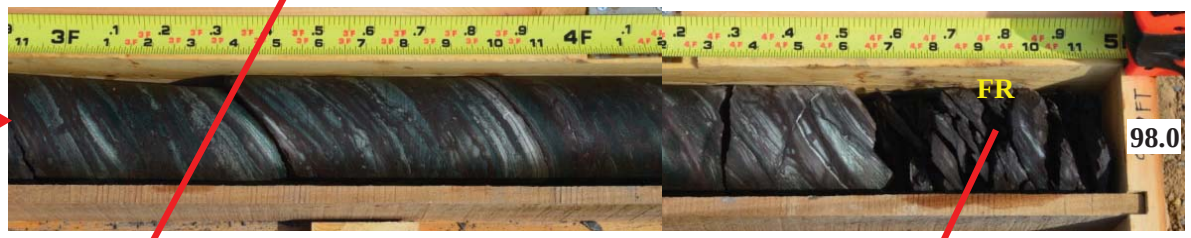
# GW-972(I) – Box 5 of 6



Interbedded laminated maroon shale and light gray calcareous siltstone/limestone with no evidence of dissolution; light gray layers at each end of photo effervesce readily with HCL



Naturally fractured intervals at depths of 98.8 and 99.5 ft bgs

Naturally fractured interval ~0.4 ft thick from 97.6-98.0 ft bgs

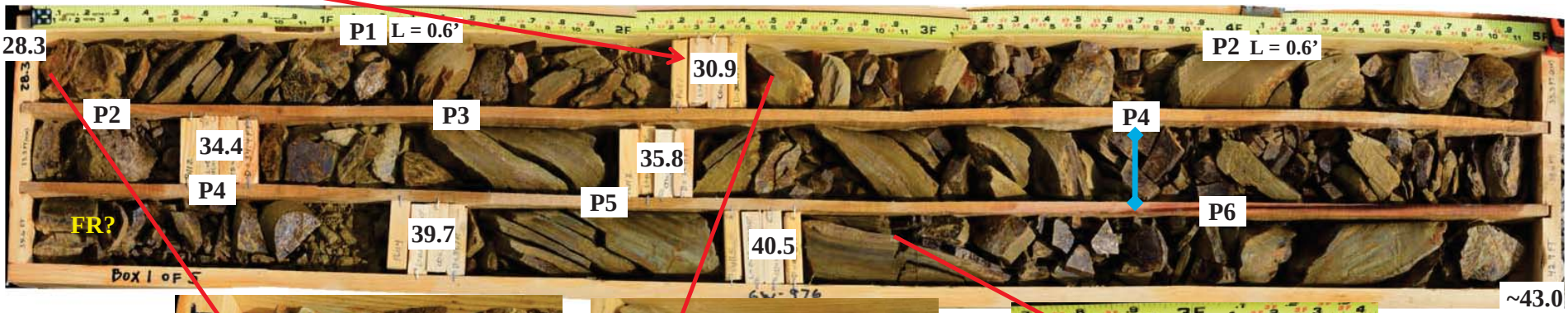
# Rock Core Photos – GW-976(I)
# Maryville Limestone (Dismal Gap Formation)

- Depths below ground surface (bgs) are shown in black and white at points along core boxes for reference to detailed boring logs; depths shown are “corrected depths” measured in borehole by weighted taper after each pull
- Core runs or “Pulls” are indicated by P1, P2, etc., located near the center of each pull; pull blocks are located at the base of each core run; Core loss >0.5 ft shown by “L” followed by core length lost in feet; core loss <0.5 ft not shown – see boring log for details on where core loss interpreted to occur; Core run gains not shown; caliper log “washout” intervals assumed to equal core loss intervals in most cases.
- Fracture intervals are indicated by “FR” at approximate midpoint of fracture interval. FR? indicates uncertainty regarding whether fractures are natural or mechanically induced
- Most breaks in relatively intact sections of cores occur along weak bedding plane partings and are mechanical breaks and likely not indicative of natural in-situ fractures
- True in-situ fracture conditions cannot be discerned from intervals with disaggregated broken up sections of core; intact core sections provide the most reliable indications of naturally occurring fracture conditions
- Boring logs should be referenced for detailed comparison of log photos with pull data, rock core descriptions, and measured maximum bedding plane dip angles

**Note:** Pull blocks located at base of each Core Barrel Pull

## GW-976(I) – Box 1 of 5

Blue line = Seasonal high water level on 1/20/15 @ 37.3 ft bgs



FeO/MnO staining of highly weathered vadose zone

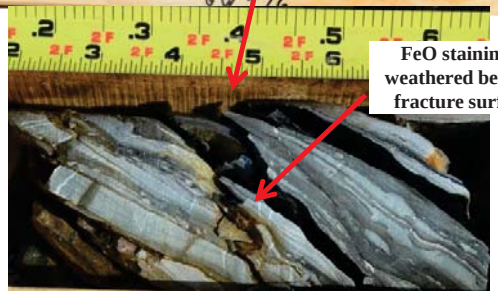
Weathered & steeply dipping siltstone & shale in zone of water table fluctuation

~Water level in borehole 9/15/14 @ ~43.0' bgs

## GW-976(I) – Box 2 of 5

Note transition in Box 2 from highly weathered brown to less weathered gray bedrock from ~50-54 ft bgs

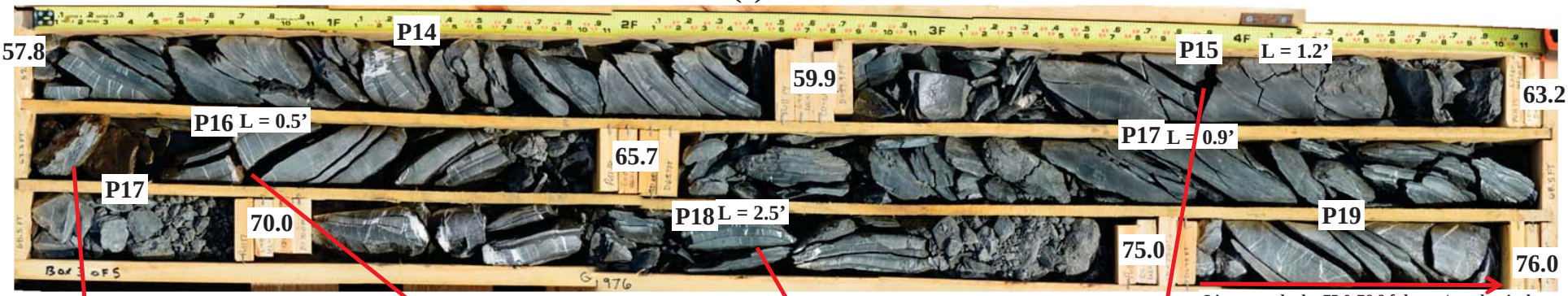
FeO staining of highly weathered bedrock fracture surfaces

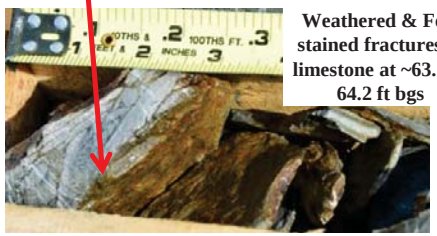


FeO staining of weathered bedrock fracture surfaces

FeO staining of fracture perpendicular to steeply dipping bedding planes in limestone layer – note fracture does not extend into next layer

# GW-976(I) – Box 3 of 5



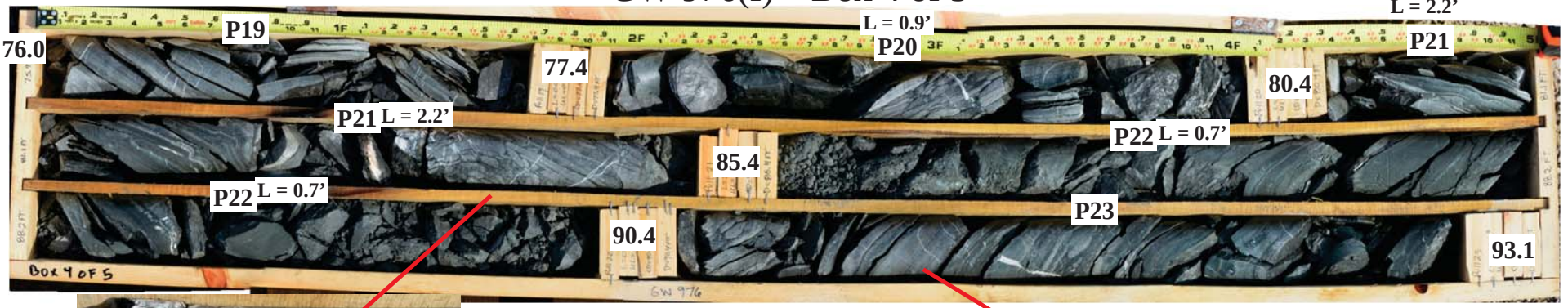
Weathered & FeO stained fractures in limestone at ~63.5 & 64.2 ft bgs

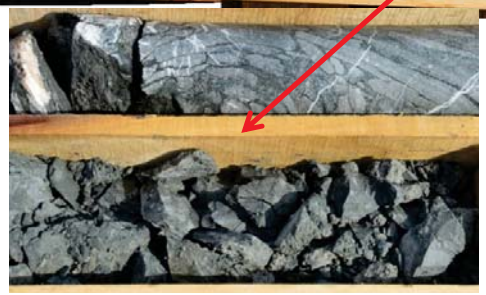
Typical mechanical break along shaly parting

Limestone bed – 75.0-76.8 ft bgs w/ mechanical fractures mostly along shaly partings

Typical homogeneous gray shale w/ mechanical fractures

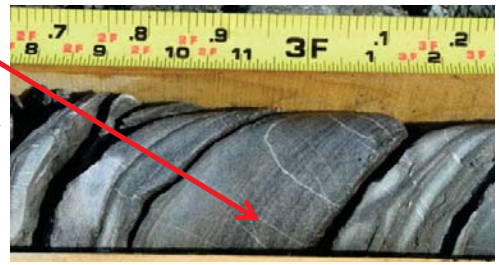
# GW-976(I) – Box 4 of 5



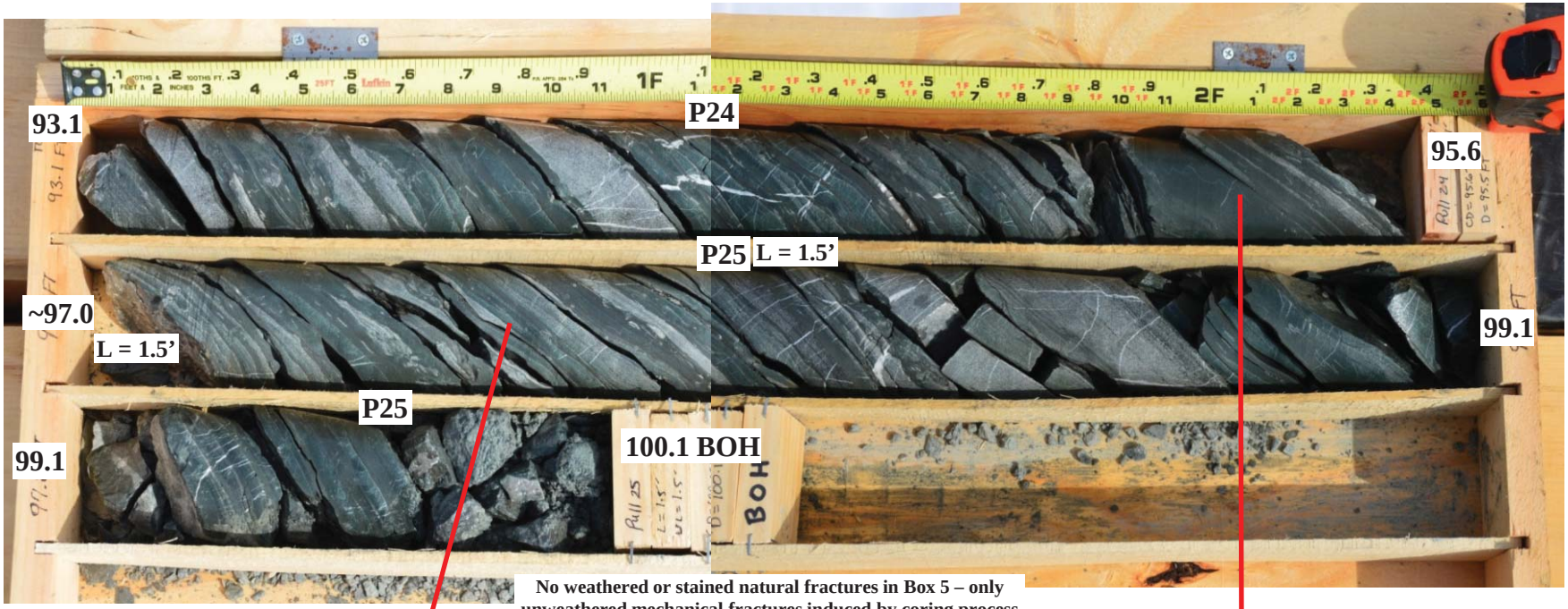
Unweathered intraclastic limestone (upper); crumbled homogeneous gray shale (lower)

No weathered or stained natural fractures in Box 4 – only unweathered mechanical fractures induced by coring process



Unweathered laminated limestone w/mechancial breaks along shaly partings

# GW-976(I) – Box 5 of 5




**No weathered or stained natural fractures in Box 5 – only unweathered mechanical fractures induced by coring process**

**Interbedded laminated to very thin bedded shale/mudstone (mostly dark gray) and limestone (light gray/greenish gray)**

**Homogeneous dense gray shale w/apparent mechanical fractures and few limestone lamina**

This page intentionally left blank.

# EXHIBIT A.8:
# URS BOREHOLE GEOPHYSICAL LOGGING REPORT

This page intentionally left blank.

# FINAL REPORT

# BOREHOLE GEOPHYSICAL LOGGING IN SUPPORT OF THE LIMITED PHASE I SITE CHARACTERIZATION AT THE PROPOSED EMDF SITE, OAK RIDGE, TENNESSEE

**Prepared For:**

**Alliant Corporation**
320 N Cedar Bluff Road, Suite 200
Knoxville, TN 37923

**Prepared By:**

**URS Corporation**
12120 Shamrock Plaza, Suite 100
Omaha, NE 68154

URS Project Number: 16170860

December 2014

URS Corporation
12120 Shamrock Plaza, Suite 100
Omaha, NE 68154
Tel: 402.334.8181
Fax: 402.334.1984

**This page intentionally left blank.**

# Table of Contents


**1. Introduction ..... 1**

1.1. Scope of Work ..... 1

**2. Borehole Geophysical Logging ..... 1**

2.1. Equipment ..... 1

2.2. Software ..... 5

2.3. Data Collection ..... 5

2.4. Log Data Processing ..... 7

**3. Results ..... 9**

3.1. GW-968 ..... 9

3.2. GW-970 ..... 10

3.3. GW-972 ..... 11

3.4. GW-974 ..... 12

3.5. GW-976 ..... 13

**4. Conclusions ..... 14**

4.1. GW-968 ..... 14

4.2. GW-970 ..... 15

4.3. GW-972 ..... 16

4.4. GW-974 ..... 16

4.5. GW-976 ..... 17

**5. References ..... 18**

**Figures**

Figure 1 Site Location Map ..... 2

Figure 2 Peak Picked on Heat Pulse Shot ..... 5

**Photos**

Photo 1- Log acquisition system ..... 1

Photo 2 - Calibration jig shown with one arm folded for transport ..... 3

**Tables**

Table 4-1 GW-968 Potential water-bearing zones ..... 15

Table 4-2 GW-970 Potential water-bearing zones ..... 15

Table 4-3 GW-972 Potential water-bearing zones ..... 16

Table 4-4 GW-974 Potential water-bearing zones ..... 17

**Tables (concluded)**

Table 4-5 GW-976 Potential water-bearing zones ..... 17

**Appendices**

Appendix A – Geophysical Logs

Appendix B – Calibration Certificates

Appendix C – Quality Control Forms

Appendix D – Radiological Control Green Tags

Appendix E – Field Log

**Acronyms and Abbreviations**

| | |
|---|---|
| ° | Degrees |
| °C | Degrees Celsius |
| Alliant | Alliant Corporation |
| ALT | Advanced Logic Technology s.a. |
| API | American Petroleum Institute |
| ASCII | American Standard Code for Information Interchange |
| ATV | Acoustic Televiewer |
| bgs | Below Ground Surface |
| CCD | Charge Coupled Device |
| CD | Compact Disk |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| ft | Feet |
| gamma | Natural Gamma Ray |
| gpm | Gallons per Minute |
| MHz | Megahertz |
| mm | Millimeter |
| Mount Sopris | Mount Sopris Instrument Company |
| mV | Millivolt |
| ohm-m | Ohm-meter |
| ORAU | Oak Ridge Associated Universities |
| OTV | Optical Televiewer |
| PDF | Portable Document Format |
| PVC | Polyvinyl Chloride |
| Pro2Serve® | Professional Project Services, Inc. |
| RADCON | Radiological Control |
| SP | Spontaneous Potential |
| TD | Total Depth |
| TVD | True Vertical Depth |
| URS | URS Corporation |

# 1. Introduction

URS Corporation (URS) was contracted by Alliant Corporation (Alliant) under Basic Ordering Agreement 14-SC-000798 to perform borehole geophysical logging in support of a Limited Phase I Site Characterization at the proposed Environmental Management Disposal Facility (EMDF) site. Alliant's Limited Phase I Site Characterization project scope is to conduct a limited evaluation of geology, ground water, and surface water at the site.

Figure 1 shows the general location of the EMDF Site. The site is a forested area of approximately 70 acres bounded on the north by Pine Ridge, on the east by North Tributary 2, on the south by the Haul Road and power line right-of-way, and on the west by the Environmental Management Waste Management Facility (EMWMF).

The site is underlain by Conasauga Group stratigraphic units, mainly the Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale. The northern edge of the EMDF and the crest of Pine Ridge are underlain by the Rome Formation (Alliant, 2014). No hazardous or radioactive contamination was expected, nor was any detected during field operations at the site.

## 1.1. Scope of Work

The URS scope of work for this project was to collect borehole geophysical logs in 5 boreholes (GW-968, -970, -972, -974 and -976) within the proposed EMDF area. Borehole depths are approximately 100-feet (ft) below ground surface (bgs). The suite of logs that was collected (in order) was:

1. Fluid temperature and fluid resistivity (simultaneous collection),
2. 3-arm caliper,
3. natural gamma ray and Spontaneous Potential (SP), (collected sequentially with the same probe),
4. optical televiewer (with deviation),
5. acoustic televiewer (with deviation), and
6. Heat Pulse Flowmeter.

The log suite chosen for this project was selected to yield data on subsurface stratigraphy, identify the nature, density and orientation of fractures, bedding planes, joints and conduits, and identify vertical flow within the borehole.

# 2. Borehole Geophysical Logging

Field activities were conducted between September 22, 2014 and October 2, 2014. Alliant personnel were present during all logging operations. Borehole logs are included in this report as hard copy (Appendix A) and electronic versions on compact disk (CD) in native (WellCAD), Portable Document Format (PDF), and American Standard Code for Information Interchange (ASCII) export files.

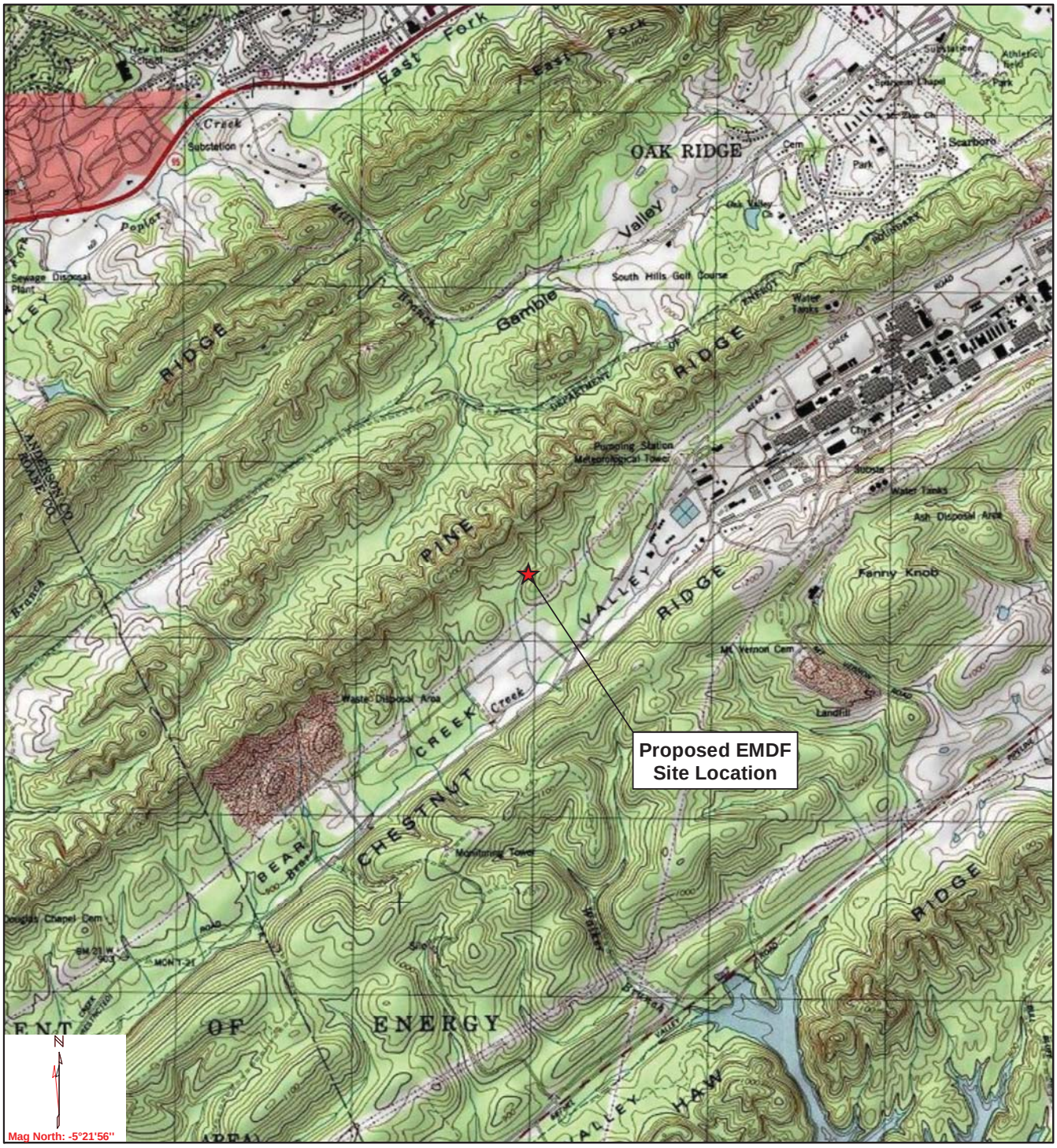
## 2.1. Equipment

Logging equipment and software for this project were rented from Mount Sopris Instruments of Denver Colorado (Mount Sopris). The acquisition system consisted of a 4MXA-1000 portable winch equipped with auto wind and 500 meters of 1/8$^{th}$ inch single-conductor cable and a 5MXA-1000 MATRIX Logging Console (Photo 1). The Mount Sopris winch and logging console are highly portable, dependable and capable of producing high-quality borehole logs when coupled with compatible downhole probes.

**Photo 1- Log acquisition system**

### 2.1.1. Fluid Temperature/Resistivity

Fluid temperature and fluid resistivity logs were acquired with a 2PFA-1000 probe. The probe was calibrated by Mount Sopris, and both measured parameter calibrations were verified prior to log collection. Calibration certifications are provided in Appendix B.



0 0.25 0.5 1

Miles

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User

URS

ALLIANT

**Site Location Map**
Proposed EMDF
Oak Ridge, Tennessee

| Drawn By: | Date: | |
|---|---|---|
| GM | 11/4/2014 | **Figure 1** |
| Checked By: | Project No. | |
| DH | 16170860 | |

C:\2014\Projects\EMDF_Alliant\GIS\fig1_install_Loc.mxd

The 2PFA-1000 utilizes a seven electrode mirrored Wenner array for measuring borehole fluid resistivity and a temperature sensor based on a fast response semiconductor device whose output voltage changes linearly with temperature. The resistivity array is an internal cylindrical array open at the bottom of the probe. Borehole fluid passes by the array as the probe is lowered in the hole. The array is completely shielded from the outside borehole, so that only fluid resistivity is measured. The temperature sensor is located at the top of the sensor body, in the center of the three exit ports where the borehole fluid returns to the borehole.

The range of measurement of the 2PFA-1000 is 0-100 ohm-meters (ohm-m) and -20 to +80 degrees Celsius (°C) (Mount Sopris, 2009).

### 2.1.2. 3-Arm Caliper

A 2PCA-1000 3-arm caliper probe was used to obtain borehole diameter data. The 2PCA-1000 was calibrated by URS with a 3-arm calibration jig (Photo 2) prior to log collection. A 2-point calibration (6 and 10 inches) was recorded into the probe tool file and used for all caliper logs collected during the project.

**Photo 2 - Calibration jig shown with one arm folded for transport**

The caliper measurement is made with arms attached to a mechanical assembly that drives a linear potentiometer. A constant reference voltage is applied across the potentiometer, and the direct current output voltage from the potentiometer is converted to a frequency that is sent up the cable conductor to be processed by the logging console. A microprocessor applies a correction to this frequency so that the frequency is linearly related to borehole diameter. The microprocessor also controls the motor that opens and closes the caliper mechanism. The caliper arms must only be opened at depth prior to beginning any up-hole logging run.

The caliper range of measurement is 1.5- to 17-inches (Mount Sopris, 2013).

### 2.1.3. Natural Gamma Ray and Spontaneous Potential

Natural gamma ray (gamma) and SP data were collected with a 2PGA-1000 Poly-gamma probe. The probe was calibrated by Mount Sopris (Appendix B) to yield gamma data in American Petroleum Institute (API) units as defined by the reference pit located on the grounds of the University of Houston, Texas.

The natural gamma measurement is made by the use of a sodium iodide crystal, which when struck by a gamma ray emits a pulse of light. This light pulse is amplified by a photo multiplier tube, which outputs a current pulse. These pulses are then transmitted up the cable line to the logging console.

The SP measurement requires two electrodes for measurement. The electrode on the 2PGA-1000 is just below the probe top. The circuit measures a DC voltage between the surface electrode (mud plug) and the probe electrode. This natural potential, which originates from electrochemical differences between borehole and formation fluid, and/or electro-kinetic "streaming" is measured by the surface electronics. This potential may be positive and/or negative with respect to the surface electrode. SP (reported in millivolts (mV)) is not measured as an absolute value, but is relative to the measuring and reference electrodes only. The SP surface electrode was installed at the maximum length of the reference wire and continuity was checked by disconnecting and reconnecting the reference wire from the Matrix logger while running in time mode prior to recording log data.

The range of measurement is 0-100,000 counts per second and ±1,500 mV for gamma and SP, respectively (Mount Sopris, 2008).

### 2.1.4. Optical Televiewer

The 2OIA-1000 optical televiewer (OTV) requires no in-field calibration. The probe was evaluated and confirmed to be operating within nominal tolerances by Mount Sopris prior to shipment (Appendix B). The OTV required adjustment to lighting intensity due to the reflectivity of the formation and water clarity.

The 2OIA-1000 incorporates a high resolution, high sensitivity charge-coupled device (CCD) digital camera with matching Pentax optics. The CCD camera, located above a conical mirror, captures the reflection of the borehole wall. The light source is provided by a light ring assembly located in the optical head. The CCD sensor consists of an array of light sensors, each representing one pixel of the complete image. To produce a coherent image the camera processing system checks all the pixels and compensates for variations (white balance).

The azimuthal resolution of the camera is defined by the user and can be set to 90, 180, 360, or 720 samples per revolution. Higher azimuthal sample rates are useful for larger diameter boreholes. The probe orientation (deviation) sensor package utilizes a 3-axis magnetometer and 3 accelerometers to provide azimuthal and inclination (tool tilt) accuracies of 1.5 degrees and 0.5 degrees, respectively (Mount Sopris, 2011).

### 2.1.5. Acoustic Televiewer

The 2AIA-1000 acoustic televiewer (ATV) requires no in-field calibration. The probe was evaluated and confirmed to be operating within nominal tolerances by Mount Sopris prior to shipment (Appendix B). The 2AIA-1000 is capable of automatic optimization of the measurement window under almost all borehole conditions; however, in some instances the probe required constraint of the time window in which the auto-picker searched for the primary echo where sediment increased scattering of the signal (e.g., at the bottom portion of the borehole).

The ATV generates an image of the borehole wall by transmitting ultrasound pulses from a rotating sensor and recording the amplitude and travel time of the signals reflected at the interface between borehole fluid and formation (borehole wall). The amplitude of the reflected signal depends principally on the acoustic impedance contrast between the borehole fluid and the formation. The ultrasonic energy wave is generated by a piezoelectric ceramic crystal and has a frequency of approximately 1.2 megahertz (MHz). By careful time sequencing the piezoelectric transducer acts as both transmitter of the ultrasonic pulse and receiver of the reflected wave. The travel time for the energy wave is the period between transmission of the source energy pulse and the return of the reflected wave measured at the point of maximum wave amplitude.

The azimuthal resolution of the ATV is defined by the user and can be set to 72, 144, or 288 samples per revolution. As with the OTV, higher azimuthal sample rates are useful for larger diameter boreholes. The probe orientation (deviation) sensor package utilizes a 3-axis magnetometer and 3 accelerometers to provide azimuthal and inclination (tool tilt) accuracies of 1.0 degrees and 0.5 degrees, respectively (Mount Sopris, 2011).

### 2.1.6. Flowmeter

The HFP-2293 Heat Pulse Flowmeter was bench calibrated by Mount Sopris (Appendix B) prior to shipping. The calibration values were confirmed to be stored in the probe tool file used by the acquisition software prior to data acquisition.

The flow measuring portion of the Heat Pulse Flowmeter consists of a heat grid with temperature sensors located above and below the grid. The tool is positioned at any desired depth with the winch and logger console. When the tool is in position to take a flow measurement a software button is pressed which commands the probe (via the conductor within the cable) to fire the heat grid. At the time the heat grid is fired the surface monitoring equipment and software to begin a flow measurement cycle. The grid heats a sheet of water that moves with the flow of the borehole to the upper or lower sensor, which detects the difference in temperature between the sensors. The response is sent up the conductor to the logging console at the surface and subsequently evaluated and recorded with the acquisition software (MatrixHeat). Upon firing of the heat grid, the tool immediately begins to charge the capacitors that produce the voltage for the heat grid in preparation for the next measurement cycle. Where vertical flow exists in the borehole, a flow measurement is made when the time has been accurately measured from when the heat grid was fired to when either the upper or lower sensor detects a peak temperature change. Figure 2 shows an example of a measurement taken in GW-970 at 45 ft bgs.

The Heat Pulse Flowmeter is capable of measuring flow rates (either up or down in the borehole) of 0.03- to 1.0-gallons per minute (gpm) (Mount Sopris, 2002). Large centralizers were used to center the probe within the borehole and the large diverter set was used to divert flow through the measuring portion of the probe.

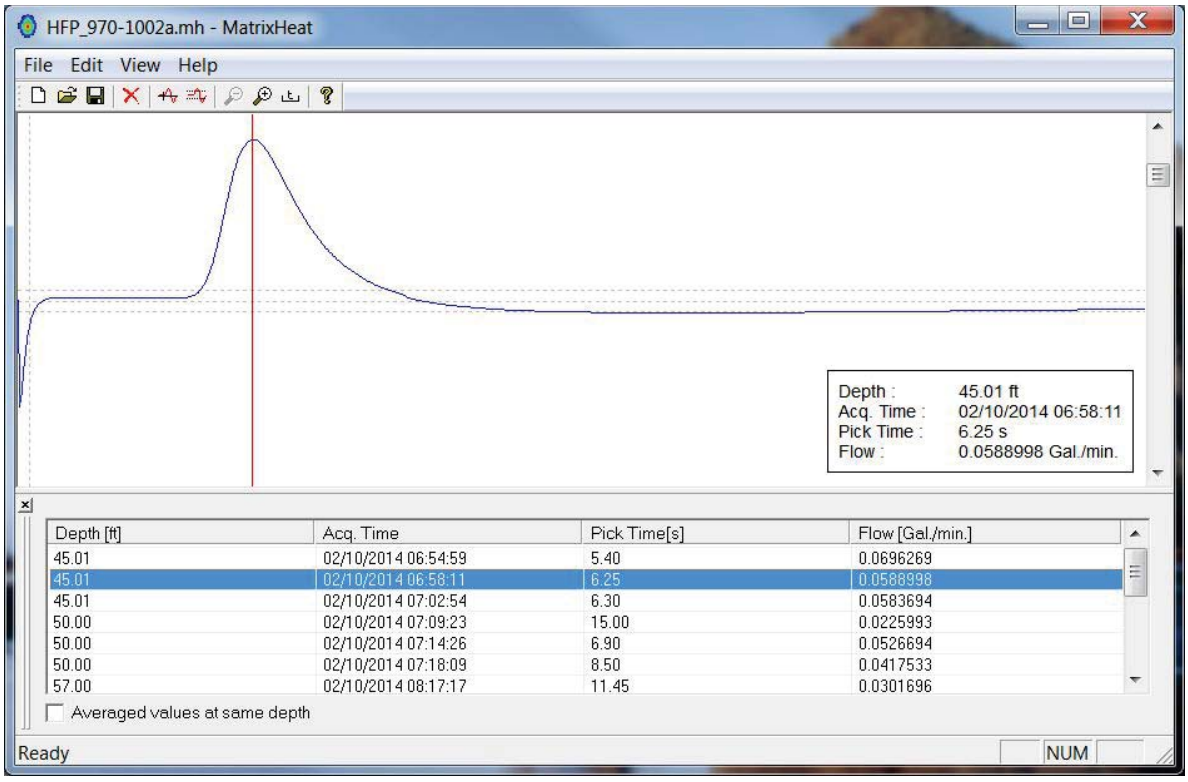



**Figure 2 Peak Picked on Heat Pulse Shot**

## 2.2. Software

The MATRIX logging console was coupled to LoggerSuite acquisition software produced by Advanced Logic Technology s.a. (ALT). LoggerSuite supports data collection with all pulse and digital probes utilized for this project with the exception of the Heat Pulse Flowmeter. MatrixHeat is acquisition software (also produced by ALT) used to collect flowmeter data that enables firing of the tool from within the software.

Log processing and preparation was completed with ALT's WellCAD processing suite. Deviation and Image modules were required to process the borehole deviation and images acquired with the televiewers.

## 2.3. Data Collection

All equipment was inspected upon receipt to ensure the gear was not damaged in transit from Mount Sopris. Oak Ridge Associated Universities (ORAU) was on site to provide radiological control (RADCON) support, and all borehole equipment (i.e., probes, winch cable and tripod sheave) was scanned by ORAU prior to being put into service.

### 2.3.1. Procedures

#### 2.3.1.1. Common Logs

The common logs (i.e., fluid, caliper, gamma) were the first logs to be run in each of the boreholes. Common log data was completed in all boreholes prior to collecting televiewer log data. The fluid

temperature/resistivity log was the first log run in each borehole. The fluid probe was completely submerged in the borehole fluid for several minutes to allow the probe temperature to equilibrate to borehole conditions. The fluid log data was collected running down the hole to reduce disturbance to the water column. The vertical sample interval for the fluid logs was 0.1 ft.

The caliper log was the next log run in each borehole in turn. The caliper probe was lowered to the maximum depth of the borehole, though sediment prevented realization of total depth (TD) in some instances as indicated on the log headers, prior to opening the caliper arms. The log was started up hole once the probe arms were confirmed open. Repeat sections were collected so that the casing/open-hole junction was captured in the repeat log section. In all boreholes except GW-974, 10-inch casing transitions to an open-hole diameter of approximately 8 inches which provided straightforward confirmation of log depth repeatability. Borehole GW-974 had 8-inch casing in 8-inch open-hole, but the smooth bore of the casing was readily identifiable with respect to the formation. The vertical sample interval for the caliper logs was 0.05 ft.

The final common logs run in each borehole were the natural gamma ray and SP logs. The 2PGA-1000 Poly-gamma probe does not allow gamma and SP data to be collected concurrently. Gamma and SP logs were both collected up and down hole. Both logs types are low resolution (2 to 3 ft), but overall repeatability was acceptable. The vertical sample interval for the gamma and SP logs was 0.1 ft.

#### 2.3.1.2. Televiewers

Once all the common logs were completed, televiewer logs were collected in each of the boreholes. Televiewers are operated with centralizers that may dislodge material from the borehole wall and diminish the optical clarity of the water column in the borehole. The OTV log was run before the ATV log to minimize mixing of fine sediments into the borehole fluid. The OTV data was collected running down-hole to further reduce disturbance of fine sediments and preserve water clarity to the extent possible. Another advantage of running the OTV down-hole is the flexibility to make adjustments to the light intensity early in the run and restart the log if necessary. The probe centralizers were adjusted for each borehole to ensure the probe would pass the smallest diameter of the borehole with resistance. The OTV was run as close to TD as possible, and down-hole motion was stopped when the optical window penetrated fine sediments at hole bottom. The OTV data was collected with an azimuthal resolution of 360 and a vertical resolution of approximately 0.006 ft (1.8 millimeters (mm)).

The ATV centralizers were adjusted for each borehole to ensure the probe would barely pass the smallest diameter of the borehole (i.e., with some resistance to the advancement of the probe). The probe was run close to TD, and efforts were made to keep the sensitive probe end from driving too deep into sediment. Because the ATV is relatively insensitive to water clarity and very sensitive to centralization (i.e., data quality diminishes when the probe is not properly centralized in the borehole), the logs were run up the borehole to maintain consistent tension on the cable. The ATV data was collected with an azimuthal resolution of 288 and a vertical resolution of approximately 0.007 ft (2.2 mm).

#### 2.3.1.3. Flowmeter

The Heat Pulse Flowmeter does not collect continuous log data, but rather requires measurement at discrete depths while stationary. Upon reaching the desired sample depth, the flowmeter was allowed to remain stationary for several minutes prior to collecting flow data to allow eddy currents generated by the probe's movement to settle out. Flowmeter sample depths were identified with the assistance/concurrence of Alliant and Professional Project Services, Inc. (Pro2Serve®). The features targeted for flowmeter sampling were identified from the previously collected logs. In particular, the fluid and televiewer logs were used to identify variations in temperature/resistivity and potential open fractures/joints, respectively. The caliper log was used to identify the most likely depth above and/or below the features targeted for flowmeter tests that would provide the highest likelihood of seating the flowmeter diverter petals in the borehole. That is, the small vertical flow gradients detectable by the flowmeter require that any vertical flow potentially present be diverted through the probe's measuring port.

### 2.3.2. Quality Control

Probe calibration certifications (Appendix B) were reviewed to ensure calibration serial numbers matched those of the probes used for this project and that the calibration values were embedded in the probe tool files. Manufacturer and industry standard practices were followed to ensure log quality was preserved. Field checklists were used in addition to the running field log to ensure borehole-specific details were documented (Appendix C).

Downhole telemetry was monitored at all times to identify any observable inconsistences (e.g., televiewer reporting tilt while hanging vertical at top of casing, caliper incorrectly reporting casing diameter, flowmeter unresponsive when tug tested, etc.).

With some exceptions (e.g., the fluid logs) repeat log data was collected to ensure log responses were repeatable and that depth encoding was accurate. The gamma and SP logs were repeated for the entire accessible borehole depth while the caliper and televiewer logs were partially repeated. In certain instances, anomalous observations within the borehole were repeated with the televiewer (e.g., the lower portion of GW-972) to confirm probe response. Repeat logs/log sections were reviewed and are maintained in the project file.

#### 2.3.2.1. Resolution of Issues Encountered

The MATRIX logger that was pressed into service September 22, 2014 was replaced September 24 prior to starting the televiewer logging. The replaced logger was observed to generate errors while collecting the common logs. These errors consisted of samples that were dropped during the logging run. The issue appeared during the afternoon of September 22 and became more pronounced as the day progressed, and was essentially absent from data collected earlier in the day. Mount Sopris was contacted and after initial troubleshooting the logger was swapped out at the earliest opportunity.

The logger generated errors were restricted to the common log collection, where the high sample rates utilized during collection ensured that any occasional loss of a sample would be unnoticeable. Repeat log sections ensured that the log data was repeatable.

The logger problem had not been observed during any of the fluid logs with the exception of GW-976. The fluid log was started in GW-976 at approximately 1220 on September 23. The log was stopped briefly at approximately 55 ft bgs because the logger generated several errors. The log was restarted after swapping to the sine wave inverter power supply and rebooting the system. The remainder of the log was collected without incident; however, there is a gap in the fluid log at approximately 55 ft bgs. The probe was not moved in the borehole before restarting the log to avoid mixing of the water column. The fluid log was not recollected due to scheduling requirements, and the small gap at approximately 55 ft bgs does not significantly reduce the usability of the fluid log data.

### 2.3.3. Decontamination

All probes were thoroughly cleaned with a Liquinox® solution after completing a log run and before entering the next borehole. ORAU personnel were on site to scan the probes after cleaning and drying to ensure none of the equipment had accumulated radiological contamination before moving to the next borehole.

Prior to removing any downhole equipment from the site (e.g., probes, cable, centralizers, etc.) the downhole components were carefully washed, rinsed and dried. ORAU RADCON scanned and smear tested all equipment before any of the gear left the project site. Green Tags were provided by ORAU documenting no radiological contamination before the downhole gear was shipped back to Mount Sopris by URS. Digital copies of the Green Tags are provided in Appendix D.

## 2.4. Log Data Processing

All log data was imported into WellCAD for review, processing and subsequent presentation. Repeat log sections were reviewed for consistency in response and instrument depth. Typically the logs did not require much if any depth adjustment. The televiewer logs were depth matched to coincide with the caliper bottom of casing depth. Omissions of single data points were interpolated, and spikes (i.e., non-repeatable) were removed and interpolated. Occurrences of the former and latter were infrequent.

### 2.4.1. Fluid Logs

A 9-point moving average was applied to the temperature logs. The delta temperature log was derived by plotting the result of the moving average minus a point 10 samples above it.

The fluid resistivity log is presented with a 5-point moving average applied to it.

### 2.4.2. Caliper log

No filtering was conducting on the caliper logs. Depth adjustments (less than 2 inches) were made where review of the shorter repeat log sections indicated a small discrepancy.

### 2.4.3. Natural Gamma Ray and SP

A 9-point moving average filter was applied to the gamma log, and a second 3-point moving average was applied for plotting/display purposes yielding a value averaged over an interval slightly more than 1 foot.

The SP logs are presented with a 9-point moving average.

### 2.4.4. Optical Televiewer

The ATV image data was enhanced by applying a static normalization. The static normalization maps the entire data range to the color palette used. The log was rotated from magnetic north to true north (approximately 5.4 degrees west), and bad traces were interpolated.

### 2.4.5. Acoustic Televiewer

The OTV image data was enhanced by auto-adjusting the brightness. Some overriding of the auto-adjustment was necessary where there was insufficient image contrast for the software to process. The log was rotated from magnetic north to true north (approximately 5.4 degrees west), and bad traces were interpolated.

### 2.4.6. Flowmeter

The flowmeter sample shots were reviewed for repeatability. Repeatable samples (multiple shots at the same depth) were averaged (arithmetic mean). Very low velocities (e.g., peak pick times greater than 25 seconds) were discarded as these were unlikely to represent actual groundwater flow and more likely to represent convection of the heat pulse through the water. Flow rates below the probe's measuring range were presented in cases where some repeatability was observed with the assumption that the low flow rate may have been a result of insufficient diverter seal.

### 2.4.7. Deviation

The deviation data was derived from the acoustic or optical televiewer log data. The most complete log was generally used to produce the deviation data set (e.g., GW-976 did not have ATV data above 44 ft bgs – the water level during logging). WellCAD's deviation module was used to generate Easting, Northing and True Vertical Depth (TVD) logs and a TVD axis. The measured borehole azimuth (angle from magnetic north to the horizontal projection of the tool reference mark axis) and tilt angle are utilized by the deviation module to generate the deviation data.

### 2.4.8. Structure

The structure logs were generated from the OTV and ATV logs. The structural features were interactively digitized on screen to best fit the feature of interest. The process is subjective, though every effort was made to maintain consistent criteria between boreholes. A conservative approach was used to ensure potentially transmissive fractures/joints were identified. In order to provide a sufficiently large, statistically representative data set, several features representative of beddings planes and mineralized partings were included in the structural log data. Using WellCAD's image module, the structural log's apparent dip and strike values were converted to true dip and strike. The true dip azimuth data was plotted (Appendix A) on lower hemisphere equal-area projections (i.e., Schmidt Plot also known as a Lambert Projection). The Schmidt plot represents a dipping plane as the projection of its great circle onto the image plane (the dip

azimuth) and the pole to the plane (the dip) is represented as a dot. Finally, azimuthal frequency plots with a mean frequency vector were plotted for the entire structural data set.

# 3. Results

Hard copy printout of the well logs are included in Appendix A and electronically as PDF and native format files that may be viewed with the WellCAD reader included on the accompanying CD.

The fluid temperature and resistivity logs were evaluated to identify depths where flow in or out of the borehole may have induced a temperature or resistivity anomaly. The boreholes were left to settle for a few days prior to logging to allow the water column to recover from mixing associated with the drilling process. The temperature logs display effects from heating of the near-surface water in the casing resulting from diurnal temperature swings and possibly residual heat from grout curing. The fluid resistivity is not a temperature compensated value, but the qualitative evaluation of the log does not require it.

The natural gamma ray log is a good indicator of shale; however, the shaly carbonates and carbonate/shale mixtures present in the geology at the site yielded a relatively elevated gamma response. The natural gamma ray probe is a poor thin bed detector, and the gamma detector is incapable of vertical resolution of anything less than approximately 18 inches (Rider & Kennedy, 2011).

The SP log is most commonly used to identify porous and permeable water-bearing sandstones. Ideally, full deflection of the SP log response to resolve a bed requires bed thickness greater than 20 times the borehole diameter (i.e., 13 feet) (Rider & Kennedy, 2011). Restraint is advised when reviewing the SP data collected for this project for this reason (i.e., thinly bedded shales and shaly limestone are ubiquitous in these boreholes).

## 3.1. GW-968

The GW-968 borehole is located along the south-facing slope of Pine Ridge in the Pumpkin Valley Shale. Approximately 10-15 feet of overburden was removed by others to create the drill pad. The 10-inch polyvinyl chloride (PVC) well casing extended approximately 5 inches above the ground surface during logging. The well was flowing, minimally, over the casing during field efforts on September 22 and 24. The water level was a few inches below the casing (not flowing) while conducting flowmeter testing on September 31. The shallow well (GW-969) located approximately 20 feet west of GW-968 was developed in the hours immediately prior to flowmeter testing. The minimal amount of rainfall in the weeks preceding September 31, and the pumping of GW-969 may have contributed to the lower potentiometric surface at GW-968 on September 31.

### 3.1.1. Fluid Temperature

The fluid temperature was approximately 6.5 °C higher in the casing than the temperature recorded at depth. Small temperature anomalies are present at approximately 25 and 37 ft bgs.

### 3.1.2. Fluid Resistivity

The fluid resistivity log has anomalous “steps” immediately below the casing at 10 ft bgs and at 39, 45, and 50 ft bgs. A relatively sharp decrease in fluid resistivity occurs at approximately 88 ft bgs; however, this decrease is associated with an increase is suspended fines at the bottom of the hole. The last few feet of the log was removed from the record as the sediment bridged the measurement array creating a short circuit. The open measuring port of the probe was solidly plugged upon returning the probe to the surface.

### 3.1.3. Diameter (Caliper)

The caliper log indicates an average borehole diameter of approximately 8.4 inches. Larger diameter intervals (greater than 8.5 inches) are centered at approximate depths of: 20, 37, 40, 43, 47, 70 and 85 ft bgs.

### 3.1.4. Natural Gamma Ray and SP

The natural gamma ray log was relatively elevated as expected for shale. The average gamma response was 147 API units. SP deflections are present at 15 (positive), 70 (negative) and below 80 ft bgs (negative).

### 3.1.5. Optical Televiewer

The optical televiewer data was of sufficiently high quality to discern structural features in the log. The water clarity diminished with depth so that details below approximately 80 ft bgs were significantly muted. The probe was advanced until the optical head penetrated the opaque layer of sediment at the bottom of the borehole. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.1.6. Acoustic Televiewer

The probe centralizers were adjusted to pass the upper reaches of the borehole where the diameter was as small as 8.2 inches. Much of the borehole exceeded 8.2 inches by a few tenths of an inch. Although the centralization was adequate, the vertical banding visible on the log is an indicator of imperfect centralization. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.1.7. Flowmeter

Flowmeter measurements were collected at the following intervals: 12, 17, 25, 26, 27, 35, 38, 42, 50, 68, and 71 ft bgs. The sample depths were chosen to evaluate features observed in the fluid and temperature logs, and at depths that were most likely to allow the probe diverters to adequately seal the borehole based on caliper data. The maximum diameter at which the diverters will work is 9 inches, and it is likely the diverter seal was insufficient is some cases.

### 3.1.8. Deviation

The measured borehole tilt is less than 3° from vertical, and the TD location of the borehole is approximately 3 ft northwest of the wellhead.

## 3.2. GW-970

Borehole GW-970 is located along the southern toe of Pine Ridge in the Pumpkin Valley Shale. The 10-inch PVC well casing extended approximately 2 inches above the ground surface during logging. The well was logged on September 23, 24, and 30 and the flowmeter testing was conducted on October 2, 2014.

### 3.2.1. Fluid Temperature

Temperature anomalies are present at approximately 35, 42, 50 and 75 ft bgs.

### 3.2.2. Fluid Resistivity

The fluid resistivity log has anomalous “steps” immediately below the casing at 35 ft bgs and at 37, and 44 ft bgs. The zone from approximately 48 to 67 ft bgs has several high frequency anomalies associated with an overall decrease in resistivity over the interval. The sharp decrease in fluid resistivity at 97 ft bgs is a result of sediment at the bottom of the hole bridging the sensor array.

### 3.2.3. Diameter (Caliper)

A relatively large diameter interval (greater than 8.0 inches) exists from the bottom of the casing to 42.5 ft bgs. The caliper log indicates an average borehole diameter of approximately 8.0 inches below the large diameter interval extending to 42.5 ft bgs. The borehole stays within gauge for most of its depth, but the diameter reaches 8.4 inches at 66.7 ft bgs.

### 3.2.4. Natural Gamma Ray and SP

The natural gamma ray log was relatively elevated as expected for shale. The average gamma response was 146 API units. SP deflections are present at 71.5 (positive), 82 (negative) and below 92 ft bgs (negative).

### 3.2.5. Optical Televiewer

The optical televiewer was of sufficiently high quality to discern structural features in the log. Many details are present in the log and diagonal bit marks and scratches from the 3-arm caliper are visible for most of the log (e.g., note where the caliper repeat section begins at 48 ft bgs). The water clarity diminished with depth so that details below approximately 75 ft bgs are significantly muted. The probe was advanced until the optical head penetrated the opaque layer of sediment at the bottom of the borehole. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.2.6. Acoustic Televiewer

The diameter of Borehole GW-970 was very consistent below 45 ft which greatly facilitated probe centralization. A significant amount of detail is present in the ATV as evidenced by the diagonal bit marks most visible at 90 ft bgs. The low amplitude (dark blue) spots present in the log below 40 ft represent localized areas of slightly increased diameter and/or rough patches that tend to scatter the ultrasonic energy. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.2.7. Flowmeter

Flowmeter measurements were collected at the following intervals: 45, 50, 57, 70, 77, and 90 ft bgs. The sample depths were chosen to evaluate features observed in the fluid and temperature logs, and at depths that were most likely to allow the probe diverters to adequately seal the borehole based on caliper data. The relatively unvarying, small diameter of the borehole created optimal conditions for the flowmeter diverter. No problems with the diverter seal were encountered.

### 3.2.8. Deviation

The measured borehole tilt reached a maximum of just over 10° from vertical at 90 ft bgs. The TD location of the borehole is approximately 6.5 ft northwest of the wellhead.

## 3.3. GW-972

Borehole GW-972 is located in a relatively level area immediately south of Pine Ridge in the Pumpkin Valley Shale. The 10-inch PVC well casing extended approximately 6 inches above the ground surface during logging. The well was logged on September 23, and 29 and the flowmeter testing was conducted on October 1, 2014.

### 3.3.1. Fluid Temperature

Temperature anomalies were detected below the bottom of the casing at 25 ft and at 44 ft bgs.

### 3.3.2. Fluid Resistivity

The fluid resistivity log has a small stepped decrease of approximately 2 ohm-m between 44 and 55 ft bgs. There are several small anomalies between 69 and 76 ft bgs.

### 3.3.3. Diameter (Caliper)

Above 76 ft bgs the borehole has an average diameter of 8.1 inches and 8.7 inches below this depth. The borehole diameter is relatively consistent above 76 ft though more variability is observed below 55 ft bgs. The diameter increase below 76 ft may be associated with the vertical stripe most noticeable in the acoustic televiewer log described below.

### 3.3.4. Natural Gamma Ray and SP

The natural gamma ray log was relatively elevated as expected for shale. The average gamma response was 142 API units. A single prominent, positive SP deflection is present from the bottom of the casing to 35 ft bgs.

### 3.3.5. Optical Televiewer

The optical televiewer was of sufficiently high quality to discern structural features in the log. The water clarity diminished with depth so that details below approximately 90 ft bgs are muted. The probe was advanced until the optical head penetrated the opaque layer of sediment at the bottom of the borehole (approximately 98 ft bgs). The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.3.6. Acoustic Televiewer

The diameter of Borehole GW-972 was relatively consistent which facilitated probe centralization. The low amplitude (dark blue) spots present in the log below 80 ft represent localized areas of slightly increased diameter and/or rough patches that tend to scatter the ultrasonic energy. The low amplitude, vertically linear stripe visible from approximately 77 ft bgs to the bottom of the log does not appear to be a naturally occurring feature. The stripe is most likely the remnant of the smaller diameter core hole that was advanced prior to reaming the borehole out with the air-rotary rig. That is, the center of the larger 8-inch hole does not coincide with the center of the previous core hole. The same feature is evident in the optical log, and may be partially responsible for the increased diameter measured by the caliper. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.3.7. Flowmeter

Flowmeter measurements were collected at the following intervals: 26, 30, 40, 45, 51, 61.5, 70, and 76 ft bgs. The sample depths were chosen to evaluate features observed in the fluid and temperature logs, and at depths that were most likely to allow the probe diverters to adequately seal the borehole based on caliper data.

### 3.3.8. Deviation

The measured borehole tilt did not exceed 4° in this borehole. The TD location of the borehole is approximately 2.3 ft northwest of the wellhead.

## 3.4. GW-974

Borehole GW-974 is located midway between the southern base of Pine Ridge and the existing Haul Road in the Rogersville Shale. The 8-inch PVC casing inside of 10-inch PVC well casing extended approximately 6.5 inches above the ground surface during logging. The well was logged on September 22, and 25, and the flowmeter testing was conducted on October 1, 2014.

### 3.4.1. Fluid Temperature

The fluid temperature was approximately 3 °C higher in the casing than the temperature recorded at depth. The temperature decreases rapidly just below the bottom of the casing. Small temperature anomalies are present at approximately 25, 36, and 45 ft bgs. The temperature increases gradual with depth below 27 ft bgs.

### 3.4.2. Fluid Resistivity

The fluid resistivity was approximately 27 ohm-m lower in the cased portion of the borehole, and several wraps are visible at approximately 17 ft bgs where the resistivity increases rapidly. There is a small anomaly at 20 ft, but the remaining portion of the log is unremarkable.

### 3.4.3. Diameter (Caliper)

The caliper log indicates an average borehole diameter of approximately 8.1 inches. Several small diameter increases are present at approximate depths of: 25, 31, 45, 66, and 93 ft bgs.

### 3.4.4. Natural Gamma Ray and SP

The natural gamma ray log was relatively elevated as expected for shale. The average gamma response was 139 API units. SP deflections are present at 16.4 (positive), 78 (negative) and 92.7 ft bgs (negative).

### 3.4.5. Optical Televiewer

The televiewer log was initially run with the water level in the casing, but the water clarity was too poor to obtain any useful data. The water was pumped to 59.4 ft bgs (as low as possible with equipment on hand), and the log was recollected. The image quality above the water level was acceptable, but the formation had minimal tonal contrasts. The portion of the log below the water is completely obscured by the opaque water column. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.4.6. Acoustic Televiewer

The diameter of Borehole GW-974 was relatively consistent which facilitated probe centralization. The low amplitude (dark blue) spots throughout the log represent localized areas of slightly increased diameter and/or rough patches that tend to scatter the ultrasonic energy. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.4.7. Flowmeter

Flowmeter measurements were collected at the following intervals: 20, 26, 35, 40, 46.5, 50, and 64 ft bgs. The sample depths were chosen to evaluate features observed in the fluid and temperature logs, and at depths that were most likely to allow the probe diverters to adequately seal the borehole based on caliper data. Flow measurements were repeated at 40 and 35 ft bgs after bailing 5 gallons of water at each depth. The measurements were taken after waiting 3 minutes after the last bailer full of water was removed.

### 3.4.8. Deviation

The measured borehole tilt exceeded 14° from vertical below 96 ft bgs, and the TD location of the borehole is approximately 9.7 ft north-northwest of the wellhead.

## 3.5. GW-976

Borehole GW-976 is located on top of a small ridge south of Pine Ridge in the Maryville Limestone. The 10-inch PVC well casing extended approximately 9 inches above the ground surface during logging. The well was logged on September 23, and 29, and the flowmeter testing was conducted on October 1, 2014. The water level in the borehole was just below 44 ft bgs during log collection.

### 3.5.1. Fluid Temperature

The fluid logs begin at 45 ft bgs (below the static water level). There is a gap in the fluid logs at approximately 55 ft bgs as described in Section 2.3.2.1. The decreasing trend in the fluid temperature log ceases abruptly between 65 and 66 ft bgs. Small temperature anomalies are present between 80 and 90 ft bgs. Another small anomaly occurs at 97 ft bgs.

### 3.5.2. Fluid Resistivity

Anomalous variation in the resistivity log is present between 47 and 54 ft bgs and between 55 and 66 ft bgs. Subtler anomalies are located at depths of 80 and 90 ft.

### 3.5.3. Diameter (Caliper)

The caliper log indicates an average borehole diameter of approximately 8.1 inches. Increases in diameter are present at depths of: 44 (coincident with the water level), 52.2, the interval 72 to 74.5, and 78.2 ft bgs.

### 3.5.4. Natural Gamma Ray and SP

The natural gamma ray log response was lower when compared to the other boreholes which have higher shale content. The gamma response is slightly elevated above 45 ft where there was no water attenuation. The average gamma response (below the water line) was 124 API units. SP deflections are present within the interval 51 to 53 (positive and negative), and 64 (small negative). The SP log response decreases below 90 ft bgs.

### 3.5.5. Optical Televiewer

The optical televiewer was of sufficiently high quality to discern structural features in the log. The image quality above the water level was very good. Scratch marks from the 3-arm caliper are visible as 3 orange hued vertical lines. The portion of the log below the water is also very high quality with only a slight decrease in water clarity. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.5.6. Acoustic Televiewer

The diameter of Borehole GW-976 was relatively consistent which facilitated probe centralization. The ATV does not function in air, and therefore no ATV data was collected above 44 ft bgs. The low amplitude (dark blue) spots throughout the log represent localized areas of slightly increased diameter and/or rough patches that tend to scatter the ultrasonic energy. The televiewer data was used to identify structural features as presented on the combo log in Appendix A.

### 3.5.7. Flowmeter

Flowmeter measurements were collected at the following intervals: 50, 62.5, 67, 75, 80.5, 88.5, and 93 ft bgs. The sample depths were chosen to evaluate features observed in the fluid and temperature logs, and at depths that were most likely to allow the probe diverters to adequately seal the borehole based on caliper data. Upward flow was measured at 75 and 80.5 ft bgs.

### 3.5.8. Deviation

The measured borehole tilt was less than 3° from vertical for all depths, and the TD location of the borehole is approximately 1.7 ft west of the wellhead.

# 4. Conclusions

The logs are presented in Appendix A in electronic and hard copy versions and should be reviewed in conjunction with the discussions below.

## 4.1. GW-968

The elevated fluid temperature measured in the casing is interpreted to be the result of solar heating and/or heat liberated during the curing of grout in the annulus as discussed in Section 3. Fluid temperature and resistivity anomalies at depth are interpreted as potential locations of fluid flux into/out of the borehole.

Unfortunately, the well was not flowing at the time the flowmeter measurements were collected, and difficulty was experienced while trying to properly seat the flowmeter diverters. Evidence for upward flow was observed at 12 and 17 ft bgs, though these results are suspect due to the very low flow rates that were measured. The flow measured at 26, 27, 42 and 68 feet is also suspect, but is presented on the log as there was continuity between repeated measurements.

As shown by the Schmidt plots, the structural features identified in GW-968 are tightly clustered around a mean dip azimuth of approximately 142° with a mean dip of approximately 46°. The distribution of interpreted structural features indicates they are related to bedding and not representative of cross-cutting fractures.

**Table 4-1 GW-968 Potential water-bearing zones**

| Potential Water Bearing Zones | |
|---|---|
| Depth (ft bgs) | Rationale |
| 25 - 30 | Fluid temperature anomaly at 25 ft, multiple potential bedding joints between 25 – 30 ft, potential flow detected at 26 and 27 ft |
| 37 - 50 | Fluid resistivity anomaly at 37 ft, potentially open joints at 37.4 and 46.8 ft |

## 4.2. GW-970

The fluid temperature and resistivity anomaly at the bottom of the casing (35 ft bgs) may represent fluid flux within the highly fractured zone at that interval. The gradual decrease in fluid resistivity from 47 to 67 ft bgs suggests this interval may have multiple, small contributions of fluid influx. The remaining temperature anomalies at 42, 50 and 75 ft bgs are interpreted as potential locations of fluid flux into/out of the borehole.

The flowmeter data correlates well with the other logs. That is, the upward flow increases above depths where potential water-bearing zones are interpreted from the fluid and televiewer logs. Development of the nearby shallow well (GW-971) likely contributed to fluctuations in the water level in GW-970 and it is not known at this time what the static potentiometric level in GW-970 is. However, the presence of upward flow indicates that outflow must be occurring very near the bottom of the casing in GW-970.

As shown by the Schmidt plots, the bedding features are clustered around a mean dip azimuth of approximately 140° with a mean dip of approximately 52°. However, there is considerable variation in the orientation of the fracture features that were identified from the televiewer logs, and most of these features are within the upper 50 ft of the borehole.

**Table 4-2 GW-970 Potential water-bearing zones**

| Potential Water Bearing Zones | |
|---|---|
| Depth (ft bgs) | Rationale |
| 35 - 45 | Fluid temperature and resistivity anomaly at 34.5 ft immediately below the bottom of casing, decrease in temperature at 42 ft and sharp decrease in fluid resistivity at 44 ft, multiple fractures including two high angle (approximately 86°) features that are not parallel with the formation dip |
| 45 - 50 | Fluid resistivity decreases across the interval, small temperature anomaly at 50 ft, increase in upward flow measured at 45 ft bgs, several fractures/joints in the interval including two high angle (approximately 79°) features |
| 55 | Fluid resistivity decreases across this depth, partial open fracture at 55 ft, increase in upward flow measured at 55 ft bgs |
| 60 | Fluid resistivity decreases across this depth, minor open joint at 59.9 ft, upward flow measured at 57 ft bgs |

Table 4-2 GW-970 Potential water-bearing zones (concluded)

| Potential Water Bearing Zones | |
|---|---|
| Depth (ft bgs) | Rationale |
| 70 - 75 | Small temperature anomaly at 75 ft, minor open joint at 71.7 ft, upward flow measured at 70 ft bgs |

## 4.3. GW-972

The fluid temperature in the casing was slightly elevated and this is interpreted to be the result of solar heating and/or heat liberated during the curing of grout in the annulus as discussed in Section 3. The fluid temperature and resistivity anomaly immediately below the casing are interpreted to be the result of potential fluid flux into/out of the borehole. There are no apparent joints or fractures in the vicinity of the fluid temperature and resistivity anomalies at 44 ft bgs. The slight stratification delineated at 44 ft bgs may be the result of recharge from a shallower depth.

Vertical flow was not confirmed in Borehole GW-972. The small flow (below documented probe measuring range) measured at 76 ft bgs was included on the log because 2 of the 4 measurements at that depth indicated similar flow rates.

As shown by the Schmidt plots, the structural features identified in GW-972 are tightly clustered around a mean dip azimuth of approximately 152° with a mean dip of approximately 47°. The distribution of interpreted structural features indicates they are related to bedding and not representative of cross-cutting fractures.

Table 4-3 GW-972 Potential water-bearing zones

| Potential Water Bearing Zones | |
|---|---|
| Depth (ft bgs) | Rationale |
| 24.5 | Fluid temperature anomaly at approximately 25 ft, potential bedding joints from the bottom of casing to 28.7 ft bgs |
| 40.5, 49.8, 59.8, 81 | Partial open joints at these depths, fluid anomalies do not correlate well, low potential for being transmissive fractures |

## 4.4. GW-974

The fluid temperature in the casing was slightly elevated and this is interpreted to be the result of solar heating and/or heat liberated during the curing of grout in the annulus as discussed in Section 3. Additional insulation and/or heating may be attributed to the addition of the 8-inch casing and grout within the 10-inch casing. The fluid temperature and resistivity anomaly immediately below the casing are interpreted to be the result of shallow groundwater water bearing zone inflow.

With the exception of the measurement at 35 ft, vertical flow was not measured in Borehole GW-974. The first set of measurements at 35 ft resulted in 2 of 3 measurements indicating the potential for upward flow (approximately 0.02 gpm average), but the third shot at 35 ft indicated no flow. The second set of measurements at 35 ft (after stressing the well) resulted in 2 of 3 measurements indicating a very low flow (approximately 0.01 gpm average) which is too far below the measurement range of the probe to be considered valid. The average of both measurement sets (0.016 gpm) is presented on the log; however, given the reduction of measured flow after stressing the well, the measured response at 35 ft bgs is considered to represent noise and not a valid flow measurement. The measurement value is presented only because there was some repeatability observed, and the possibility of an incomplete diverter seal could not be ruled out when the logs were created. After the borehole was pumped September 25 while collecting optical televiewer data, the water level eventually recovered to near pre-pumping levels. Based

on the results of the geophysical logs, there is the potential that in-flow is occurring at or near the bottom of the well casing.

As shown by the Schmidt plots, the structural features identified in GW-974 are loosely clustered around a mean dip azimuth of approximately 151° with a mean dip of approximately 54°. The distribution of interpreted structural features indicates they are related to bedding and not representative of cross-cutting fractures.

**Table 4-4 GW-974 Potential water-bearing zones**

| Potential Water Bearing Zones | |
|---|---|
| Depth (ft bgs) | Rationale |
| 15 - 20 | Fluid temperature/resistivity anomaly at approximately 15 to 17 ft, no confirmed vertical flow in the borehole after stressing, but the well recharged after pumping |

## 4.5. GW-976

The fluid temperature and resistivity logs begin just below the static water level (approximately 44 ft bgs) in the borehole at the time it was logged. The anomalous variation in the resistivity log present between 47 and 54 ft bgs and between 55 and 66 ft bgs is interpreted as potential fluid flux into/out of the borehole, and may be related to the decreasing trend in the fluid temperature log that ceases abruptly between 65 and 66 ft bgs. Both the fluid temperature and resistivity logs demonstrate small anomalies between 80 and 90 ft bgs that may indicate fluid flux occurring at depth.

Vertical flow was measured in 2 of the 7 depths where data was collected. The measurements at 80.5 and 75 ft bgs were repeatable and indicate fluid influx occurring between the measurement stations. That is, the measured up flow increased slightly at 75 ft over the flow measured at 80.5 ft bgs.

As shown by the Schmidt plots, the bedding features are clustered around a mean dip azimuth of approximately 133° with a mean dip of approximately 58°. Several joints/fractures have dip azimuths that are not aligned with the bedding trend and instead are oriented to the south and west. The primary examples of “off-trend” structural features are visible at 44, 51.4, 52 and 77.7 ft bgs.

**Table 4-5 GW-976 Potential water-bearing zones**

| Potential Water Bearing Zones | |
|---|---|
| Depth (ft bgs) | Rationale |
| 44 | Significant low-angle (35°) fracture, no fluid log data as this feature was coincident with the water level at the time of logging |
| 47 - 54 | Fluid resistivity anomaly spans the interval, potential transmissive structural features including two low-angle (<20°) features within the interval |
| 55 - 66 | Fluid resistivity and temperature variation, several structural features identified; however, all of them parallel the bedding, no flow was measured above within or below the interval |
| 77.7 | Sub-horizontal fracture (6°) identified from televiewer data, increase in measured up-flow across this zone, very minor fluid temperature fluctuations recorded above/below this feature |
| 80 - 90 | Small fluid temperature/resistivity anomalies across this interval although there were no significant structural features identified from the televiewer data, potential vertical flow measured at 80.5 ft bgs |

URS certifies this geophysical investigation was conducted using state-of-the-art technology using current best practices for the equipment. Original data files and field notes are maintained in URS project files and are available for the client to review. A geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, either expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations, or ordinances.

## 5. References


Alliant Corporation. *Final Work Plan, Limited Phase I Site Characterization Proposed Environmental Management Disposal Facility*. August 2014.

Mount Sopris Instruments Company, Inc. Instrument Operations Manuals:

HFP-2293, *Heat Pulse Flow Meter.* 2002

2PGA-1000, *Poly-Gamma Probe.* 2008

2PFA-1000, *Fluid Resistivity / Temperature Probe*. 2009

QL40 ABI, *Acoustic Borehole Imager*. 2011

QL40 OBI, *Optical Borehole Imager*. 2011

2PCA-1000, *PolyCaliper Probe*. 2013

Rider, M. and Kennedy, M. *The Geologic Interpretation of Well Logs* (3rd ed.). 2011. Reprint, Rider-French Consulting Ltd., Scotland. 2013, 432p.

**APPENDIX A**

**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-968

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, SP, Fluid Temperature and Resistivity

**DATE:** September 22, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2PFA, 2PCA, 2PGA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

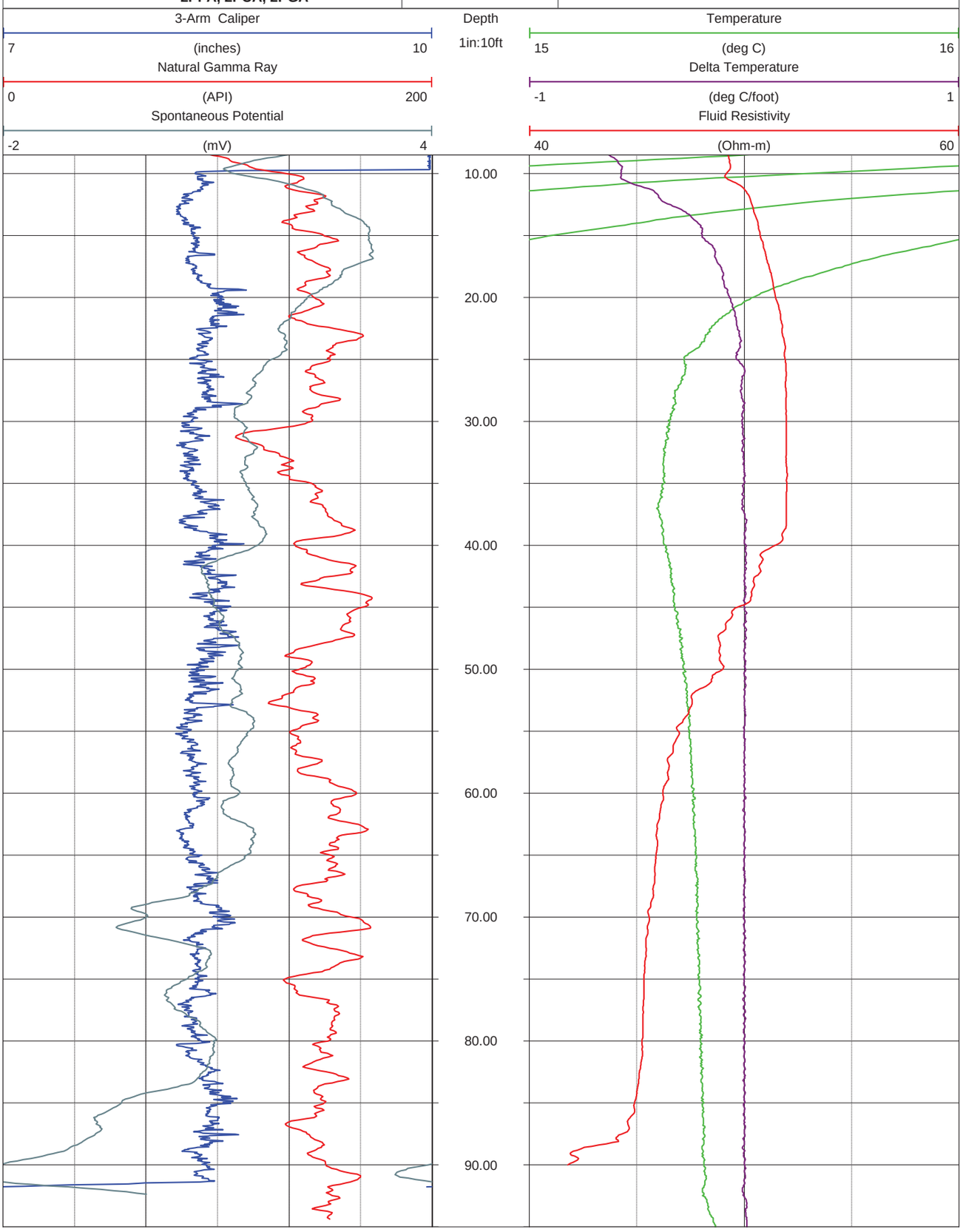
**CASED:** -0.4 to 9.7 feet (10 inch PVC)

**OPEN HOLE:** 9.7 to 95+ feet

**MAX LOG DEPTH:** 95 feet

**WATER LEVEL:** TOC (flowing)

**COMMENTS:** Several feet of fines at bottom of borehole.



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-968

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, Acoustic and Optical Televiewer

**DATE:** September 22 & 24, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA

URS Corporation
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

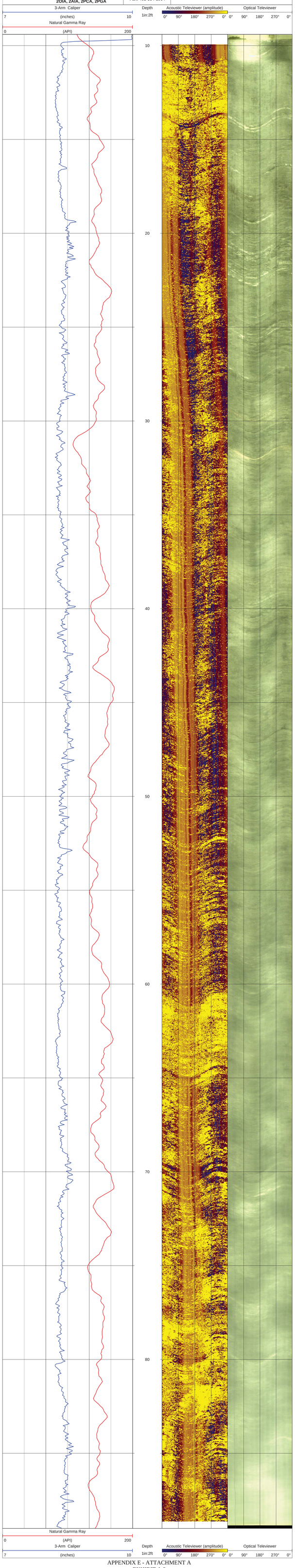
**CASED:** -0.4 to 9.7 feet (10 inch PVC)

**OPEN HOLE:** 9.7 to 95+ feet

**MAX LOG DEPTH:** 88.8 feet

**WATER LEVEL:** TOC (flowing)

**COMMENTS:** Several feet of fines at bottom of borehole. Water clarity diminished with depth.



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF — **WELL ID:** GW-968

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, Acoustic and Optical Televiewer, Fluid Temp. and Resistivity, Flow

**DATE:** September 22 - 30, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA, 2PFA, HFP-2293


**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984


**DRILLING METHOD:** Air-rotary

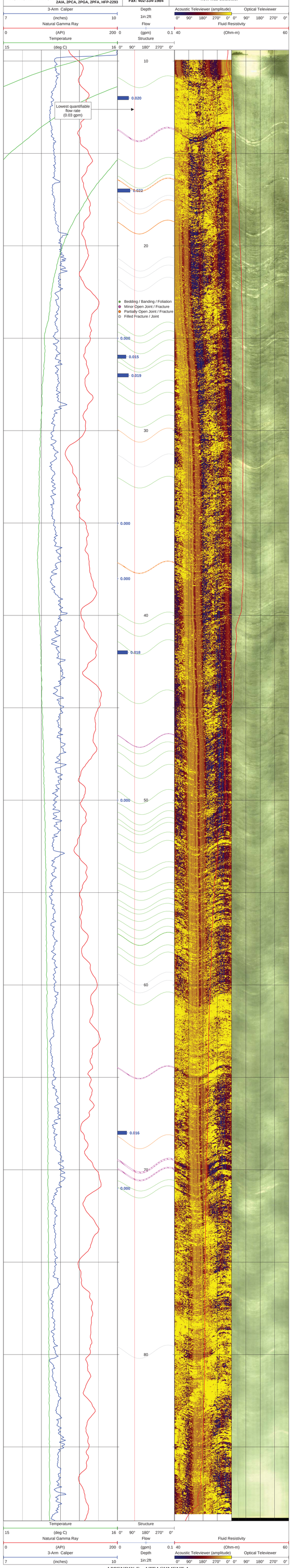
**CASED:** -0.4 to 9.7 feet (10 inch PVC)

**OPEN HOLE:** 9.7 to 95+ feet

**MAX LOG DEPTH:** 88.8 feet

**WATER LEVEL:** TOC (flowing)

**COMMENTS:** Flow rates below the documented manufacturer's range of measurement are presented for qualitative purposes only, and may not represent actual flow rates. Zero value flow rates may be the result of inadequate diverter seal. No downward flow was detected.



| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-968** |

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (acoustic televiewer)

**DATE:** September 24, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** ABI_U_968-0924b.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2AIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

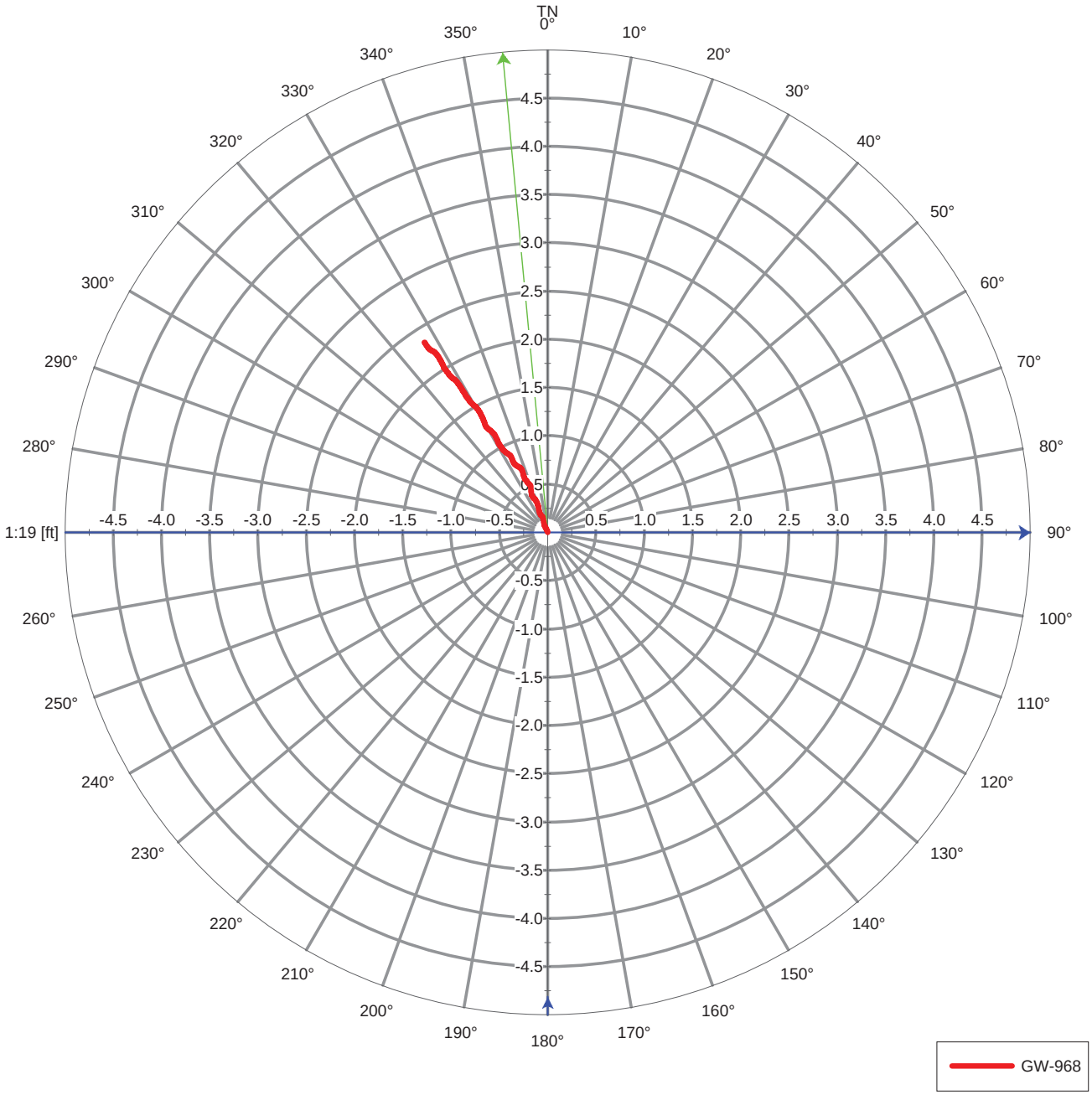
**CASED:** -0.4 to 10 feet (10 inch PVC)

**OPEN HOLE:** 10 to 95+ feet

**MAX LOG DEPTH:** 87.5 feet

**WATER LEVEL:** TOC (flowing)

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



PROJECT: **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** WELL ID: GW-968

CLIENT: Alliant Corporation

LOCATION: Proposed Environmental Management Disposal Facility (EMDF)

LOG TYPE: Deviation (acoustic televiewer)

DATE: September 24, 2014

OBSERVER: Mark Maki, PG, (Alliant)

RECORDED BY: Garrick Marcoux, PGP, PG

DATA FILES: **ABI_U_968-0924b.tfd**

LOG DATUM: Ground Surface

INSTRUMENTATION: Mt. Sopris Matrix logger, 2AIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

DRILLING METHOD: Air-rotary

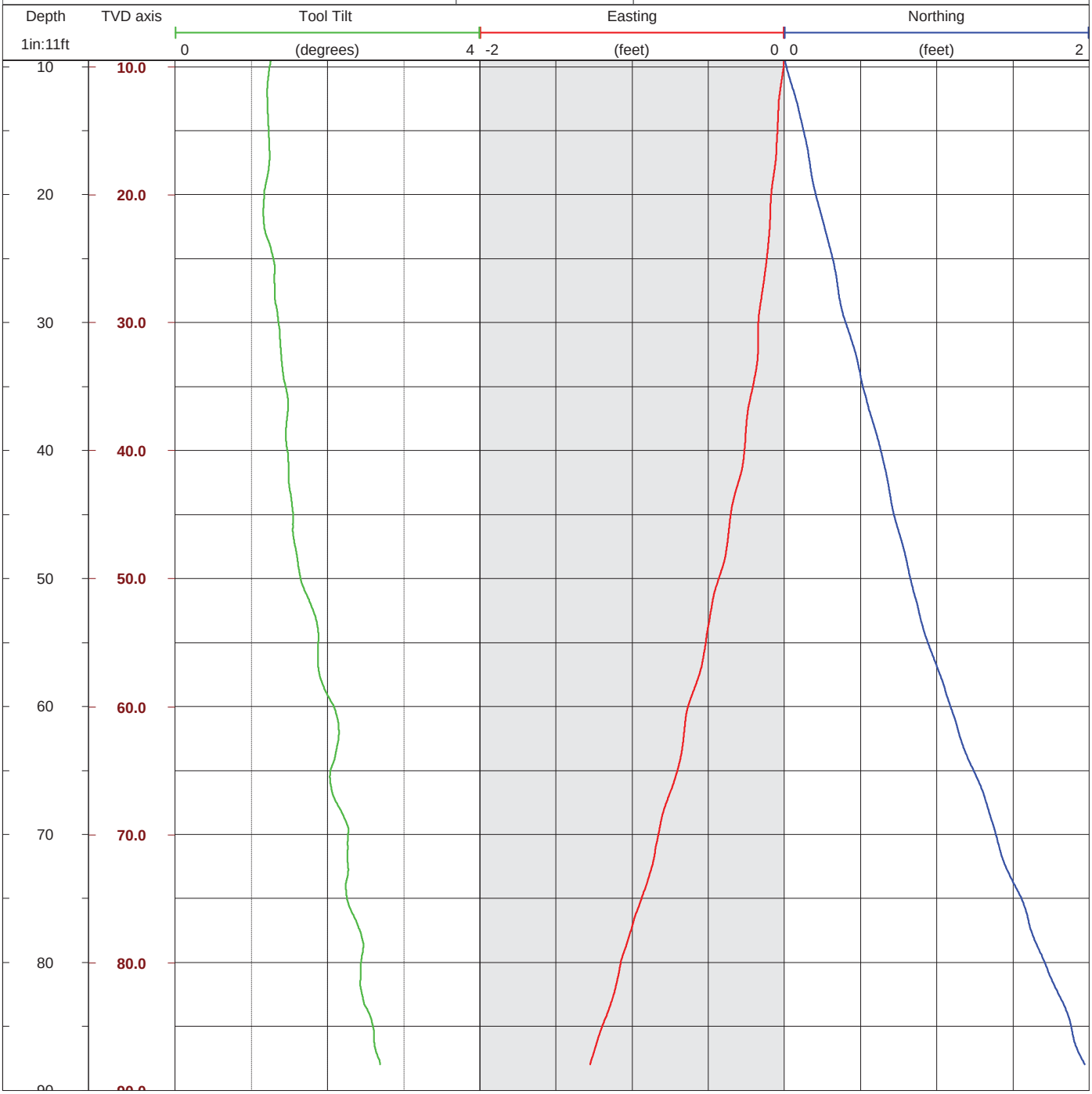
CASED: -0.4 to 10 feet (10 inch PVC)

OPEN HOLE: 10 to 95+ feet

MAX LOG DEPTH: 87.5 feet

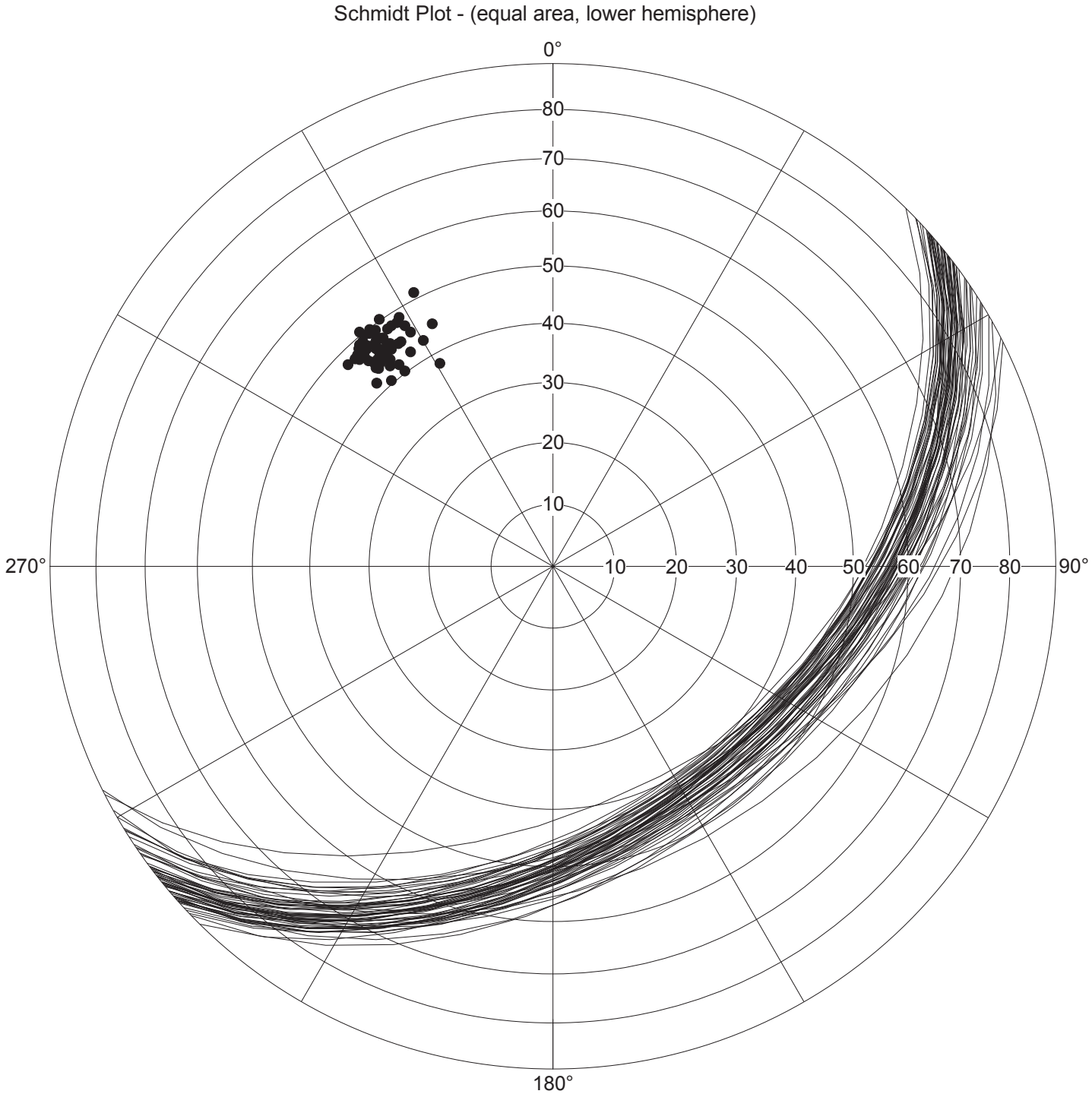
WATER LEVEL: TOC (flowing)

COMMENTS: Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



GW-968

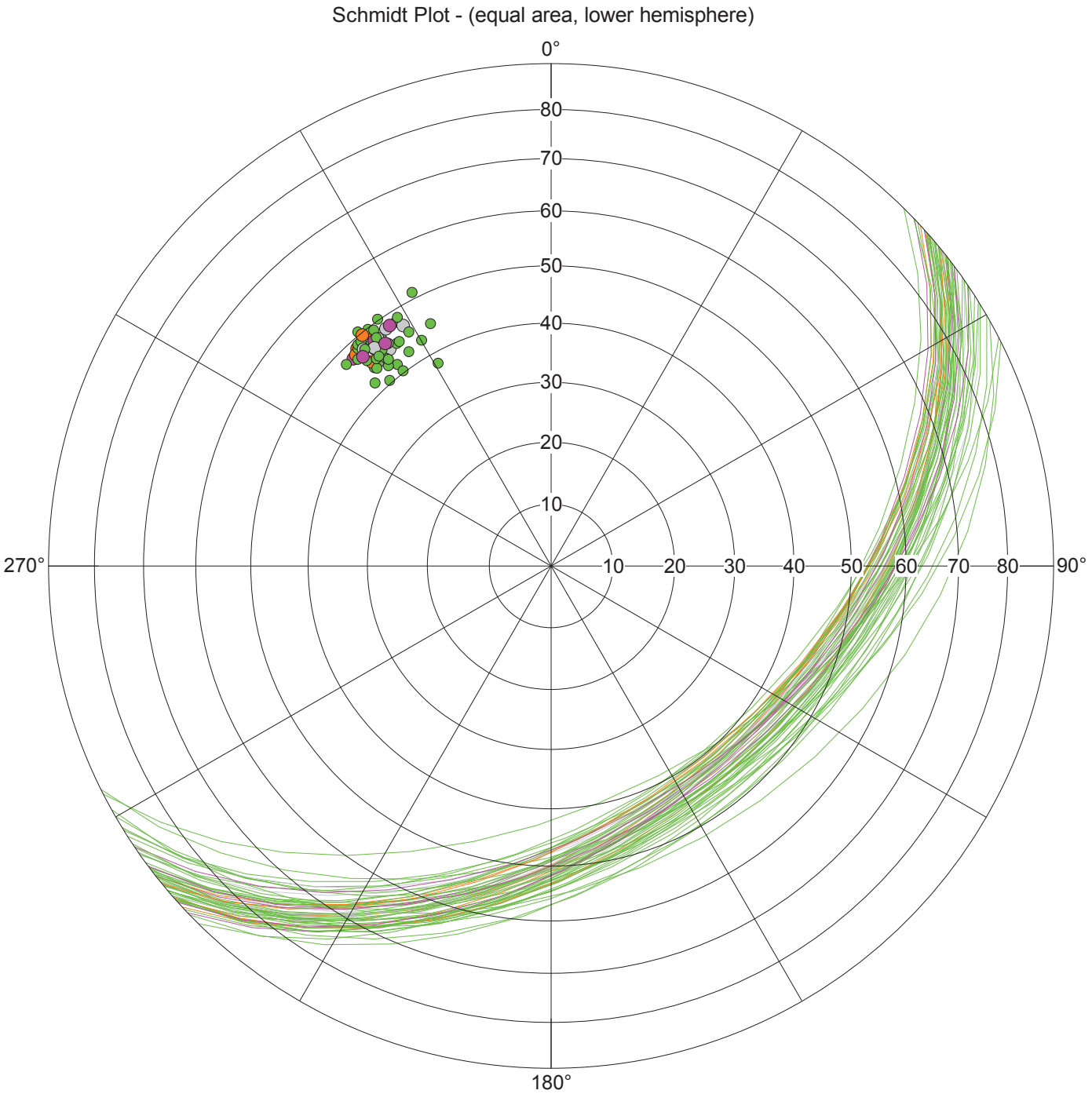
Dip and dip azimuths for all features.




| | Counts | Dip[deg] | Azi[deg] |
|---|---|---|---|
| Mean | 59 | 46.13 | 142.08 |

GW-968

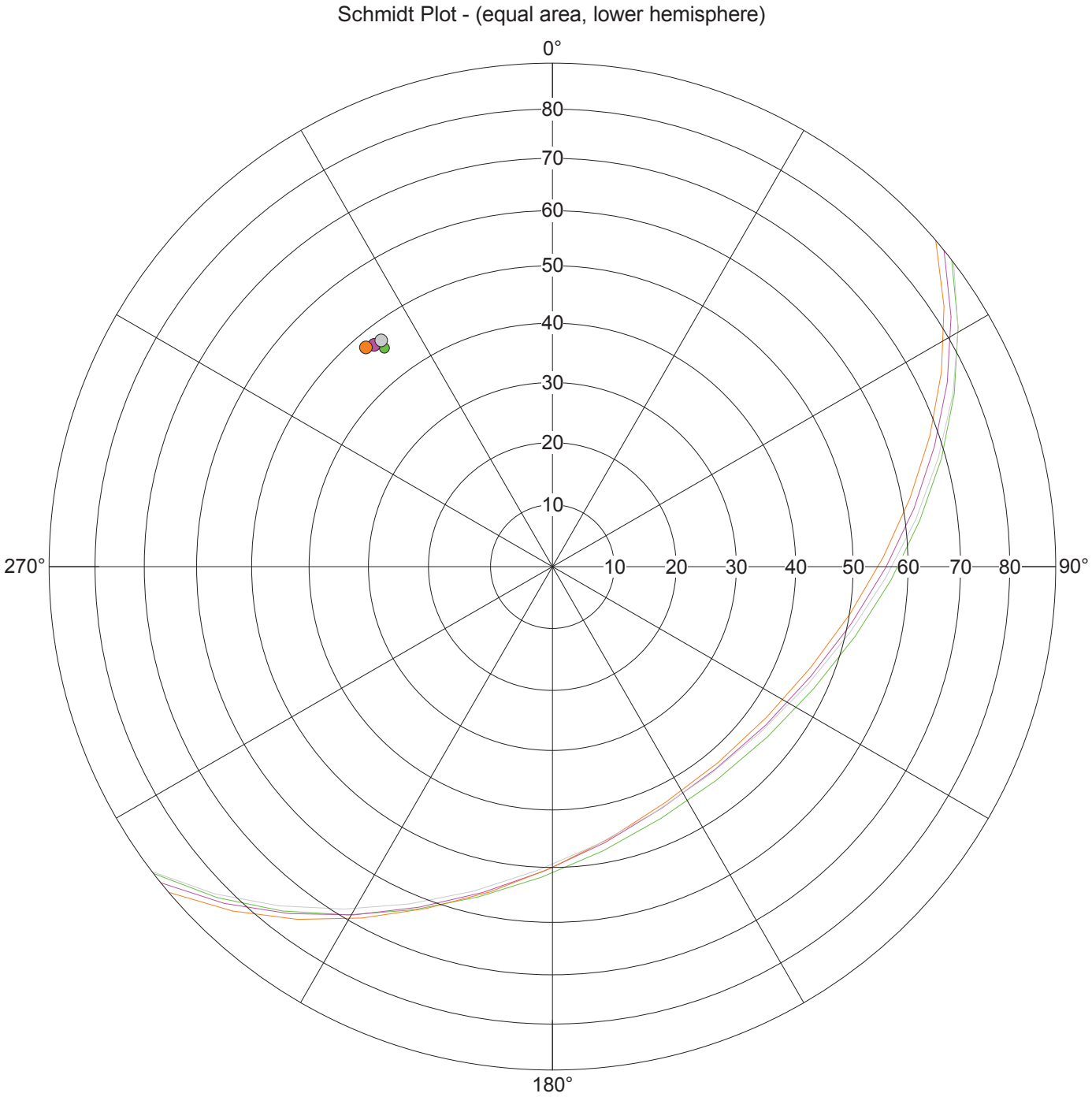
Dip and dip azimuths differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 59 | 46.13 | 142.08 | |
| ● | 41 | 45.60 | 142.45 | Bedding / Banding / Foliation |
| ● | 5 | 47.16 | 141.12 | Minor Open Joint / Fracture |
| ● | 6 | 47.79 | 139.64 | Partially Open Joint / Fracture |
| ● | 7 | 47.03 | 142.79 | Filled Fracture / Joint |

GW-968

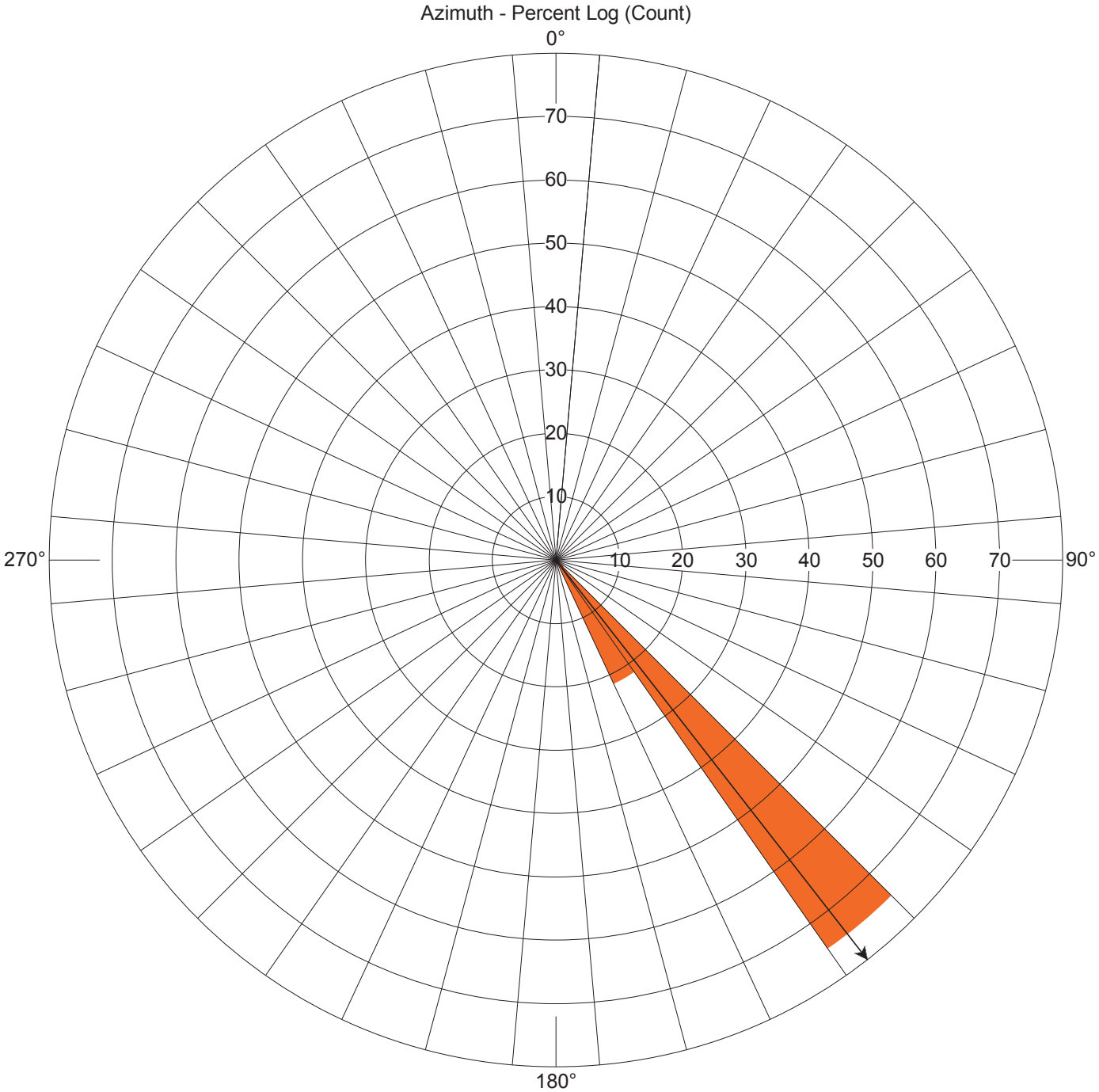
Average dip and dip azimuth differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 59 | 46.13 | 142.08 | |
| ● | 41 | 45.60 | 142.45 | Bedding / Banding / Foliation |
| ● | 5 | 47.16 | 141.12 | Minor Open Joint / Fracture |
| ● | 6 | 47.79 | 139.64 | Partially Open Joint / Fracture |
| ● | 7 | 47.03 | 142.79 | Filled Fracture / Joint |

GW-968

Directional histogram of dip azimuth with mean vector (scale unit is a value in percent of the total number of counts for all structures). Counting sector uses a 10 degree step with a 10 degree width.




| | |
|---|---|
| Counts: | 59.00 |
| Mean: | 142.08 |
| Min: | 134.59 |
| Max: | 153.51 |

**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-970

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, SP, Fluid Temperature and Resistivity

**DATE:** September 24, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2PFA, 2PCA, 2PGA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

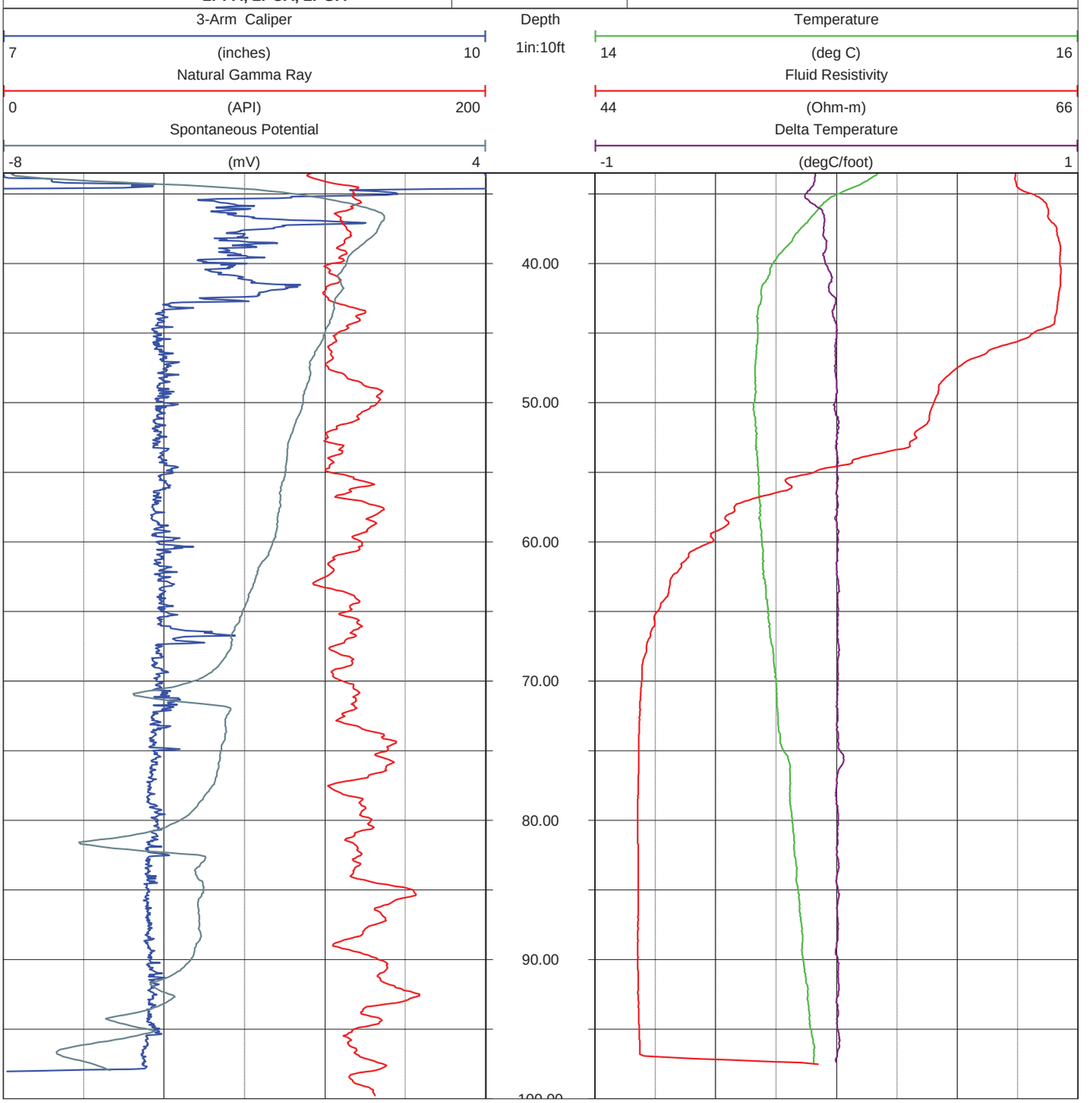
**CASED:** -0.17 to 34.1 feet (10 inch PVC)

**OPEN HOLE:** 34.1 to 101 feet

**MAX LOG DEPTH:** 99.8 feet

**WATER LEVEL:** Approximately 13 feet bgs

**COMMENTS:** Approximately two feet of fines at bottom of borehole.



PROJECT: **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** WELL ID: **GW-970**

CLIENT: **Alliant Corporation**

LOCATION: **Proposed Environmental Management Disposal Facility (EMDF)**

LOG TYPE: **Caliper, Gamma, Acoustic and Optical Televiewer**

DATE: **September 30, 2014**

OBSERVER: **Mark Maki, PG, (Alliant)**

RECORDED BY: **Garrick Marcoux, PGP, PG**

DATA FILES: **Multiple**

LOG DATUM: **Ground Surface**

INSTRUMENTATION: **Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA**

**URS Corporation**
**12120 Shamrock Plaza, Suite 300**
**Omaha, NE 68154**
**Ph: 402-334-8181**
**Fax: 402-334-1984**

DRILLING METHOD: **Air-rotary**

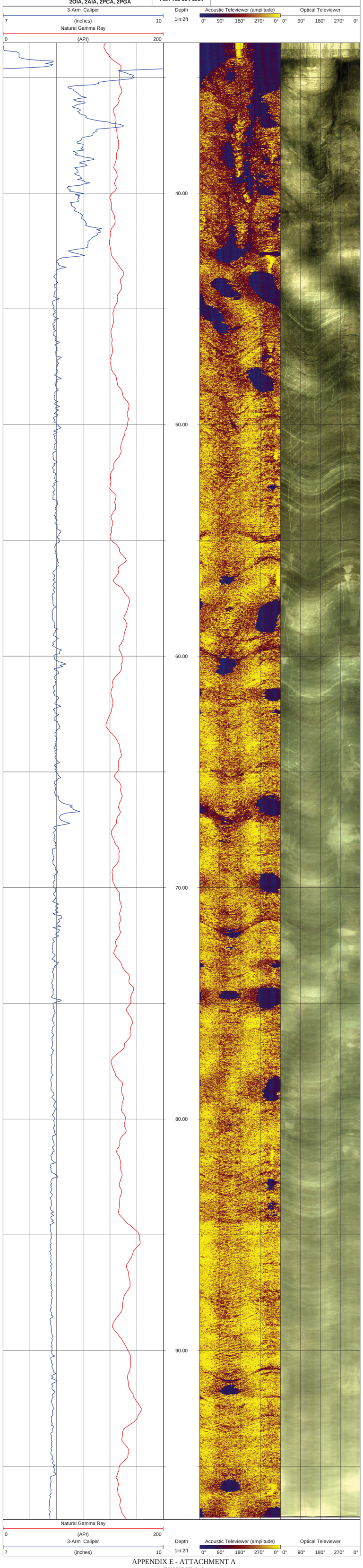
CASED: **-0.17 to 34.1 feet (10 inch PVC)**

OPEN HOLE: **34.1 to 101 feet**

MAX LOG DEPTH: **97.2 feet**

WATER LEVEL: **Approximately 17 feet bgs**

COMMENTS: **Approximately two feet of fines at bottom of borehole.**



PROJECT: **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** WELL ID: **GW-970**

CLIENT: **Alliant Corporation**

LOCATION: **Proposed Environmental Management Disposal Facility (EMDF)**

LOG TYPE: **Caliper, Gamma, Acoustic and Optical Televiewer, Fluid Temp. and Resistivity, Flow**

DATE: **September 30 - October 2, 2014**

OBSERVER: **Mark Maki, PG, (Alliant)**

RECORDED BY: **Garrick Marcoux, PGP, PG**

DATA FILES: **Multiple**

LOG DATUM: **Ground Surface**

INSTRUMENTATION: **Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA, 2PFA, HFP-2293**

**URS Corporation**
**12120 Shamrock Plaza, Suite 300**
**Omaha, NE 68154**
**Ph: 402-334-8181**
**Fax: 402-334-1984**

DRILLING METHOD: **Air-rotary**

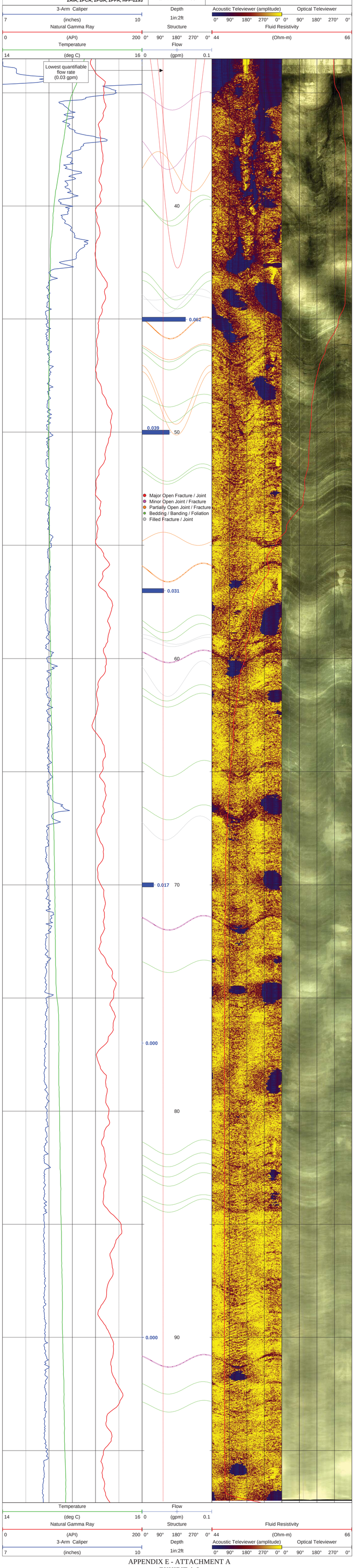
CASED: **-0.17 to 34.1 feet (10 inch PVC)**

OPEN HOLE: **34.1 to 101 feet**

MAX LOG DEPTH: **97.2 feet**

WATER LEVEL: **Approximately 17 feet bgs**

COMMENTS: **Flow rates below the documented manufacturer's range of measurement are presented for qualitative purposes only, and may not represent actual flow rates. Zero value flow rates may be the result of inadequate diverter seal. No downward flow was detected.**



| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-970** |

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (acoustic televiewer)

**DATE:** September 30, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** AIA_U_970-0930a.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2AIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

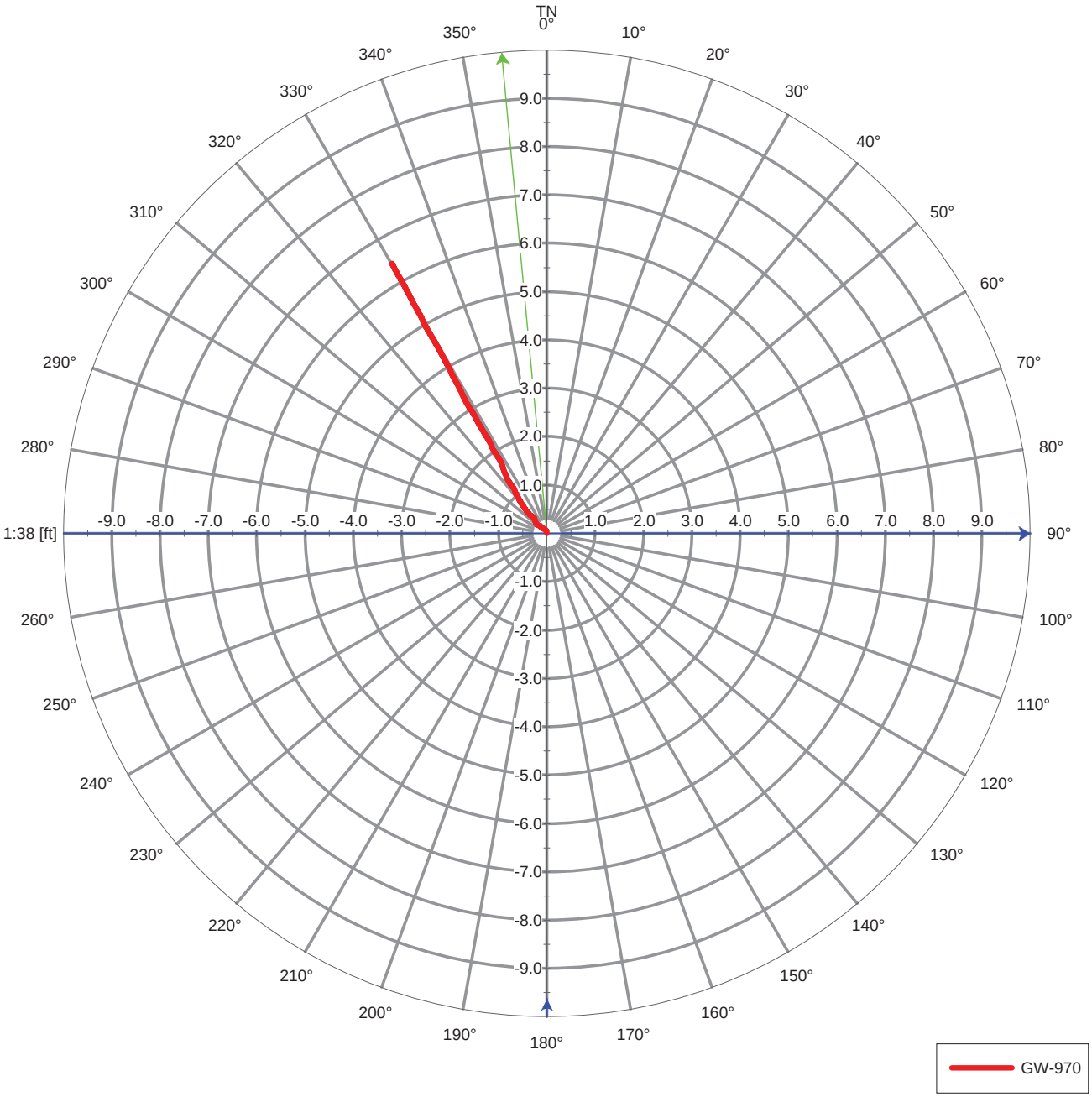
**CASED:** -0.17 to 33.8 feet (10 inch PVC)

**OPEN HOLE:** 33.8 to 101 feet

**MAX LOG DEPTH:** 96.9 feet

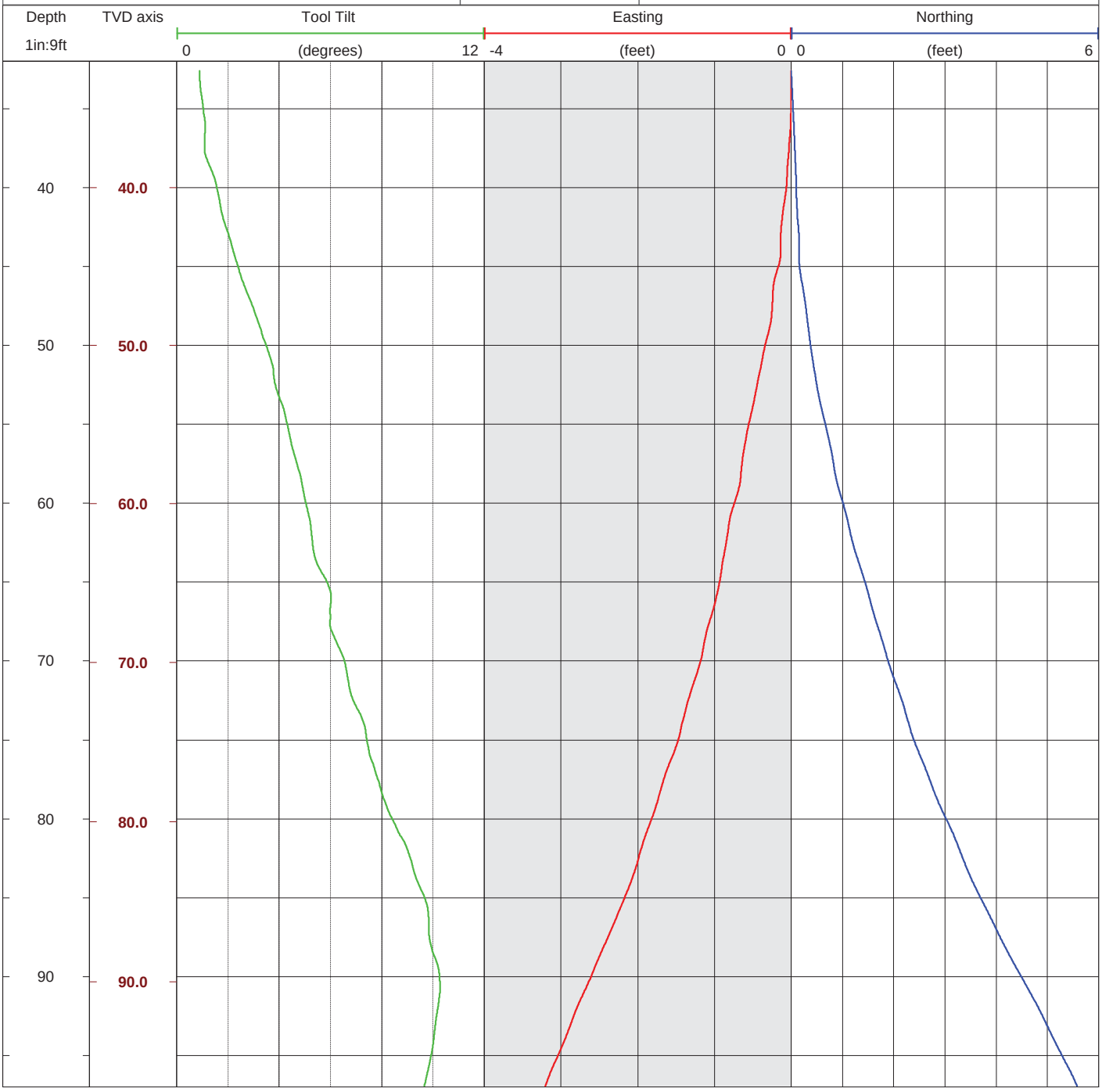
**WATER LEVEL:** Approximately 17 feet bgs

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



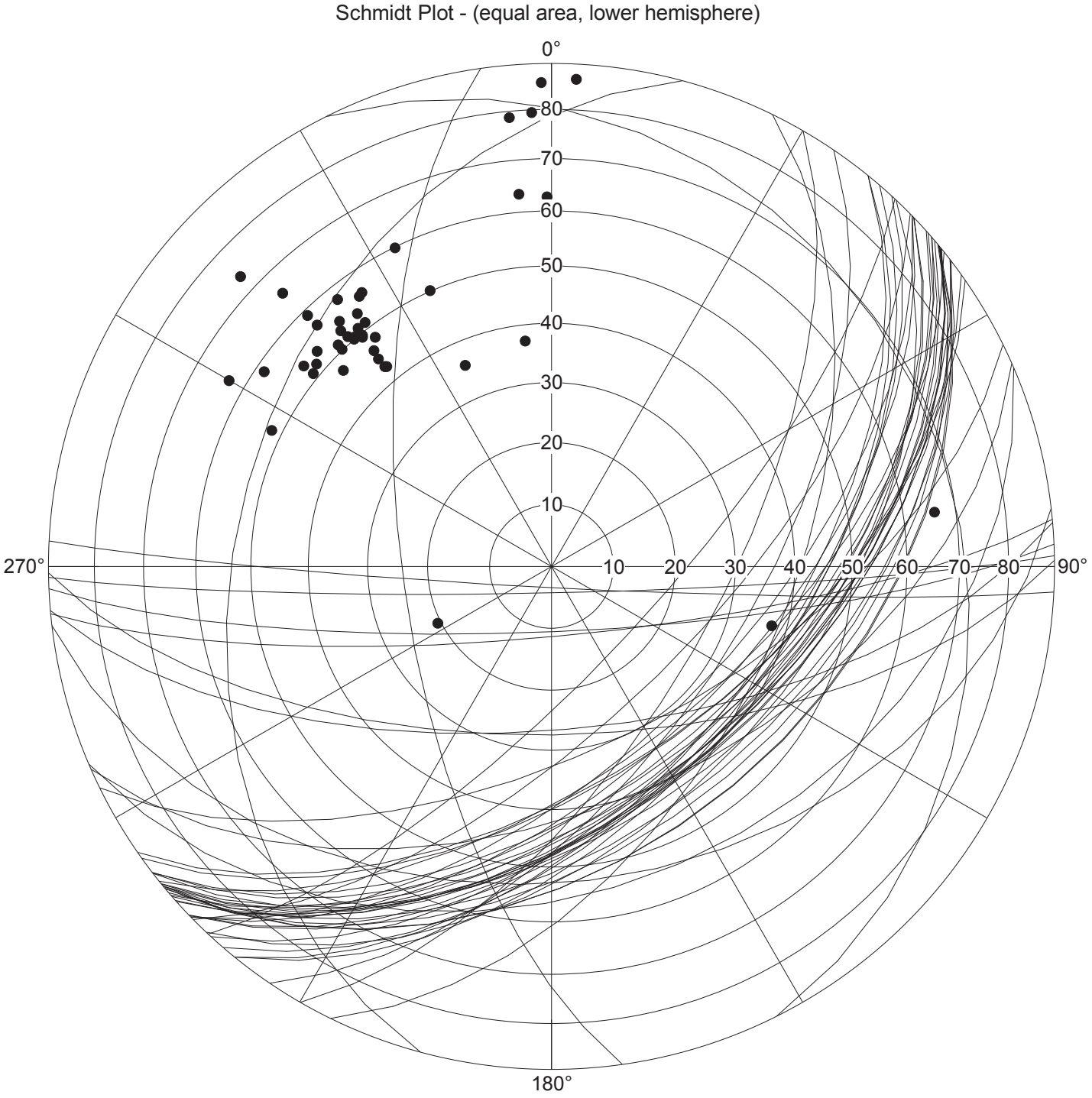
| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-970** |
| **CLIENT:** | Alliant Corporation | **DRILLING METHOD:** | Air-rotary |
| **LOCATION:** | Proposed Environmental Management Disposal Facility (EMDF) | **CASED:** | -0.17 to 33.8 feet (10 inch PVC) |
| **LOG TYPE:** | Deviation (acoustic televiewer) | **OPEN HOLE:** | 33.8 to 101 feet |
| **DATE:** | September 30, 2014 | **MAX LOG DEPTH:** | 96.9 feet |
| **OBSERVER:** | Mark Maki, PG, (Alliant) | **WATER LEVEL:** | Approximately 17 feet bgs |
| **RECORDED BY:** | Garrick Marcoux, PGP, PG | **COMMENTS:** | Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010) |
| **DATA FILES:** | AIA_U_970-0930a.tfd | | |
| **LOG DATUM:** | Ground Surface | | |
| **INSTRUMENTATION:** | Mt. Sopris Matrix logger, 2AIA | | |

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984



GW-970

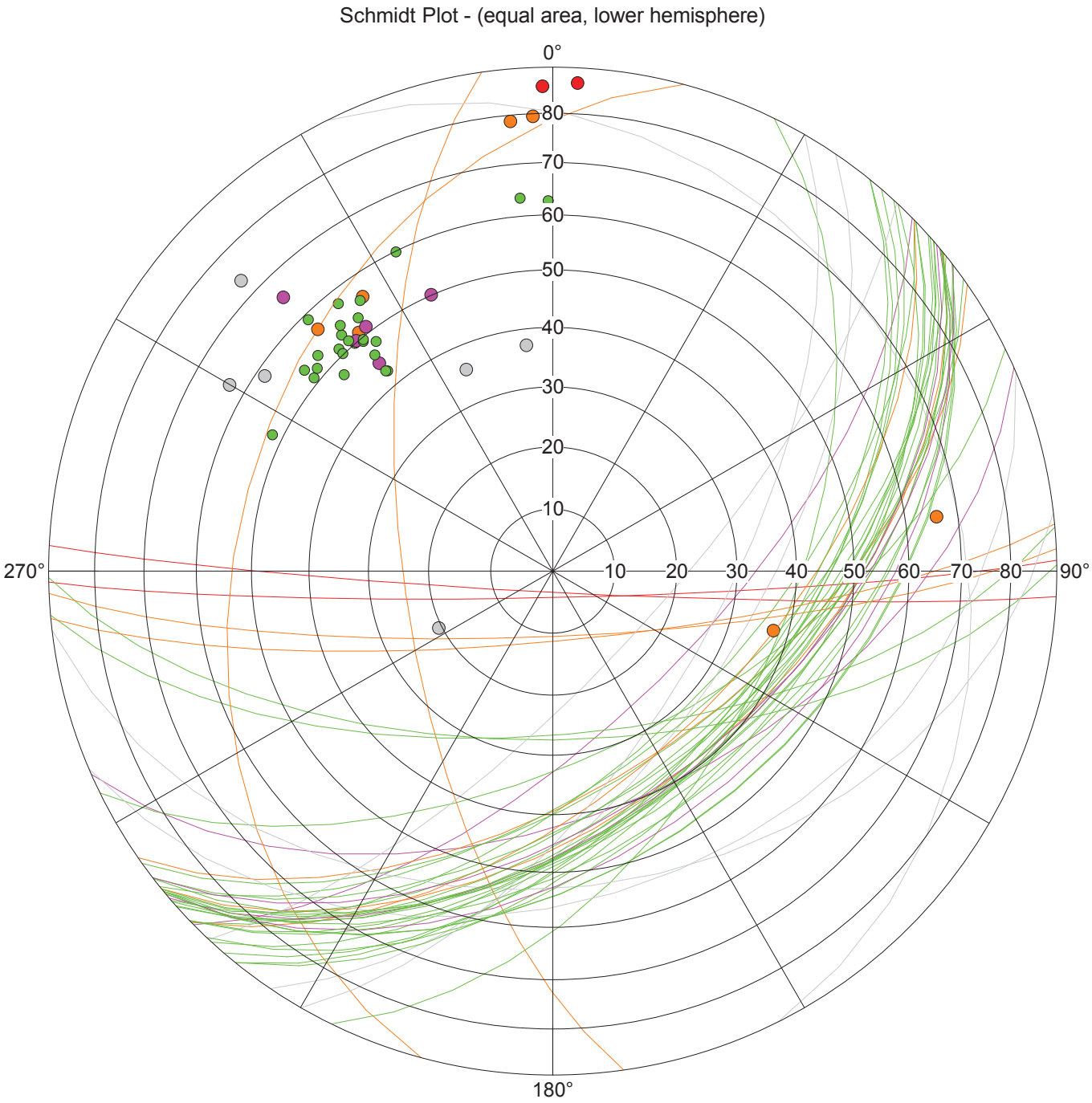
Dip and dip azimuths for all features.




| | Counts | Dip[deg] | Azi[deg] |
|---|---|---|---|
| Mean | 45 | 52.94 | 143.20 |

GW-970

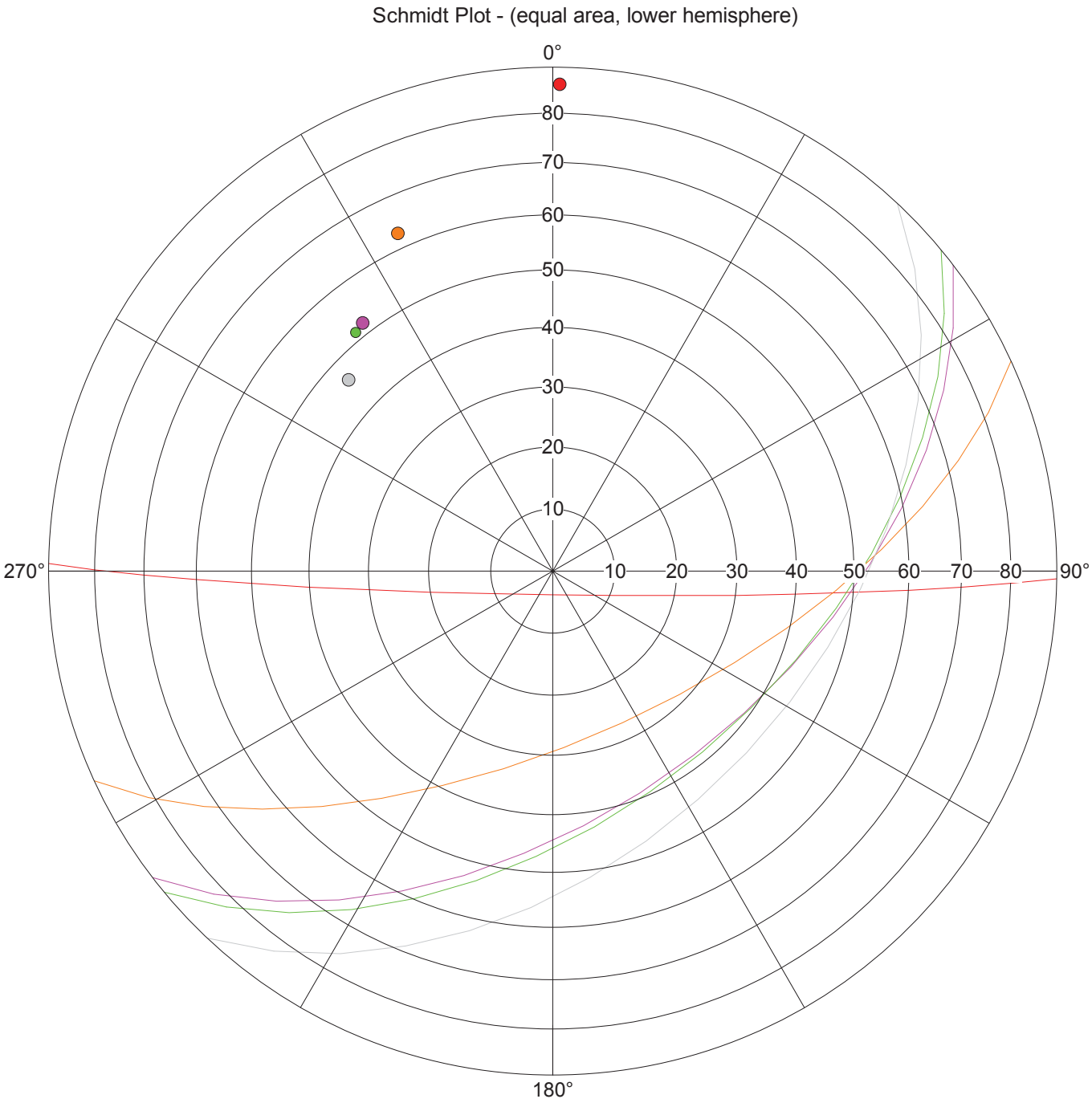
Dip and dip azimuths differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 45 | 52.94 | 143.20 | |
| | 2 | 86.18 | 180.85 | Major Open Fracture / Joint |
| | 5 | 52.07 | 142.55 | Minor Open Joint / Fracture |
| | 7 | 62.93 | 155.37 | Partially Open Joint / Fracture |
| | 25 | 51.57 | 140.41 | Bedding / Banding / Foliation |
| | 6 | 46.25 | 133.19 | Filled Fracture / Joint |

GW-970

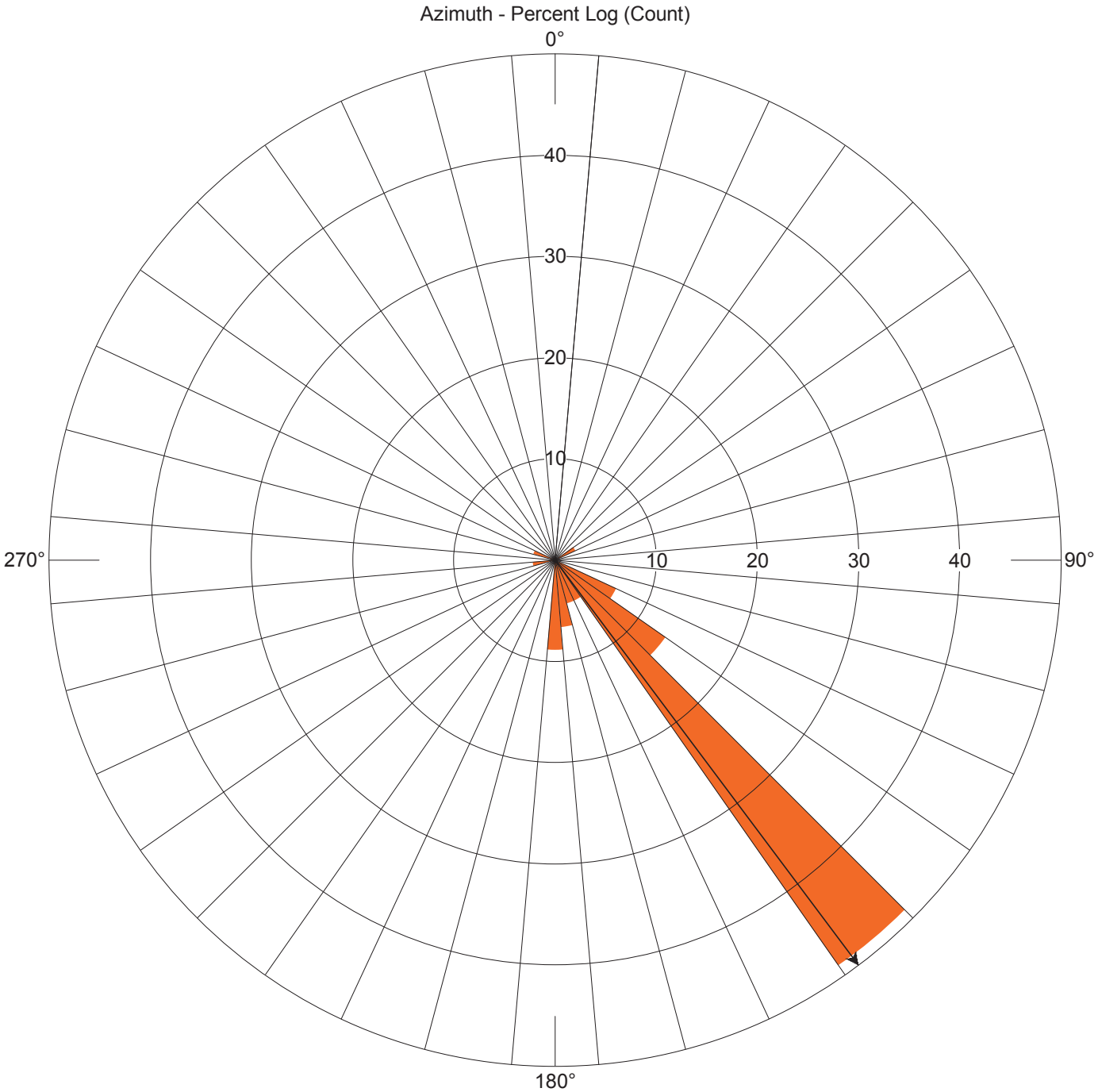
Average dip and dip azimuth differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 45 | 52.94 | 143.20 | |
| ● | 2 | 86.18 | 180.85 | Major Open Fracture / Joint |
| ● | 5 | 52.07 | 142.55 | Minor Open Joint / Fracture |
| ● | 7 | 62.93 | 155.37 | Partially Open Joint / Fracture |
| ● | 25 | 51.57 | 140.41 | Bedding / Banding / Foliation |
| ● | 6 | 46.25 | 133.19 | Filled Fracture / Joint |

GW-970

Directional histogram of dip azimuth with mean vector (scale unit is a value in percent of the total number of counts for all structures). Counting sector uses a 10 degree step with a 10 degree width.




| | |
|---|---|
| Counts: | 45.00 |
| Mean: | 143.20 |
| Min: | 63.46 |
| Max: | 285.07 |

**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-972

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, SP, Fluid Temperature and Resistivity

**DATE:** September 23, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2PFA, 2PCA, 2PGA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

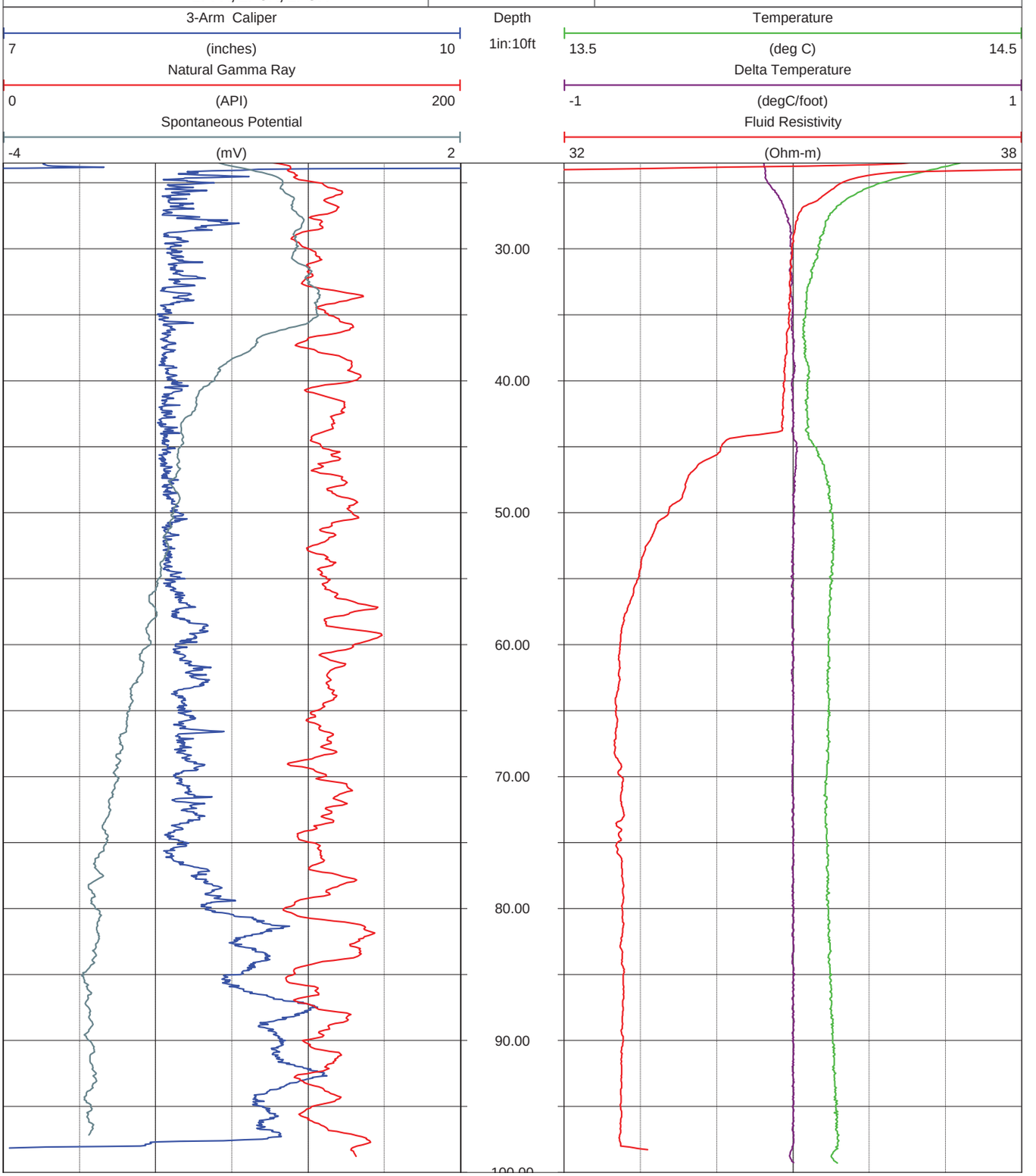
**CASED:** -0.5 to 24 feet (10 inch PVC)

**OPEN HOLE:** 24 to 99+ feet

**MAX LOG DEPTH:** 98 feet

**WATER LEVEL:** Approximately 9 feet bgs

**COMMENTS:** Approximately two feet of fines at bottom of borehole.



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-972

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, Acoustic and Optical Televiewer

**DATE:** September 29, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA


**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984


**DRILLING METHOD:** Air-rotary

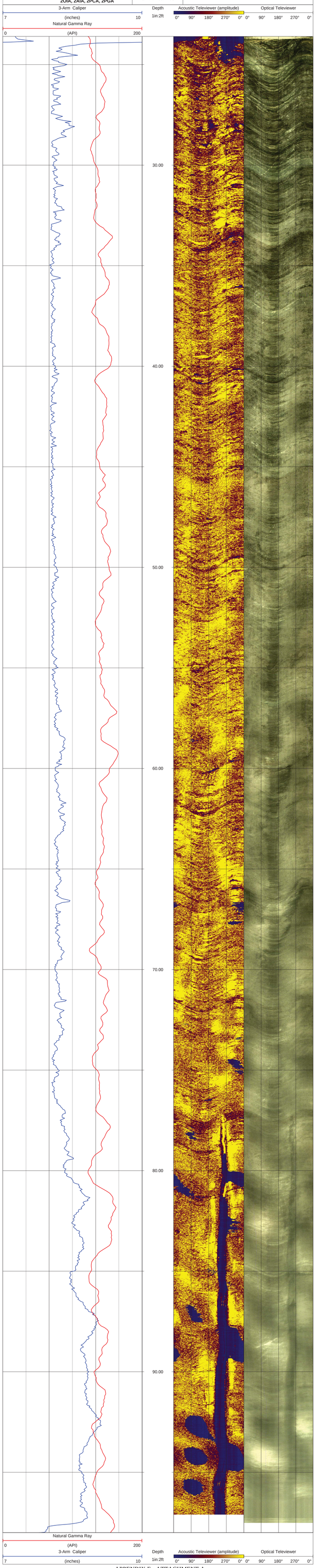
**CASED:** -0.5 to 24 feet (10 inch PVC)

**OPEN HOLE:** 24 to 99+ feet

**MAX LOG DEPTH:** 97.8 feet

**WATER LEVEL:** Approximately 9 feet bgs

**COMMENTS:** Approximately two feet of fines at bottom of borehole.



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-972

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, Acoustic and Optical Televiewer, Fluid Temp. and Resistivity, Flow

**DATE:** September 30 - October 1, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA


**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984


**DRILLING METHOD:** Air-rotary

**CASED:** -0.5 to 24 feet (10 inch PVC)

**OPEN HOLE:** 24 to 99+ feet

**MAX LOG DEPTH:** 97.5 feet

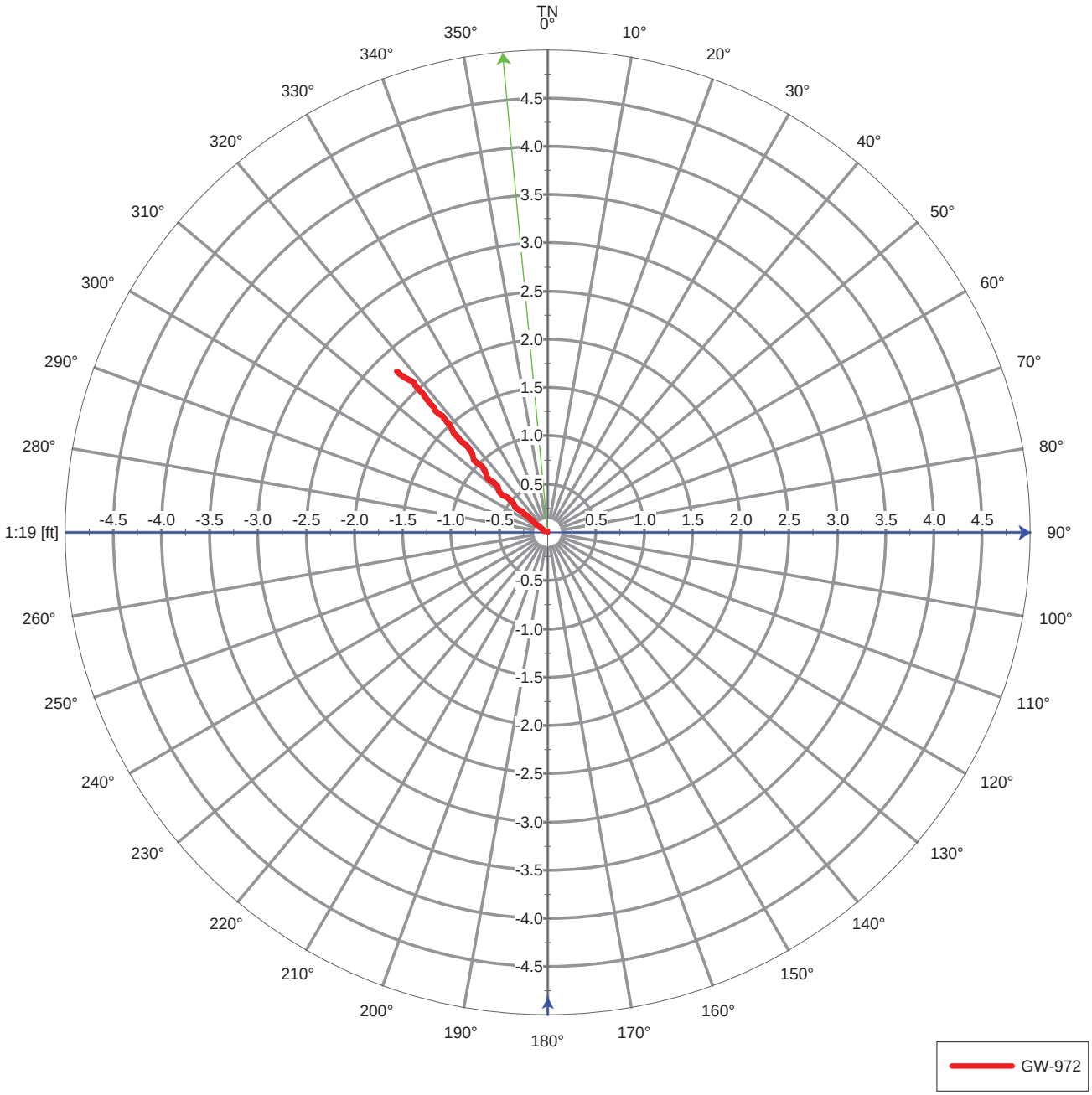
**WATER LEVEL:** Approximately 9 feet bgs

**COMMENTS:** Flow rates below the documented manufacturer's range of measurement are presented for qualitative purposes only, and may not represent actual flow rates. Zero value flow rates may be the result of inadequate diverter seal. No downward flow was detected.

| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-972** |

| | | |
|---|---|---|
| **CLIENT:** Alliant Corporation | | **DRILLING METHOD:** Air-rotary |
| **LOCATION:** Proposed Environmental Management Disposal Facility (EMDF) | | **CASED:** -0.5 to 24 feet (10 inch PVC) |
| **LOG TYPE:** Deviation (acoustic televiewer) | | **OPEN HOLE:** 24 to 99+ feet |
| **DATE:** September 29, 2014 | | **MAX LOG DEPTH:** 97 feet |
| **OBSERVER:** Mark Maki, PG, (Alliant) | | **WATER LEVEL:** Approximately 17 feet bgs |
| **RECORDED BY:** Garrick Marcoux, PGP, PG | | **COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010) |
| **DATA FILES:** ABI_U_972-0929a.tfd | | |
| **LOG DATUM:** Ground Surface | | |
| **INSTRUMENTATION:** Mt. Sopris Matrix logger, 2AIA | | |

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-972

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (acoustic televiewer)

**DATE:** September 29, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** ABI_U_972-0929a.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2AIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

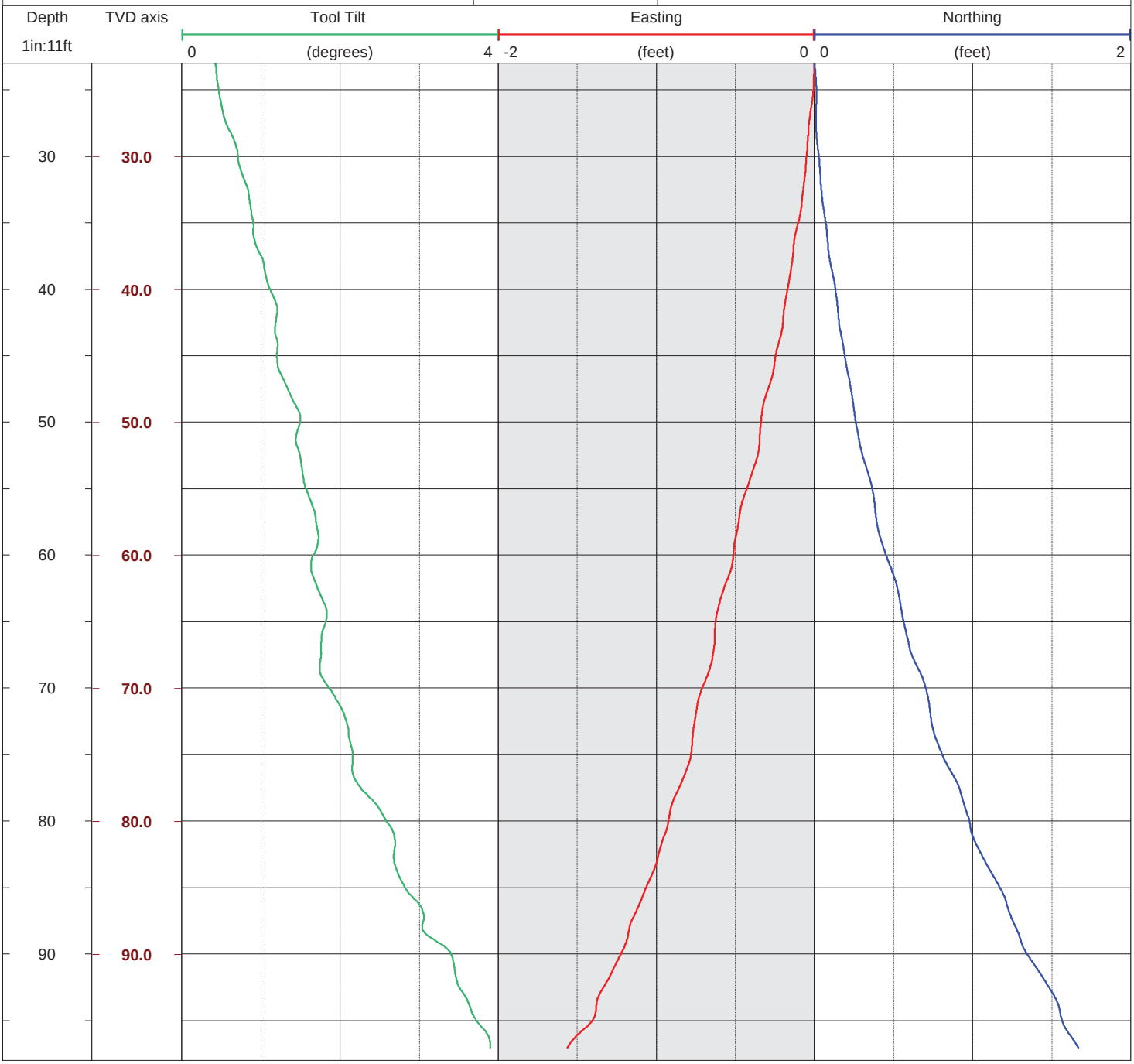
**CASED:** -0.5 to 24 feet (10 inch PVC)

**OPEN HOLE:** 24 to 99+ feet

**MAX LOG DEPTH:** 97 feet

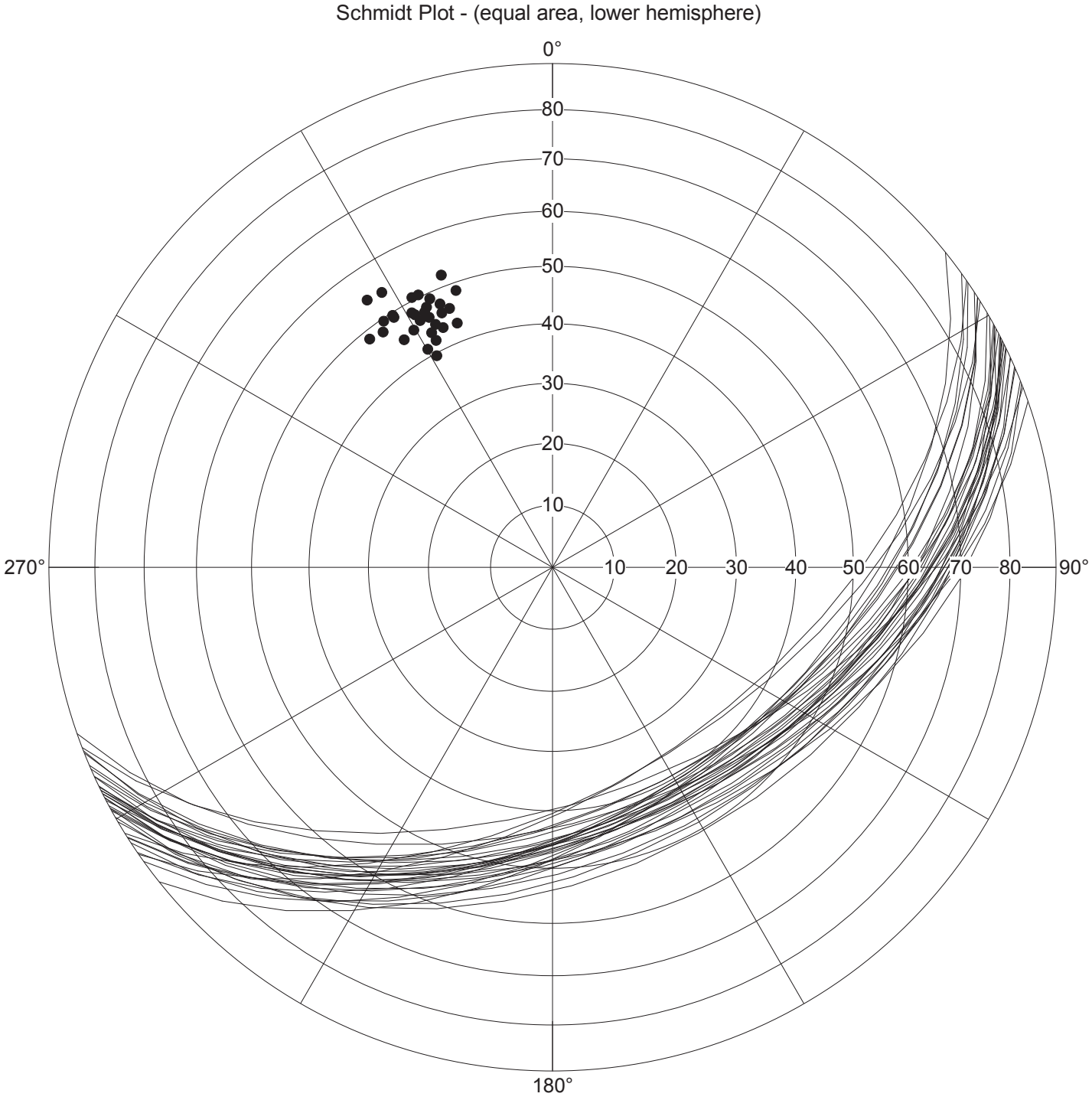
**WATER LEVEL:** Approximately 17 feet bgs

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



GW-972

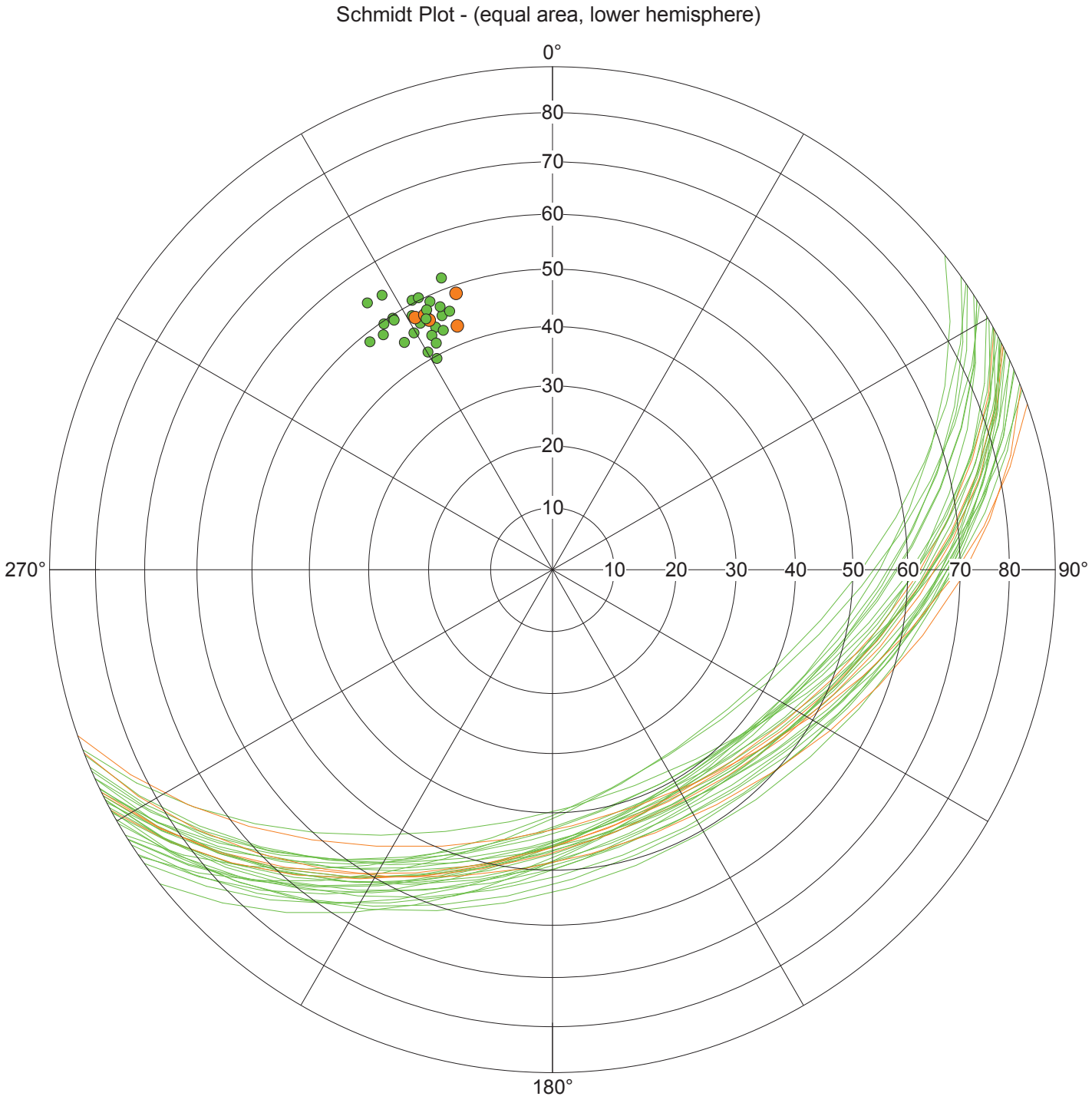
Dip and dip azimuths for all features.




| | Counts | Dip[deg] | Azi[deg] |
|---|---|---|---|
| Mean | 31 | 47.09 | 151.99 |

GW-972

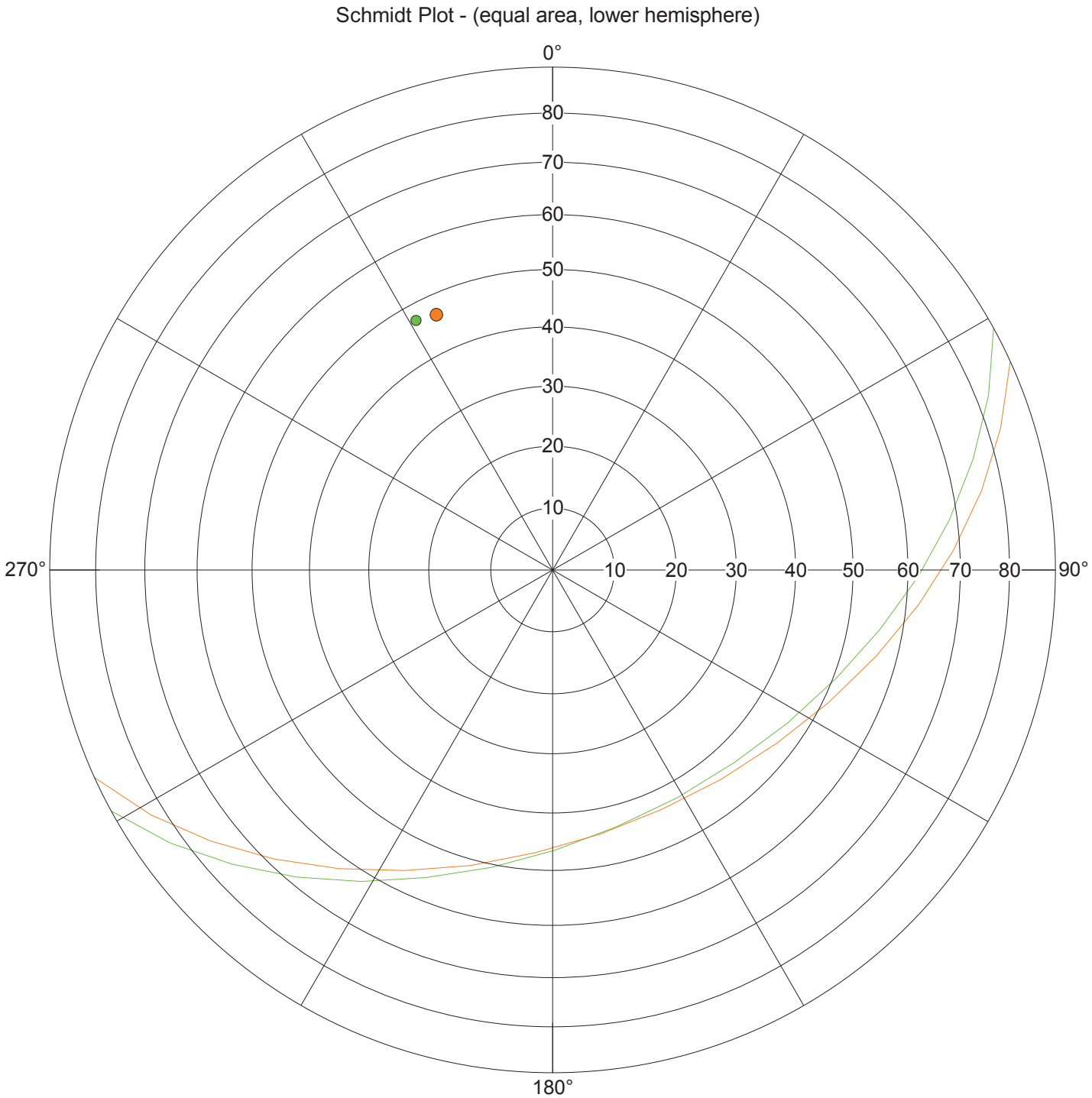
Dip and dip azimuths differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 31 | 47.09 | 151.99 | |
| ● | 26 | 47.20 | 151.32 | Bedding / Banding / Foliation |
| ● | 5 | 46.56 | 155.53 | Partially Open Joint / Fracture |

GW-972

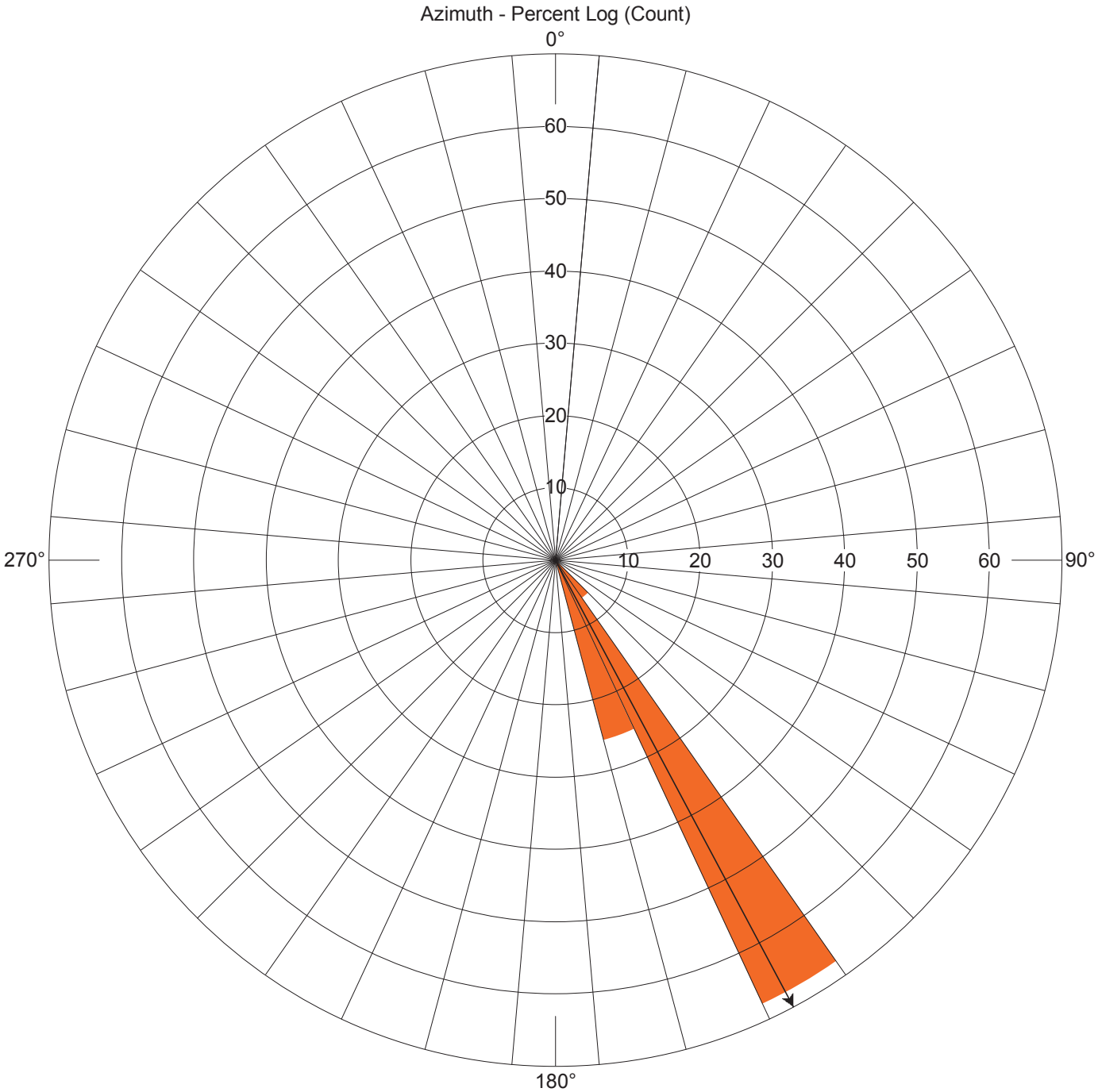
Average dip and dip azimuth differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 31 | 47.09 | 151.99 | |
| ● | 26 | 47.20 | 151.32 | Bedding / Banding / Foliation |
| ● | 5 | 46.56 | 155.53 | Partially Open Joint / Fracture |

GW-972

Directional histogram of dip azimuth with mean vector (scale unit is a value in percent of the total number of counts for all structures). Counting sector uses a 10 degree step with a 10 degree width.




| | |
|---|---|
| Counts: | 31.00 |
| Mean: | 151.99 |
| Min: | 141.36 |
| Max: | 160.70 |

**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-974

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, SP, Fluid Temperature and Resistivity

**DATE:** September 22, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2PFA, 2PCA, 2PGA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

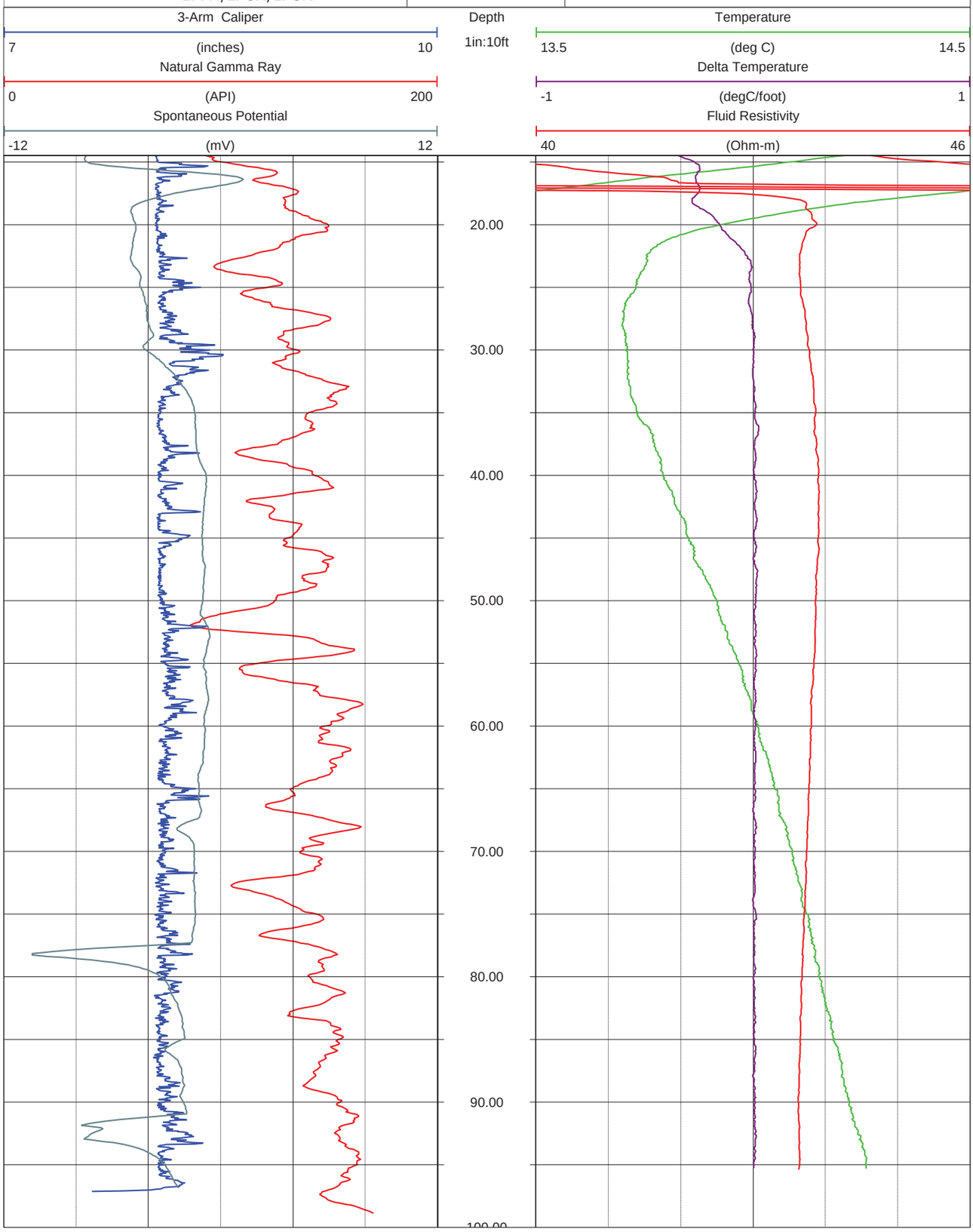
**CASED:** -0.5 to 15 feet (8 inch PVC)

**OPEN HOLE:** 15 to 99+ feet

**MAX LOG DEPTH:** 98.9 feet

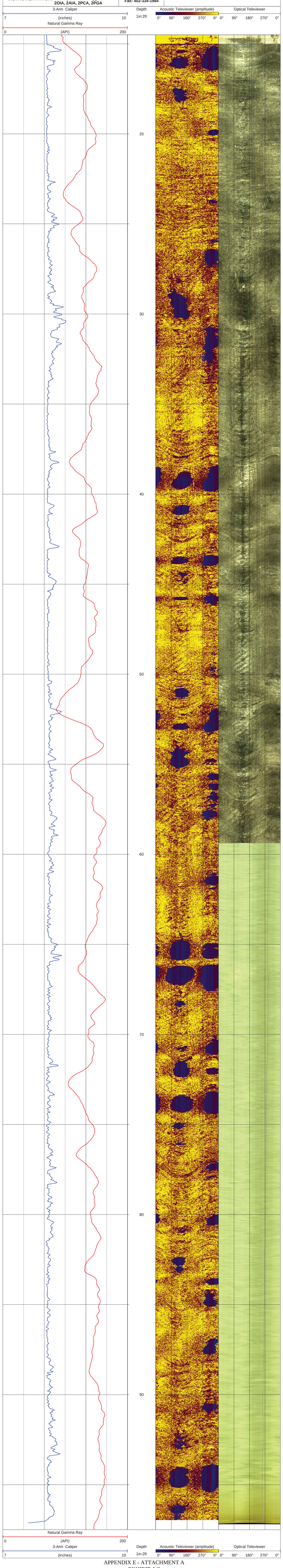
**WATER LEVEL:** Approximately 7.5 feet bgs

**COMMENTS:** Approximately three feet of fines at bottom of borehole.



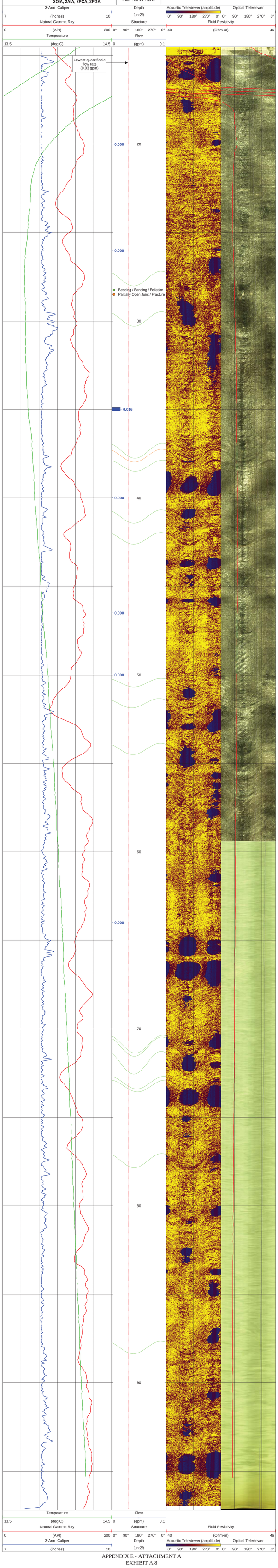
| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-974** |
| **CLIENT:** | Alliant Corporation | **DRILLING METHOD:** | Air-rotary |
| **LOCATION:** | Proposed Environmental Management Disposal Facility (EMDF) | **CASED:** | -0.5 to 15 feet (8 inch PVC) |
| **LOG TYPE:** | Caliper, Gamma, Acoustic and Optical Televiewer | **OPEN HOLE:** | 15 to 99+ feet |
| **DATE:** | September 22 & 24, 2014 | **MAX LOG DEPTH:** | 97 feet |
| **OBSERVER:** | Mark Maki, PG, (Alliant) | **WATER LEVEL:** | 59.4 (OTV only), ~7.5 feet (all others) |
| **RECORDED BY:** | Garrick Marcoux, PGP, PG | **COMMENTS:** | Approximately three feet of fines at bottom of borehole. Water pumped to approximately 59 feet bgs to facilitate OTV log. |
| **DATA FILES:** | **Multiple** | | |
| **LOG DATUM:** | Ground Surface | | |
| **INSTRUMENTATION:** | **Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA** | | |


**URS Corporation**
**12120 Shamrock Plaza, Suite 300**
**Omaha, NE 68154**
**Ph: 402-334-8181**
**Fax: 402-334-1984**

| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-974** |
| **CLIENT:** | **Alliant Corporation** | **DRILLING METHOD:** | **Air-rotary** |
| **LOCATION:** | **Proposed Environmental Management Disposal Facility (EMDF)** | **CASED:** | **-0.5 to 15 feet (8 inch PVC)** |
| **LOG TYPE:** | **Caliper, Gamma, Acoustic and Optical Televiewer, Fluid Temp. and Resistivity, Flow** | **OPEN HOLE:** | **15 to 99+ feet** |
| **DATE:** | **September 30 - October 1, 2014** | **MAX LOG DEPTH:** | **97 feet** |
| **OBSERVER:** | **Mark Maki, PG, (Alliant)** | **WATER LEVEL:** | **59.4 (OTV only), ~7.5 feet (all others)** |
| **RECORDED BY:** | **Garrick Marcoux, PGP, PG** | **COMMENTS:** | **Flow rates below the documented manufacturer's range of measurement are presented for qualitative purposes only, and may not represent actual flow rates. Zero value flow rates may be the result of inadequate diverter seal. No downward flow was detected.** |
| **DATA FILES:** | **Multiple** | | |
| **LOG DATUM:** | **Ground Surface** | | |
| **INSTRUMENTATION:** | **Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA** | | |


**URS Corporation**
**12120 Shamrock Plaza, Suite 300**
**Omaha, NE 68154**
**Ph: 402-334-8181**
**Fax: 402-334-1984**

| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-974** |

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (acoustic televiewer)

**DATE:** September 25, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** ABI_U_974-0925b.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2AIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

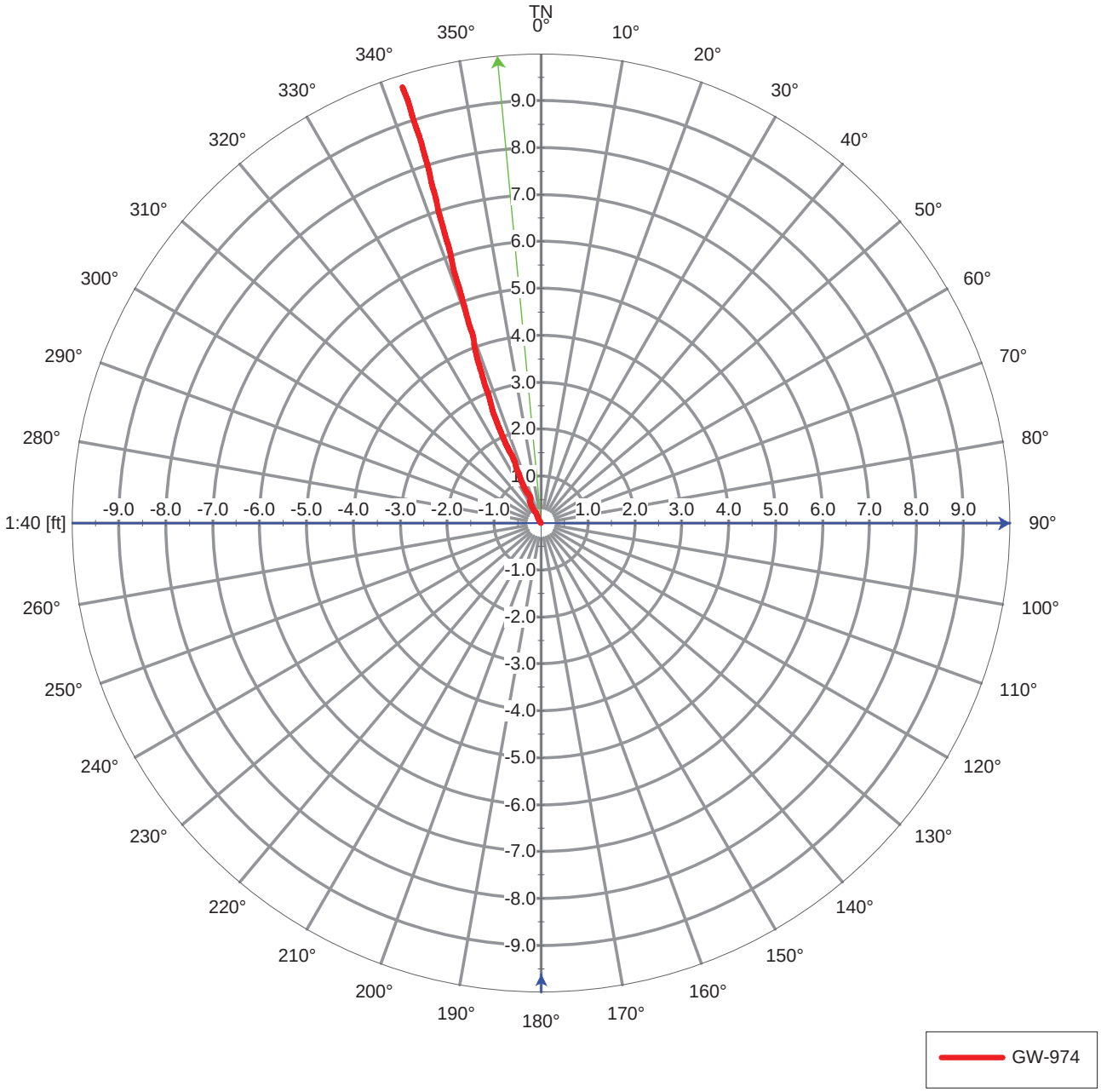
**CASED:** -0.5 to 15 feet (8 inch PVC)

**OPEN HOLE:** 15 to 99+ feet

**MAX LOG DEPTH:** 97 feet

**WATER LEVEL:** Approximately 7.5 feet bgs

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-974

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (acoustic televiewer)

**DATE:** September 25, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** ABI_U_974-0925b.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2AIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

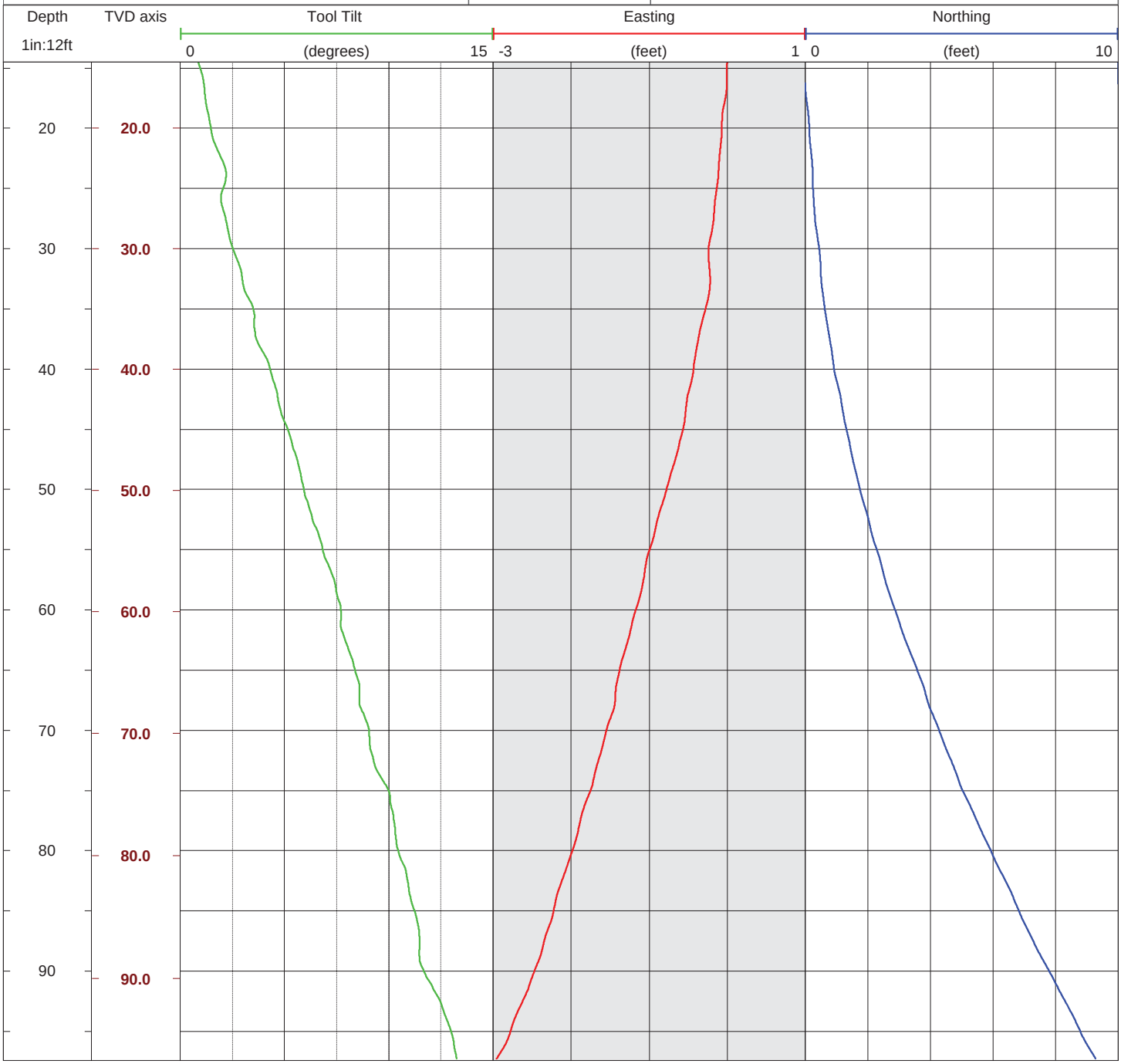
**CASED:** -0.5 to 15 feet (8 inch PVC)

**OPEN HOLE:** 15 to 99+ feet

**MAX LOG DEPTH:** 97 feet

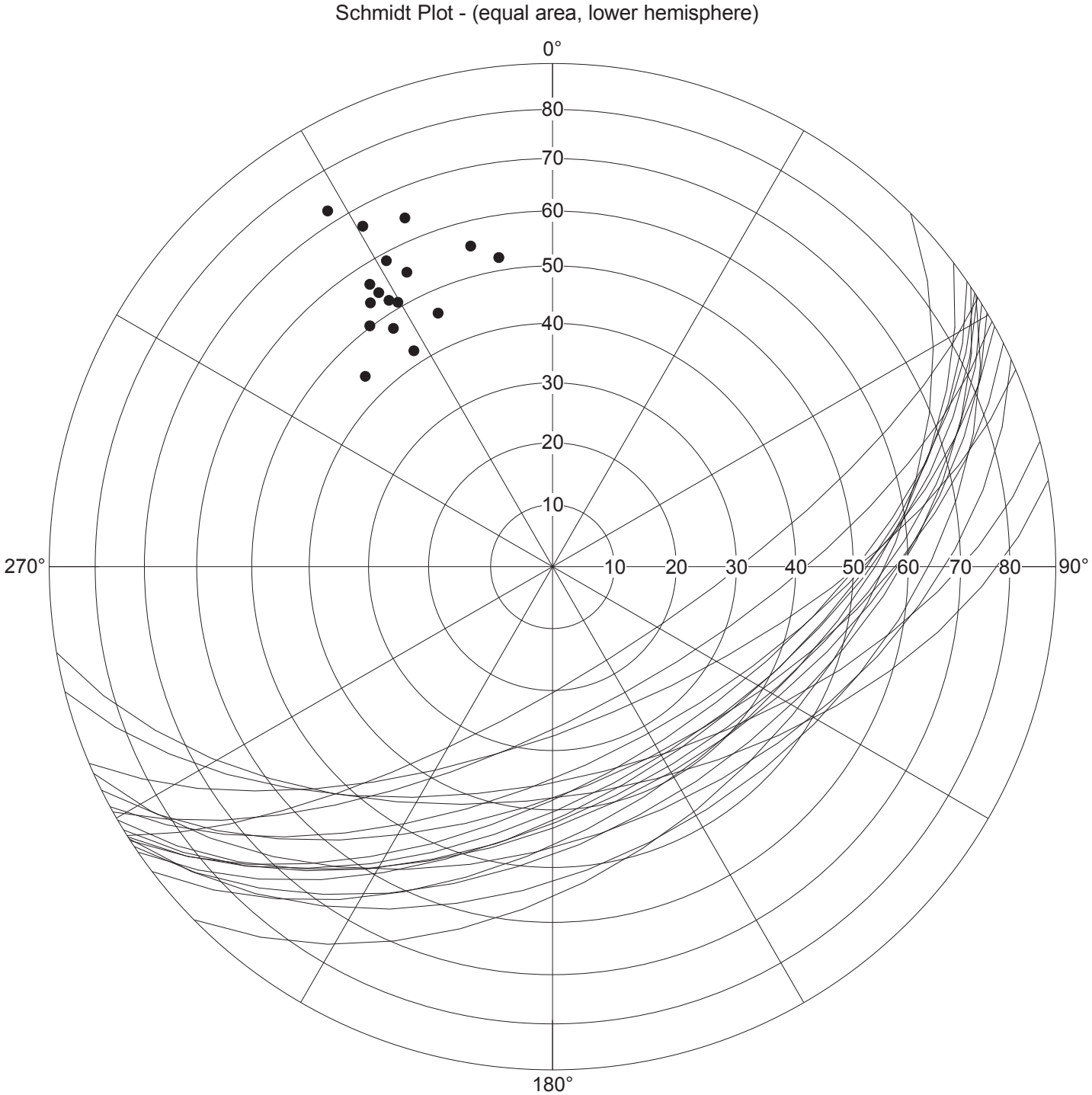
**WATER LEVEL:** Approximately 7.5 feet bgs

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



GW-974

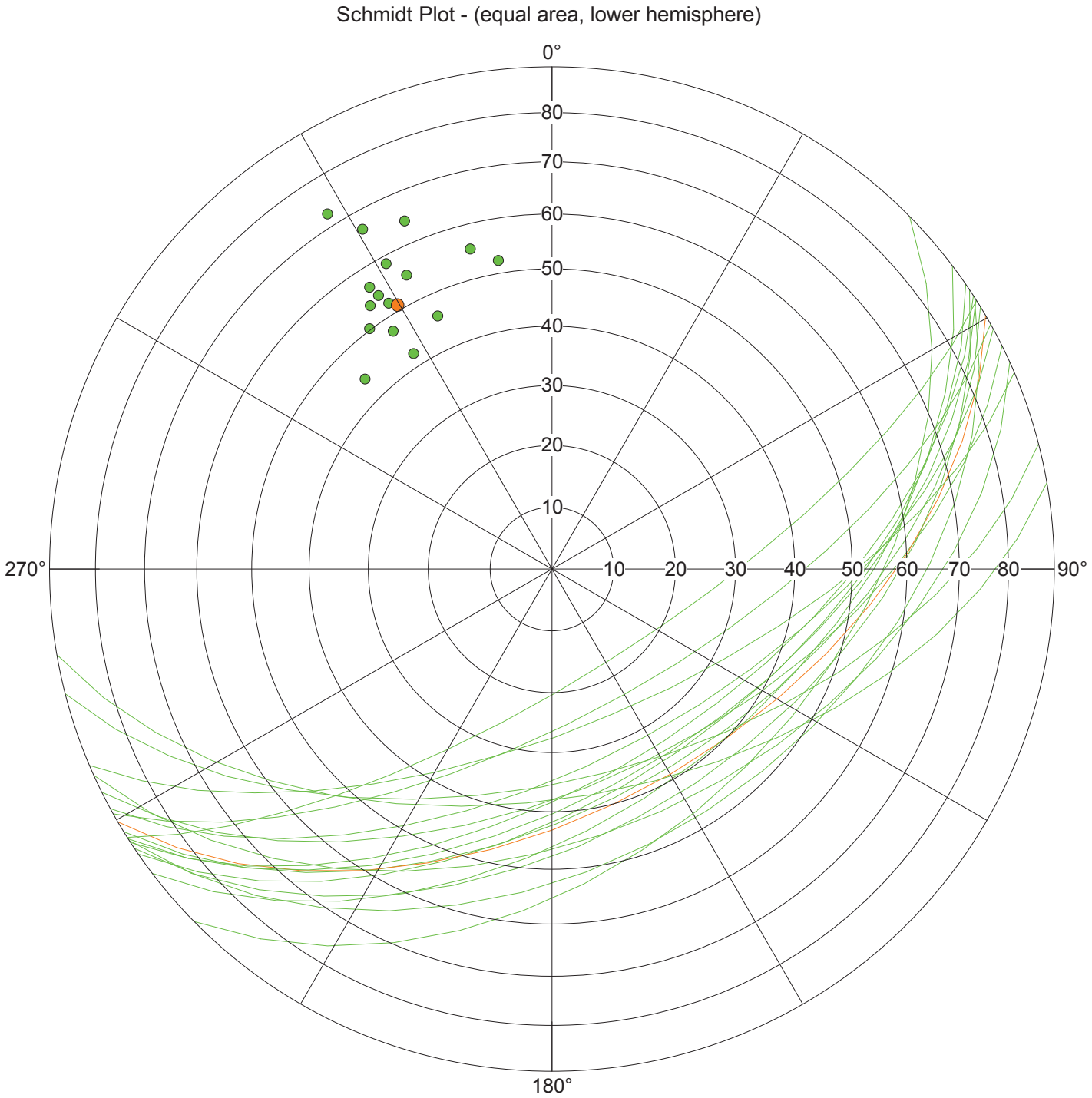
Dip and dip azimuths for all features.




| | Counts | Dip[deg] | Azi[deg] |
|---|---|---|---|
| Mean | 17 | 53.99 | 150.85 |

GW-974

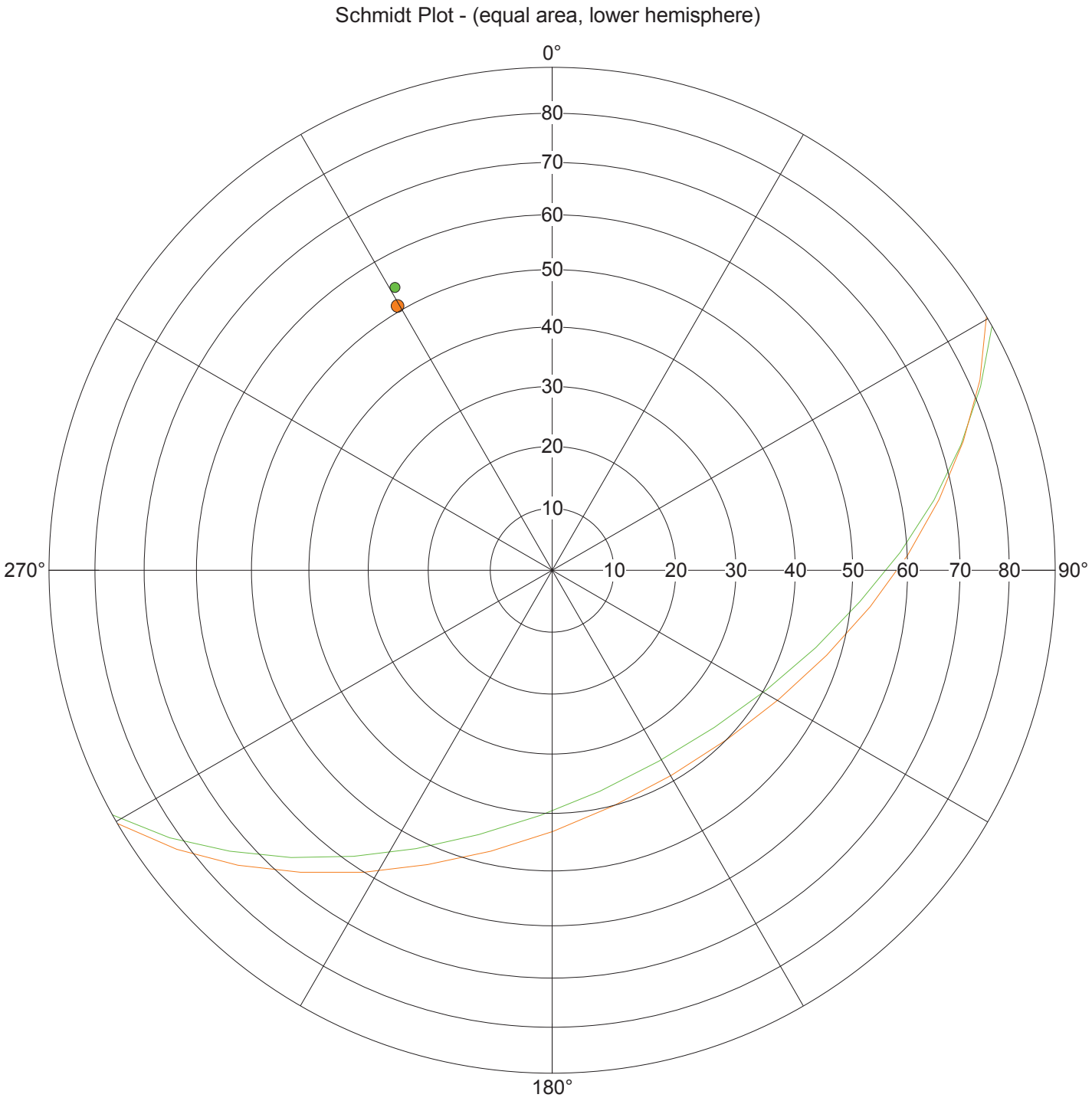
Dip and dip azimuths differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 17 | 53.99 | 150.85 | |
| ● | 16 | 54.19 | 150.93 | Bedding / Banding / Foliation |
| ● | 1 | 51.09 | 149.72 | Partially Open Joint / Fracture |

GW-974

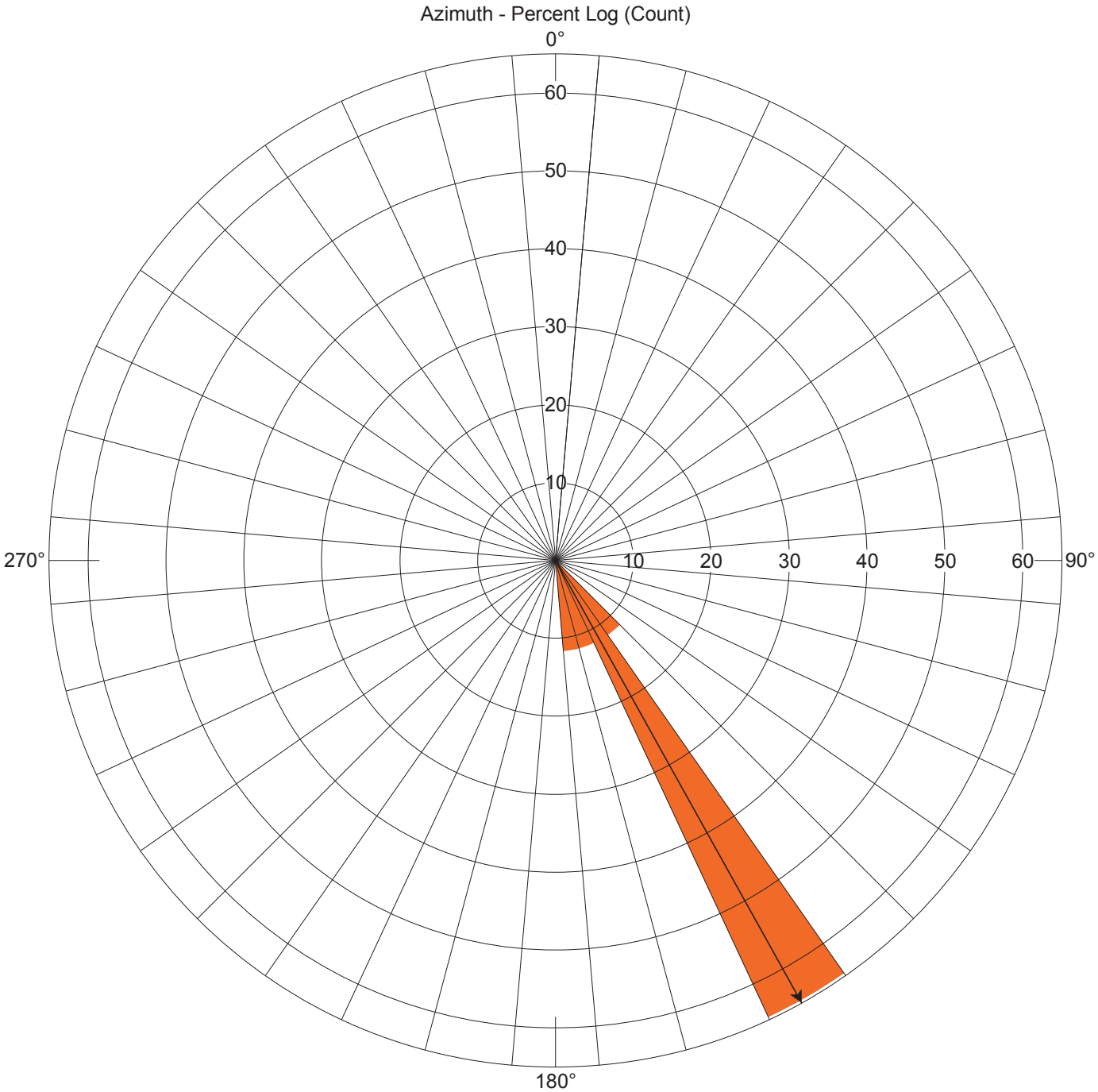
Average dip and dip azimuth differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 17 | 53.99 | 150.85 | |
| ● | 16 | 54.19 | 150.93 | Bedding / Banding / Foliation |
| ● | 1 | 51.09 | 149.72 | Partially Open Joint / Fracture |

GW-974

Directional histogram of dip azimuth with mean vector (scale unit is a value in percent of the total number of counts for all structures). Counting sector uses a 10 degree step with a 10 degree width.




| | |
|---|---|
| Counts: | 17.00 |
| Mean: | 150.85 |
| Min: | 135.44 |
| Max: | 170.13 |

**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-976

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Caliper, Gamma, SP, Fluid Temperature and Resistivity

**DATE:** September 23, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** Multiple

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2PFA, 2PCA, 2PGA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

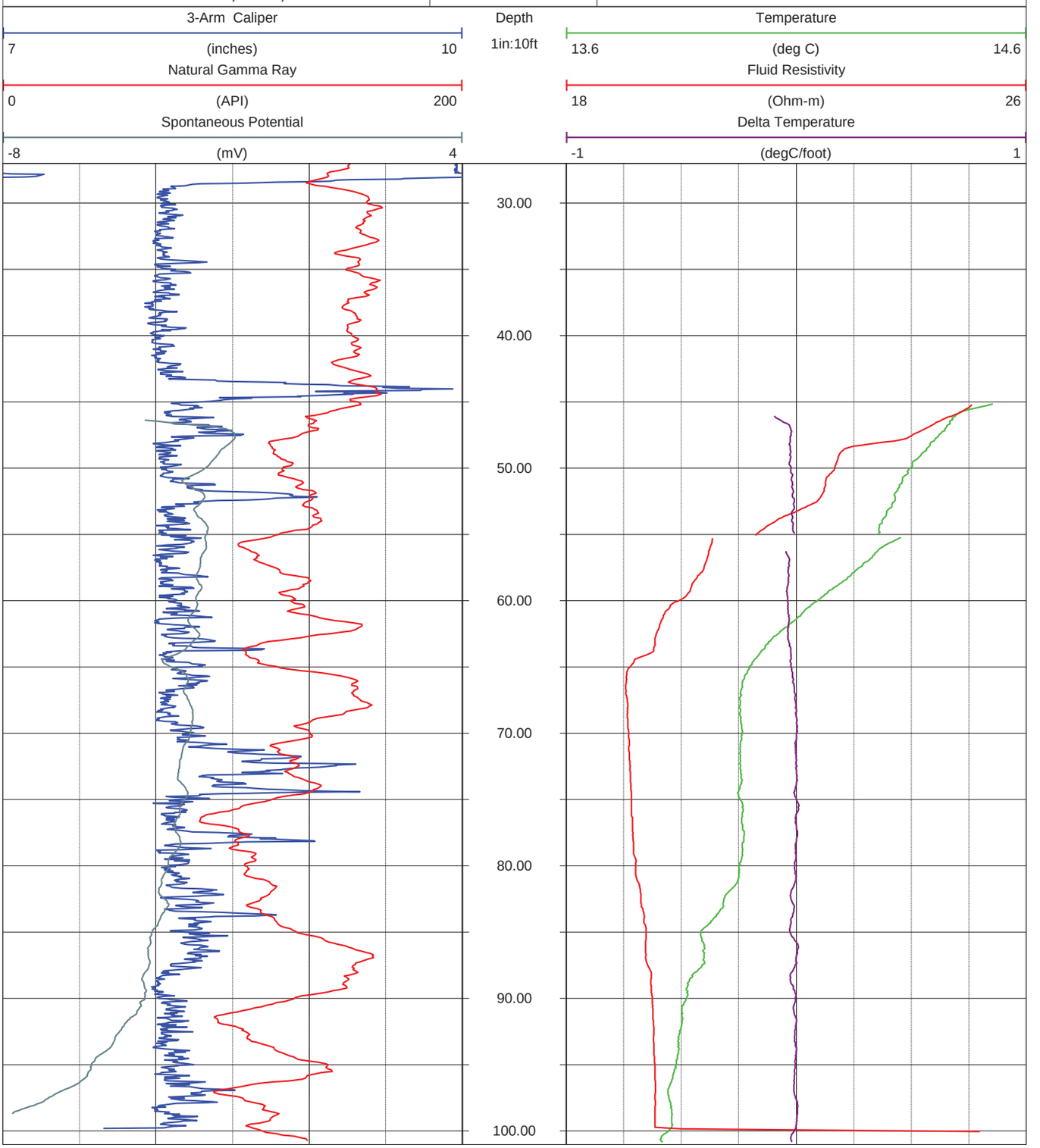
**CASED:** -0.75 to 28 feet (10 inch PVC)

**OPEN HOLE:** 28 to 101 feet

**MAX LOG DEPTH:** 101 feet

**WATER LEVEL:** Approximately 44.3 feet bgs

**COMMENTS:** The fluid log was stopped at 55 feet and restarted to evaluate anomalous system behavior. The 2PFA probe was not moved up before restarting to minimize mixing of borehole fluids.



| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-976** |
| **CLIENT:** | Alliant Corporation | **DRILLING METHOD:** | Air-rotary |
| **LOCATION:** | Proposed Environmental Management Disposal Facility (EMDF) | **CASED:** | -0.75 to 28 feet (10 inch PVC) |
| **LOG TYPE:** | Caliper, Gamma, Acoustic and Optical Televiewer | **OPEN HOLE:** | 28 to 101 feet |
| **DATE:** | September 29, 2014 | **MAX LOG DEPTH:** | 99.6 feet (OTV) |
| **OBSERVER:** | Mark Maki, PG, (Alliant) | **WATER LEVEL:** | Approximately 44.3 feet bgs |
| **RECORDED BY:** | Garrick Marcoux, PGP, PG | **COMMENTS:** | |
| **DATA FILES:** | **Multiple** | | |
| **LOG DATUM:** | Ground Surface | | |
| **INSTRUMENTATION:** | **Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA** | | |


**URS Corporation**
**12120 Shamrock Plaza, Suite 300**
**Omaha, NE 68154**
**Ph: 402-334-8181**
**Fax: 402-334-1984**

PROJECT: **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** WELL ID: GW-976

CLIENT: Alliant Corporation

LOCATION: Proposed Environmental Management Disposal Facility (EMDF)

LOG TYPE: Caliper, Gamma, Acoustic and Optical Televiewer, Fluid Temp. and Resistivity, Flow

DATE: September 23 - 29, 2014

OBSERVER: Mark Maki, PG, (Alliant)

RECORDED BY: Garrick Marcoux, PGP, PG

DATA FILES: Multiple

LOG DATUM: Ground Surface

INSTRUMENTATION: Mt. Sopris Matrix logger, 2OIA, 2AIA, 2PCA, 2PGA, 2PFA, HFP-2293

URS Corporation
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

DRILLING METHOD: Air-rotary

CASED: -0.75 to 28 feet (10 inch PVC)

OPEN HOLE: 28 to 101 feet

MAX LOG DEPTH: 99.6 feet (OTV)

WATER LEVEL: Approximately 44.3 feet bgs

COMMENTS: Flow rates below the documented manufacturer's range of measurement are presented for qualitative purposes only, and may not represent actual flow rates. Zero value flow rates may be the result of inadequate diverter seal. No downward flow was detected.

| | | | |
|---|---|---|---|
| **PROJECT:** | **LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF** | **WELL ID:** | **GW-976** |

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (optical televiewer)

**DATE:** September 29, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** OIA_D_976-0929a.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2OIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

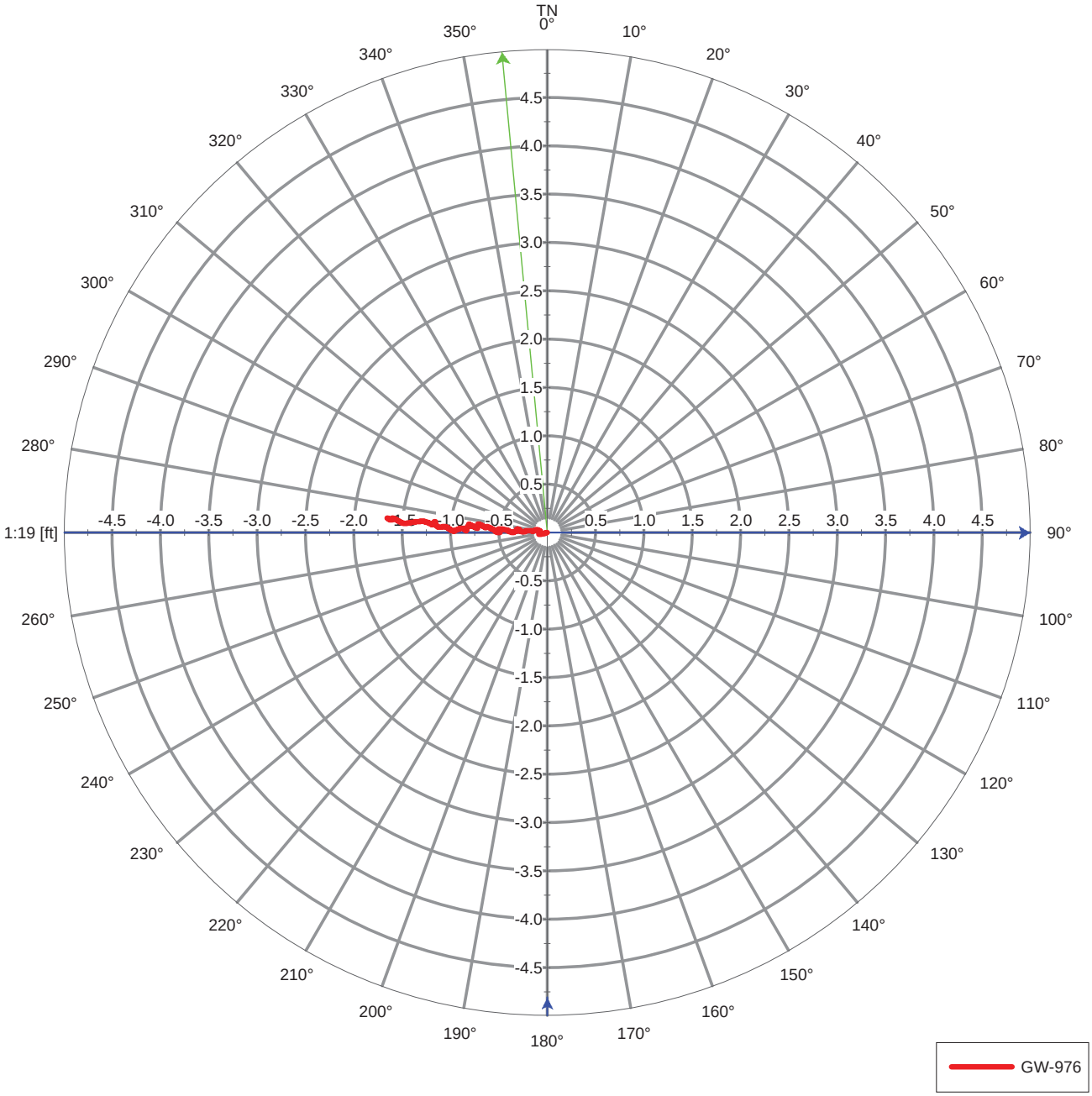
**CASED:** -0.75 to 28 feet (10 inch PVC)

**OPEN HOLE:** 28 to 101 feet

**MAX LOG DEPTH:** 99.6 feet (OTV)

**WATER LEVEL:** Approximately 44.3 feet bgs

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



**PROJECT:** LIMITED PHASE I SITE CHARACTERIZATION PROPOSED EMDF **WELL ID:** GW-976

**CLIENT:** Alliant Corporation

**LOCATION:** Proposed Environmental Management Disposal Facility (EMDF)

**LOG TYPE:** Deviation (optical televiewer)

**DATE:** September 29, 2014

**OBSERVER:** Mark Maki, PG, (Alliant)

**RECORDED BY:** Garrick Marcoux, PGP, PG

**DATA FILES:** OIA_D_976-0929a.tfd

**LOG DATUM:** Ground Surface

**INSTRUMENTATION:** Mt. Sopris Matrix logger, 2OIA

**URS Corporation**
12120 Shamrock Plaza, Suite 300
Omaha, NE 68154
Ph: 402-334-8181
Fax: 402-334-1984

**DRILLING METHOD:** Air-rotary

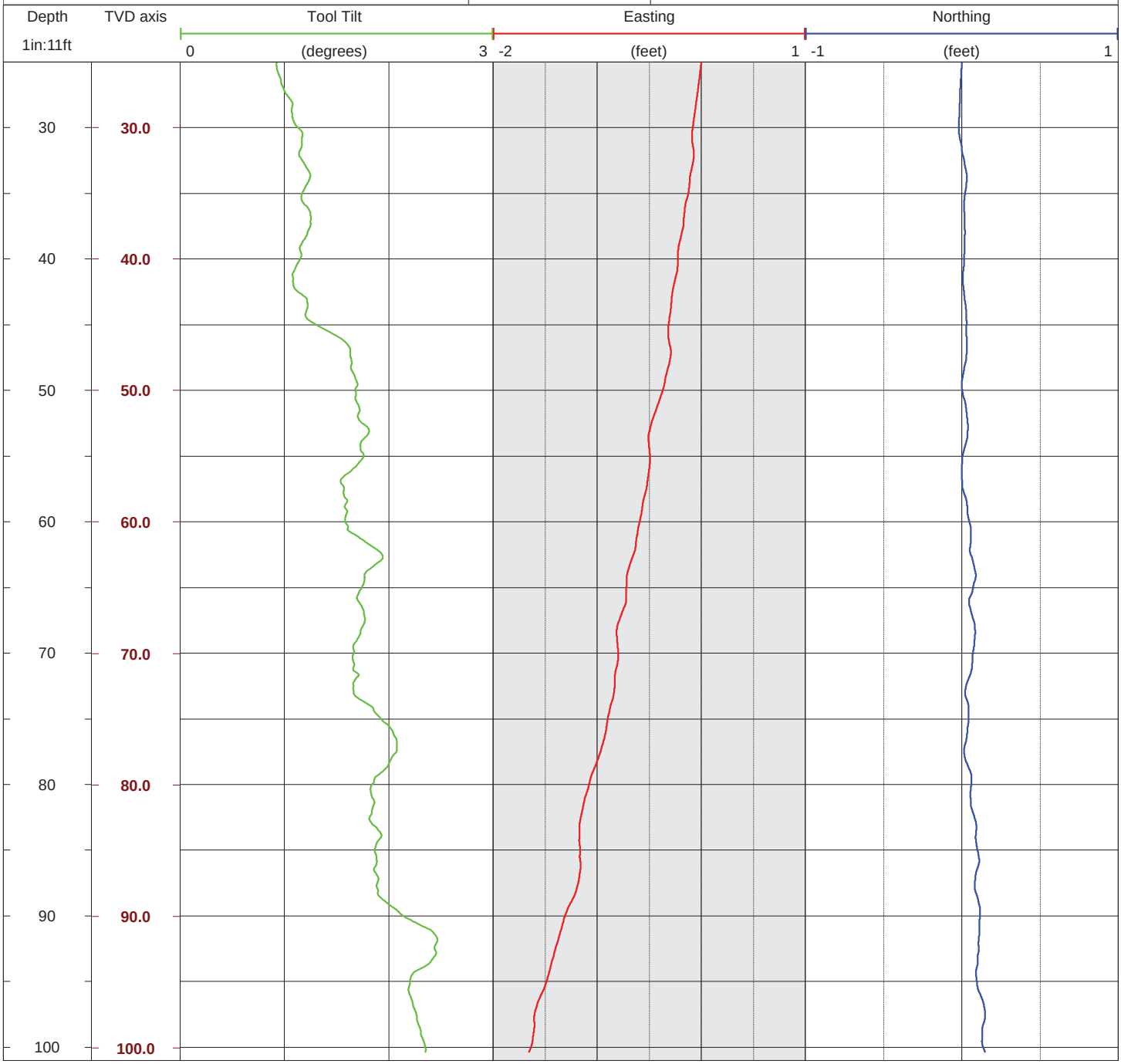
**CASED:** -0.75 to 28 feet (10 inch PVC)

**OPEN HOLE:** 28 to 101 feet

**MAX LOG DEPTH:** 99.6 feet (OTV)

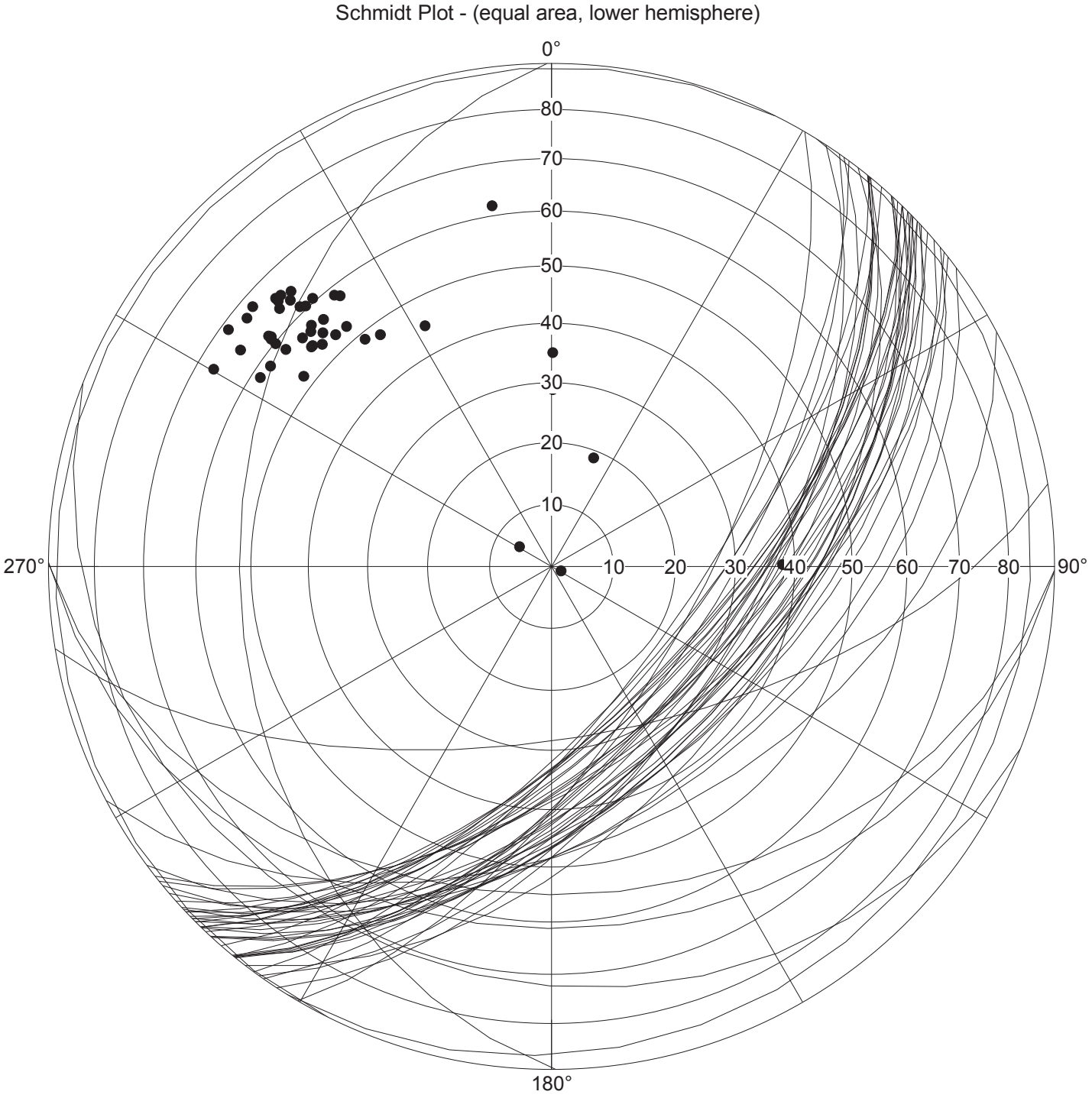
**WATER LEVEL:** Approximately 44.3 feet bgs

**COMMENTS:** Magnetic declination = 5 degrees, 21.93 minutes west (WMM 2010)



GW-976

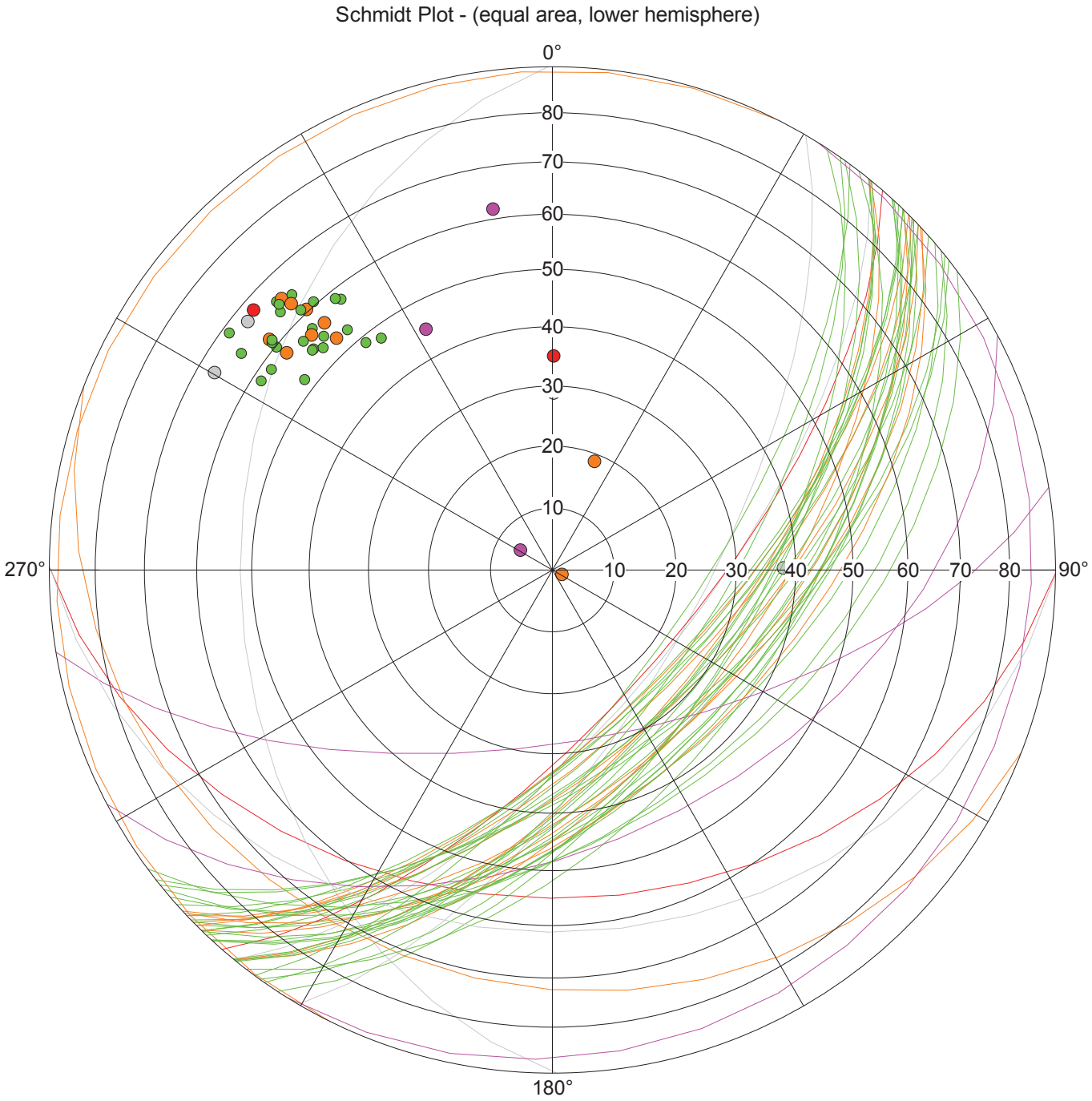
Dip and dip azimuths for all features.




| | Counts | Dip[deg] | Azi[deg] |
|---|---|---|---|
| Mean | 44 | 55.28 | 135.73 |

GW-976

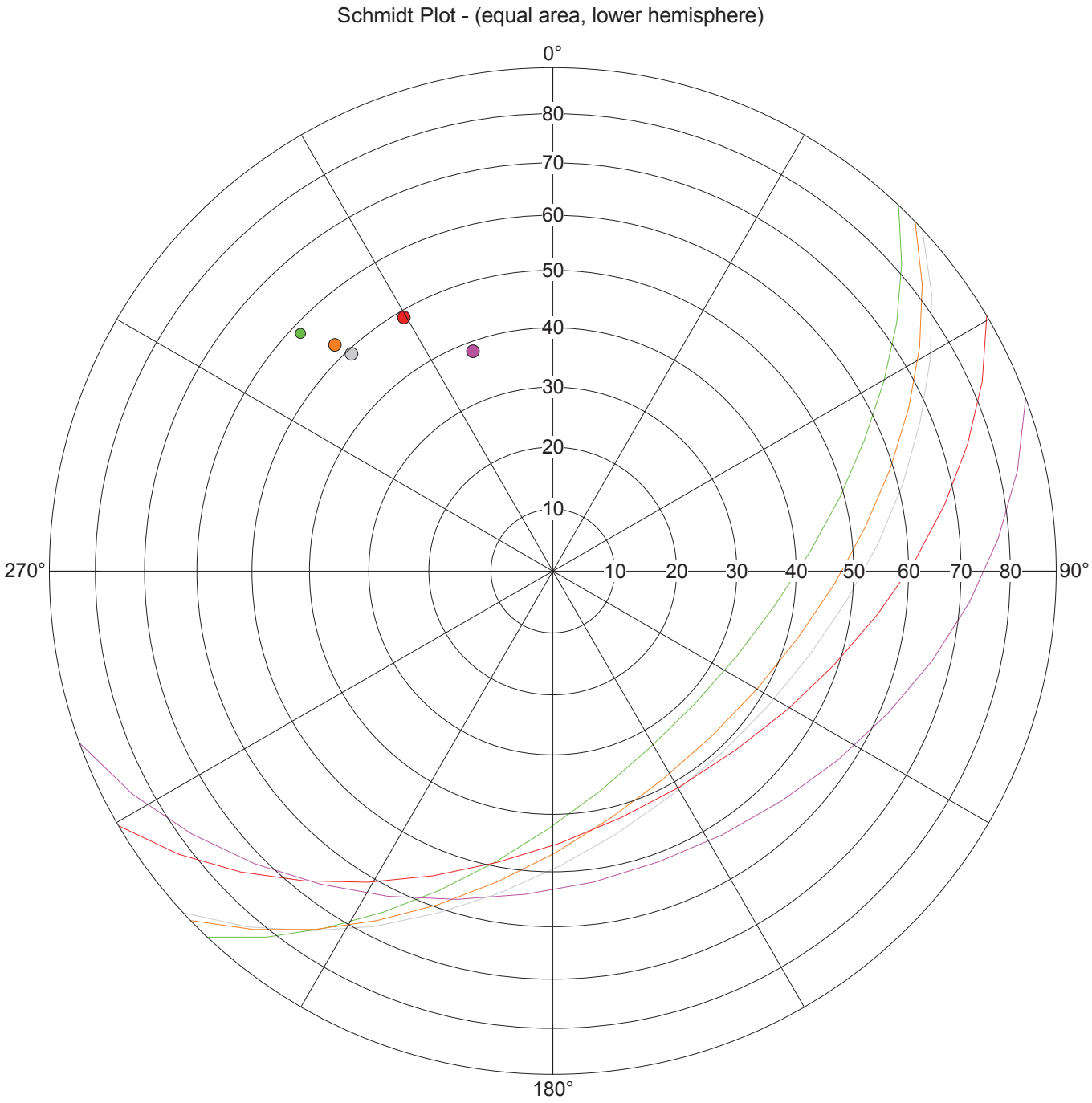
Dip and dip azimuths differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 44 | 55.28 | 135.73 | |
| | 4 | 49.23 | 137.23 | Filled Fracture / Joint |
| | 25 | 58.36 | 133.35 | Bedding / Banding / Foliation |
| | 10 | 52.47 | 136.03 | Partially Open Joint / Fracture |
| | 2 | 48.85 | 149.55 | Major Open Fracture / Joint |
| | 3 | 38.45 | 159.93 | Minor Open Joint / Fracture |

GW-976

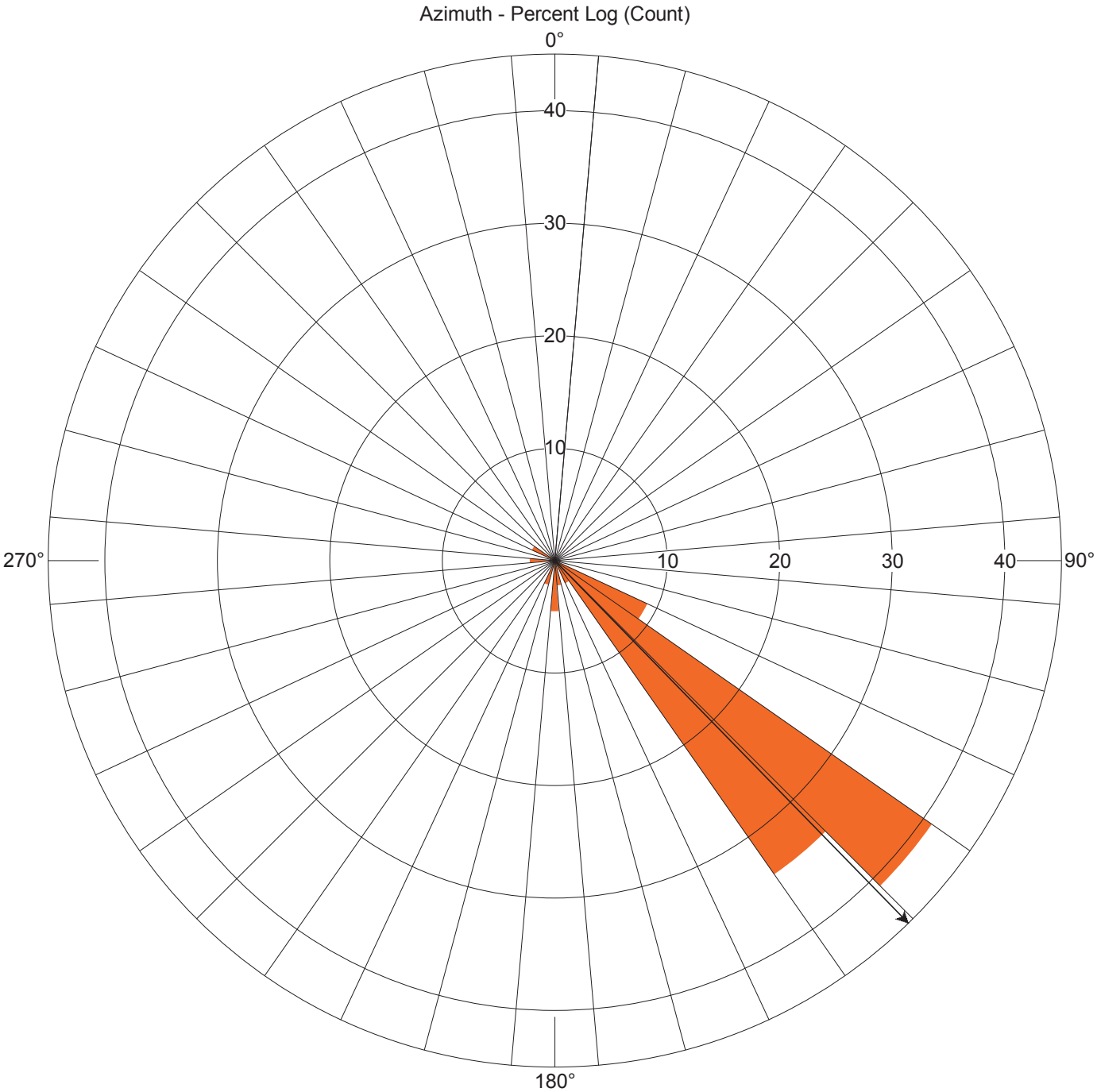
Average dip and dip azimuth differentiated by type.




| | Counts | Dip[deg] | Azi[deg] | |
|---|---|---|---|---|
| Mean | 44 | 55.28 | 135.73 | |
| | 4 | 49.23 | 137.23 | Filled Fracture / Joint |
| | 25 | 58.36 | 133.35 | Bedding / Banding / Foliation |
| | 10 | 52.47 | 136.03 | Partially Open Joint / Fracture |
| | 2 | 48.85 | 149.55 | Major Open Fracture / Joint |
| | 3 | 38.45 | 159.93 | Minor Open Joint / Fracture |

GW-976

Directional histogram of dip azimuth with mean vector (scale unit is a value in percent of the total number of counts for all structures). Counting sector uses a 10 degree step with a 10 degree width.




| | |
|---|---|
| Counts: | 44.00 |
| Mean: | 135.73 |
| Min: | 120.29 |
| Max: | 296.40 |

**APPENDIX B**

**(Electronic only)**

## Mount Sopris Instruments

# EQUIPMENT CERTIFICATION FORM

## Department Name: Rental

**___I hereby certify that the Equipment listed below has been tested, and is operating within specification. Note that serial numbers may change due to equipment availability; any replacements will be certified to operate within specification. Tools with Calibration sheets are marked.**

**Signature**

**Rental Manager**

**9-19-14**
**Date**

| Item | Description | SN | Cal Sheet |
|---|---|---|---|
| 5MXA-1000 | Matrix Console | 0736 | no |
| 4MXC-1000 | Winch, 500M, 1/8” cable | 2207 | no |
| 4TPC-1000 | Tripod Assembly | none | no |
| 2OIA-1000 | Probe, OBI Optical Televiewer | 4389 | no |
| 2AIA-1000 | Probe, ABI Acoustic Televiewer | 122901 | no |
| 2PCA-1000 | Probe, 3 Arm Caliper | 4824 | no |
| 2PGA-1000 | Probe, Gamma, SP, SPR 41mm, 1.61” O.D. | 4884 | Yes |
| HFP-2293 | Probe, Heat Pulse Flowmeter | 3645 | Yes |
| 2PFA-1000 | Probe, Temperature, Fluid Resistivity. | 3587 | Yes |

## Certificate of Calibration: Mount Sopris Instruments

## Probe Identification: 2PFA-1000 Serial Number 3587

## Company: MSI Rental

Go to the MCHNum, Calibration Settings by right clicking on the blue portion of the MCHNum window and enter these values in the appropriate dialog boxes.
In Matrix click Compute and Store to write these values to the TOL, tool configuration file.
In MSLog click the Save button to write these values to the TOL file.
Restart all the browsers and processors, as they must read the new values from the TOL file.

Save or make a copy of this sheet as you may need to reference these numbers if you upgrade software or change computers

Date: 09-17-2014
By: Paul Staples

**Channel Name: Fluid Res**

| First Point | | Second Point | |
|---|---|---|---|
| **Reference:** | 1.792 Ohm-m | **Reference:** | 79.365 Ohm-m |
| **Value:** | 30806.99 CPS | **Value** | 12347.37 CPS |

**Channel Name: Fluid Temp**

| First Point | | Second Point | |
|---|---|---|---|
| **Reference:** | 1.2 Deg C | **Reference:** | 71 Deg C |
| **Value:** | 1365.3 CPS | **Value:** | 5145.9 CPS |

MOUNT SOPRIS
INSTRUMENTS

# Certificate of Calibration

This is to certify that the 2PGA-1000 natural gamma tool s/n 4884 delivered to Mount Sopris Instruments Rental has been calibrated against the Mount Sopris Instrument Company master calibrator (610 API unit) and has been assigned an API calibration factor of **1.248** api units per cps. The master calibration was performed at the University of Houston API test pits on June 6, 2009. For reference copies of the master calibration, contact Mount Sopris Instrument Company.

Date of Calibration: 9-17-14

For Mount Sopris Instrument Company:

Paul L Staples
Systems Engineer

4975 East 41st Avenue, Denver, CO USA 80216 ph 303 279 3211 fax 303 279 2730 www.mountsopris.com

Certificate of Calibration: Mount Sopris Instruments

Tests performed by: Steve Phung

Probe Identification: HFP-2293

Company Name: Rental

**Calibration Numbers for HFP-2293 Serial Number 3465**

| Direction | Time (sec) | Flow (gpm) | Time (sec) | Flow (gpm) |
|---|---|---|---|---|
| Up | 8.95 | 0.03 | 0.75 | 1.0 |
| Down | 11.50 | -.03 | 0.600 | -1.0 |

**05-16-2013**

**Steve Phung**

**APPENDIX C**

**(Electronic only)**

URS

**Log QA/QC Checklist (Fluid temperature & resistivity)**

Well ID GW 968

Date 9/22/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PFA 3587

Calibration (field or vendor) Vendor

Casing diameter 10"

Casing stickup 5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 1.64' end 1.65'

Logging speed ~9.5 ft/min

Logging Direction(s) down

Repeat-log interval (usually 100ft) NA

Logs appear reasonable Yes

File Name(s) PFA_D_968-0922a

Notes Well is flowing artesian

0.1ft is sample interval

Vendor calibration confirmed

Probe end full w/ mud upon return to surface

Diagram if necessary

**Probe specific Comments:**

2PFA-1000 Length is 20.6 inches (52 cm)
Should be first probe run
Warm-up electronics in hole until stabilized
Recommended max logging speed is 10-15 fpm
Log down (subsequent logs may not be repeatable)
FR 0-100 ohm-m, T -20-80 C (scale 48-55 F, 8-13 C)
***Power off prior to connecting or disconnecting***

URS

**Log QA/QC Checklist (3-arm caliper)**

Well ID GW968

Date 9/22/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PCA 4824

Calibration (field or vendor) Field 6" and 10"

Casing diameter 10'

Casing stickup 5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 5.12' end 5.10', 5.12 on repeat

Logging speed ~8.5 ft/min

Logging Direction(s) UP

Repeat-log interval (usually 100ft) from 50'

Logs appear reasonable yes

File Name(s) PCA_U_968-0922a, PCA_U_968-0922b (Repeat from 50')

Notes Dt is sample interval 0.05'

Started up from 95.55', caliper arms were well into the mud at this depth

| **Probe specific Comments:** | Diagram if necessary |
|---|---|
| Length is 59.5 inches (151 cm)<br>Probe current light remains on while opening or closing<br>Recommended max logging speed is 15-20 fpm<br>Log up only<br>*Unless you need to calibrate the tool or are at the bottom of the desired logging interval **DO NOT press the Tool Power On button or the Arms will begin to open.**<br>***Power off prior to connecting or disconnecting** | |

URS

## Log QA/QC Checklist (Natural Gamma, SP, SPR)

Well ID GW 968

Date 9/22/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PGA 4884

Calibration (field or vendor) vendor (API)

Casing diameter 10"

Casing stickup 5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) 2.19 start, 2.13 end / Repeat 2.19 start, 2.17 end

Logging speed 13 ft/min, 10 ft/min (repeat)

Logging Direction(s) Down SP

Repeat-log interval (usually 100ft) P6A_D_968-0922a (Repeat down) .01/min

Logs appear reasonable ~~P6A_U_968-09~~ P6A_U SP_968-0922a (Repeat SP up)

File Name(s) P6A_D-SP_968-0922a (SP down), P6A_U_968-0922a (Gup)

Notes interval is 0.1', errors logged in Gup file, will repeat entire length down

**Probe specific Comments:**

SP & SPR down, gamma up if not connected to 2PEA

Confirm distance to scintillation counter

Electrical tape probe top to at least 2' above measure electrode

SP & SPR require mud plug placement

~620 ohms between center conductor (probe top) & electrode

***Probe is susceptible to physical shock damage**

**handle with care**

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (optical televiewer)

Well ID GW 968

Date 9/24/14

Location (site and/or geographic) EMDF

Logging Geophysicist G.M

Client Observer Mark Maki

Power source Generator

Probe model and S/N 20IA-4389

Calibration (field or vendor) Vendor

Casing diameter 10"

Casing stickup 5'

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 5.32', end 5.24'

Logging speed ~~20~~ 2 ft/min

Logging Direction(s) Down

Repeat-log interval (usually 100ft) From 15', but modon probe end

Logs appear reasonable yes, poor water quality

File Name(s) OIA_D_968-0924d, OIA_U_968-0924a (Repeat)

Notes Water is moderately cloudy, 2 attempts to centralize, Resolution set to 360 azimuthal and 0.006' vertical, Experimented with light intensity (~80%) / Stopped at ~89.2' due to mud, tried to repeat from 15' up, but ~~to~~ mud was stuck to camera and lights

**Probe specific Comments:**

Exposure, aperature, etc. should be set to auto
Proper centalization is critical - compression ring on top
Probe head is extremely delicate - handle with care

Suggested sample rates

| Azimuthal | Vertical |
|---|---|
| 180 | 3.5mm (0.012') |
| 360 | 1.77mm (0.006') |
| 720* | 0.89mm (0.003') |

*Logging speed will be <3ft/min

Diagram if necessary

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (acoustic televiewer)

Well ID GW 968

Date 9/24/14

Location (site and/or geographic) FMDF

Logging Geophysicist G.M

Client Observer Mark Mak

Power source Generator

Probe model and S/N 2 AFA 5528

Calibration (field or vendor) Vendor

Casing diameter 8"

Casing stickup 5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 4.67' end 4.58'

Logging speed logged about 1.3'/min max

Logging Direction(s) up

Repeat-log interval (usually 100ft)

Logs appear reasonable

File Name(s) AFI_U-968-0924b

Notes probe was tightly centralized, took some persuasion to get to bottom, due to mud at bottom, I had to come up to ~85.53' to see

**Probe specific Comments:**

Confirm time gates

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

Suggested sample rates

| | Azimuthal | Vertical |
|---|---|---|
| | 144 | 4.4mm (0.014') |
| | ~~288~~ | 2.2mm (0.007') |

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

**Log QA/QC Checklist (heat pulse flow meter)**

Well ID GW-968

Date 9/30/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N HFP-2293 S/N: 3465

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 2.76', End 2.73'

Logging speed NA

Logging Direction(s) NA

Repeat-log interval (usually 100ft)

Logs appear reasonable

File Name(s) HFP_968-0930a

Notes Lack of repeatability at very low flow rates (likely due to inadequate seal of diverter petals.

| **Probe specific Comments:** | Diagram if necessary |
|---|---|
| Use proper diverter size (large for 8" hole)<br>Performance check should include firing the heat grid & moving the probe up and down to simulate flow. | |

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (Fluid temperature & resistivity)

Well ID 6W970

Date 9/23/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Sinewave inverter

Probe model and S/N 2PFA 3587

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 2"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 1.89', end 1.80'

Logging speed 8FT/min

Logging Direction(s) Down

Repeat-log interval (usually 100ft)

Logs appear reasonable yes

File Name(s) PFA_D_970-0923a

Notes there were several errors and a few spikes in temp

**Probe specific Comments:**

2PFA-1000 Length is 20.6 inches (52 cm)
Should be first probe run
Warm-up electronics in hole until stabilized
Recommended max logging speed is 10-15 fpm
Log down (subsequent logs may not be repeatable)
FR 0-100 ohm-m, T -20-80 C (scale 48-55 F, 8-13 C)
***Power off prior to connecting or disconnecting***

Diagram if necessary

URS

## Log QA/QC Checklist (3-arm caliper)

Well ID GW970

Date 9/24/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2 PCA 4824

Calibration (field or vendor) new field

Casing diameter 10"

Casing stickup 2'

Depth Reference ground Surface

Depth Reference return discrepancy (+ or -) Start 5.37', end 5.47 / Start 5.37', end 5.40 (Repeat)

Logging speed 6 ft/min

Logging Direction(s) up

Repeat-log interval (usually 100ft) up from 50'

Logs appear reasonable yes

File Name(s) PCA_U_970-0924a, PCA_U_970-0924b (Repeat)

Notes Few errors logged - negligible

Interval is 0.05'

**Probe specific Comments:**

Length is 59.5 inches (151 cm)
Probe current light remains on while opening or closing
Recommended max logging speed is 15-20 fpm
Log up only
*Unless you need to calibrate the tool or are at the bottom of the desired logging interval **DO NOT press the Tool Power On button or the Arms will begin to open.**
***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (Natural Gamma, SP, SPR)

Well ID GW970

Date 9/24/14

Location (site and/or geographic) EMDF

Logging Geophysicist G.M

Client Observer —

Power source Generator

Probe model and S/N 2PGA 4884

Calibration (field or vendor) Vendor (API)

Casing diameter 10"

Casing stickup 2"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 2.48', end 2.47' / Start 2.48', end 2.45' (Repeat)

Logging speed 10 ft/min

Logging Direction(s) Down/up

Repeat-log interval (usually 100ft) down SP to 60' then up with G

Logs appear reasonable yes

File Name(s) P6A_D_970-0924a, P6A_U_SP_970-0924a

Notes interval is 0.1' | P6A_D_SP_970-0924a (SP repeat)

SP up from 100.15' | P6A_U_970-0924a (G repeat)

Diagram if necessary

**Probe specific Comments:**

SP & SPR down, gamma up if not connected to 2PEA

Confirm distance to scintillation counter

Electrical tape probe top to at least 2' above measure electrode

SP & SPR require mud plug placement

~620 ohms between center conductor (probe top) & electrode

***Probe is susceptible to physical shock damage***

**handle with care**

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (optical televiewer)

Well ID GW-970

Date 9/30/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki, Richard Stout

Power source Generator

Probe model and S/N 2OIA-4389

Calibration (field or vendor) Vendor

Casing diameter 10"

Casing stickup 2"

Depth Reference Ground Surface

Depth Reference return discrepancy (+ or -) Start +5.57', end 5.49'

Logging speed 2.5 ft/min

Logging Direction(s) down

Repeat-log interval (usually 100ft) OIA_D_970-09306 (up from 254')

Logs appear reasonable

File Name(s) OID_D_970-0930a

Notes Mud at 97.5' - end log

**Probe specific Comments:**

Exposure, aperature, etc. should be set to auto

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

Suggested sample rates

| Azimuthal | Vertical |
|---|---|
| 180 | 3.5mm (0.012') |
| (360) | 1.77mm (0.006') |
| 720* | 0.89mm (0.003') |

*Logging speed will be <3ft/min

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (acoustic televiewer)

Well ID 6W-970

Date 9/30/14

Location (site and/or geographic) EMDF

Logging Geophysicist GW

Client Observer ~~Mark Schaefer~~ Mark Mak

Power source

Probe model and S/N 2AIA-5528

Calibration (field or vendor) Vendor

Casing diameter 10"

Casing stickup 2"

Depth Reference ground Surface

Depth Reference return discrepancy (+ or -) Start +5.41', end ~~5~~.24'

Logging speed ~ 1.5 ft/min

Logging Direction(s) UP

Repeat-log interval (usually 100ft) AIA U_970 0930b (from ~55')

Logs appear reasonable YES

File Name(s) AIA-U_970-0930a

Notes

**Probe specific Comments:**

Confirm time gates

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

| Suggested sample rates | Azimuthal | Vertical |
|---|---|---|
| | 144 | 4.4mm (0.014') |
| | 288 | 2.2mm (0.007') |

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (heat pulse flow meter)

Well ID GW-G70

Date 10/02/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N HPP-293 S/N: 3465

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 2"

Depth Reference Ground surface

Depth Reference return discrepancy (+ or -) Start 3.02', end 2.92'

Logging speed NA

Logging Direction(s) NA

Repeat-log interval (usually 100ft)

Logs appear reasonable

File Name(s) HFP_970-1002a

Notes

**Probe specific Comments:**

Use proper diverter size (large for 8" hole)
Performance check should include firing the heat grid & moving the probe up and down to simulate flow.

Diagram if necessary

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (Fluid temperature & resistivity)

Well ID ~~GW927~~ 972

Date 9/23/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PFA 3587

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 6"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) 1.56 start, 1.57 end

Logging speed ~9.5 ft/min

Logging Direction(s) Down

Repeat-log interval (usually 100ft) NA

Logs appear reasonable yes

File Name(s) PFA_D_972-0923a

Notes interval is 0.1 ft

**Probe specific Comments:**

2PFA-1000 Length is 20.6 inches (52 cm)

Should be first probe run

Warm-up electronics in hole until stabilized

Recommended max logging speed is 10-15 fpm

Log down (subsequent logs may not be repeatable)

FR 0-100 ohm-m, T -20-80 C (scale 48-55 F, 8-13 C)

***Power off prior to connecting or disconnecting***

| Diagram if necessary |
| --- |
| |

URS

## Log QA/QC Checklist (3-arm caliper)

Well ID GW972

Date 9/23/14

Location (site and/or geographic) EMDF

Logging Geophysicist G.M

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PCA 4824

Calibration (field or vendor) field

Casing diameter 10"

Casing stickup 6"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) 5', 04's-start, 5.08' end / Repeat 5.04's-start, 5.05' end

Logging speed ~9 ft/min

Logging Direction(s) up

Repeat-log interval (usually 100ft) up from 50'

Logs appear reasonable yes

File Name(s) PCA_U_972-0923a, PCA-U-972-0923a (repeat)

Notes 0.05' sample interval

**Probe specific Comments:**

Length is 59.5 inches (151 cm)
Probe current light remains on while opening or closing
Recommended max logging speed is 15-20 fpm
Log up only
*Unless you need to calibrate the tool or are at the bottom of the desired logging interval **DO NOT press the Tool Power On button or the Arms will begin to open.**
***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (Natural Gamma, SP, SPR)

Well ID GW 972

Date 9/23/14

Location (site and/or geographic) EMOF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PGA 4854

Calibration (field or vendor) vendor (API)

Casing diameter 10"

Casing stickup 6"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start +2.04', end 2.15' (GR) / start +2.04' end 2.04' (SP)

Logging speed 12.5 ft/min

Logging Direction(s) down/up

Repeat-log interval (usually 100ft) full Repeat GR / full Repeat SP

Logs appear reasonable yes

File Name(s) PGA_D_972-0923a / PGA_U_972.0923a (Repeat)

Notes Repeat up from TD(99.33'): GR | PGA-D-SP_972-0923a

SP log repeat up had some errors ~40' | PGA_U_SP_972-0923a

~~PGA_D_SP_972-0923a~~

Diagram if necessary

**Probe specific Comments:**

SP & SPR down, gamma up if not connected to 2PEA
Confirm distance to scintillation counter
Electrical tape probe top to at least 2' above measure electrode
SP & SPR require mud plug placement
~620 ohms between center conductor (probe top) & electrode
***Probe is susceptible to physical shock damage***
**handle with care**
***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (optical televiewer)

Well ID 64, 972

Date 9/29/14

Location (site and/or geographic) EMDF

Logging Geophysicist G.M

Client Observer Mark Maki

Power source Generator

Probe model and S/N 20IA-4389

Calibration (field or vendor) Vendor

Casing diameter 10"

Casing stickup 6"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) 5.24' start, end 5.11'

Logging speed ~2ft/min

Logging Direction(s) down/up (Repeat)

Repeat-log interval (usually 100ft) OIA_U-972-0929a (97.8'-90') / OIA_U-972-0929b (60'-30')

Logs appear reasonable yes

File Name(s) OIA_D-972-0929a

Notes Water quality better in upper half of well

**Probe specific Comments:**

Exposure, aperature, etc. should be set to auto

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

Suggested sample rates

| Azimuthal | Vertical |
|---|---|
| ~~180~~ | 3.5mm (0.012') |
| (360) | 1.77mm (0.006') |
| 720* | 0.89mm (0.003') |

*Logging speed will be <3ft/min

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (acoustic televiewer)

Well ID GW 972

Date 9/29/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Mak.

Power source Generator

Probe model and S/N 2AIA5528

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 6"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) 5.08' start, end 4.99, 5.08' start, end 4.99' Reverse

Logging speed ~2.2ft/min

Logging Direction(s) UP

Repeat-log interval (usually 100ft) From 94' to about 76'

Logs appear reasonable yes

File Name(s) ABI_U_974_0929a Note filename incorrectly identifies

Notes as GW974, should be 972 - Vertical "streak" from TD to about 85', will Repeat tomorrity / ABI_U_972-0929b (Repeat)

**Probe specific Comments:**

Confirm time gates

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

Suggested sample rates

| Azimuthal | Vertical |
|---|---|
| 144 | 4.4mm (0.014') |
| (288) | 2.2mm (0.007') |

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (heat pulse flow meter)

Well ID GW-972

Date 10/01/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N ~~HFP~~ HFP-2293 S/N: 3465

Calibration (field or vendor) vendor (field verified)

Casing diameter 10"

Casing stickup 6"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 2.68', end 2.66'

Logging speed NA

Logging Direction(s) NA

Repeat-log interval (usually 100ft)

Logs appear reasonable

File Name(s) HFP_972-1001a

Notes

**Probe specific Comments:**

Use proper diverter size (large for 8" hole)

Performance check should include firing the heat grid & moving the probe up and down to simulate flow.

Diagram if necessary

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (Fluid temperature & resistivity)

Well ID GW 974

Date 9/22/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PFA 3587

Calibration (field or vendor) Vendor

Casing diameter 8" inside 10"

Casing stickup 6.5" surface

Depth Reference ground

Depth Reference return discrepancy (+ or -) Start 1.5a' end 1.5'

Logging speed 10ft/min

Logging Direction(s) down

Repeat-log interval (usually 100ft) NA

Logs appear reasonable

File Name(s) PFA-D_974-0922a

Notes Interval 0.1 ft

**Probe specific Comments:**

2PFA-1000 Length is 20.6 inches (52 cm)

Should be first probe run

Warm-up electronics in hole until stabilized

Recommended max logging speed is 10-15 fpm

Log down (subsequent logs may not be repeatable)

FR 0-100 ohm-m, T -20-80 C (scale 48-55 F, 8-13 C)

***Power off prior to connecting or disconnecting***

Diagram if necessary

URS

## Log QA/QC Checklist (3-arm caliper)

Well ID GW974

Date 9/22/14

Location (site and/or geographic) EMF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2PCA 4824

Calibration (field or vendor) field

Casing diameter 8"

Casing stickup 6.5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 5.00' end 4.86', Repeat 5.0' start end 4.9'

Logging speed ~8.4 ft/min, on file a' then 60 ft/min

Logging Direction(s) up

Repeat-log interval (usually 100ft) PCA_U_974_0922c (from 50')

Logs appear reasonable Yes, some errors as documented below

File Name(s) PCA_U_974-0922a, PCA_U_974-0922b

Notes Caliper up from 99.62', Fluid probe must have stopped above bottom, interval is 0.05', logged errors again ~22' - will repeat across this interval

**Probe specific Comments:**

Length is 59.5 inches (151 cm)
Probe current light remains on while opening or closing
Recommended max logging speed is 15-20 fpm
Log up only
*Unless you need to calibrate the tool or are at the bottom of the desired logging interval **DO NOT press the Tool Power On button or the Arms will begin to open.**
***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (Natural Gamma, SP, SPR)

Well ID GW 974

Date 9/22/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki, Jack Strader

Power source Generator

Probe model and S/N 2PGA 4884

Calibration (field or vendor) Vendor (API)

Casing diameter 8"

Casing stickup 6.5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) 2.05 start, end 2.01 on x / 2.07 start, end 2.00 SP

Logging speed 12 ft/min

Logging Direction(s) down/up

Repeat-log interval (usually 100ft) PGA_U_974-0922a, PGA_U-SP_974-0922a

Logs appear reasonable YES

File Name(s) PGA_D_974-0922a, PGA_D-SP_974-0922a

Notes errors on top portion of 1st log – Repeat entire well up

78' probe stopped during SP down / SP up from 99.04'

**Probe specific Comments:**

SP & SPR down, gamma up if not connected to 2PEA
Confirm distance to scintillation counter
Electrical tape probe top to at least 2' above measure electrode
SP & SPR require mud plug placement
~620 ohms between center conductor (probe top) & electrode
***Probe is susceptible to physical shock damage***
**handle with care**
***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (optical televiewer)

Well ID GW 974

Date 9/25/14

Location (site and/or geographic) EMDF

Logging Geophysicist G.M

Client Observer Mark Maki

Power source Generator

Probe model and S/N OIA-4359

Calibration (field or vendor)

Casing diameter 8"

Casing stickup 6.5"

Depth Reference Ground surface

Depth Reference return discrepancy (+ or -)

Logging speed 2.5 ft/min.

Logging Direction(s) down

Repeat-log interval (usually 100ft) Start 5.20' and 5.12' / 5.20' start and end 5.15' (Repeat)

Logs appear reasonable no visibility

File Name(s) OIA_D_974-0925c

Notes Files 'a' and 'b' were trying to get proper light intensity
(Water is cloudy (minimal visibility)
OIA_D_974-0925d is a repeat from ~60' above water

| Probe specific Comments: | | Diagram if necessary |
|---|---|---|
| Exposure, aperature, etc. should be set to auto | | |
| Proper centalization is critical - compression ring on top | | |
| Probe head is extremely delicate - handle with care | | |
| Suggested sample rates | Azimuthal / Vertical | |
| | 180 / 3.5mm (0.012') | |
| | 360 / 1.77mm (0.006') | |
| | 720* / 0.89mm (0.003') | |
| | *Logging speed will be <3ft/min | |

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (acoustic televiewer)

Well ID 6W974

Date 9/25/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2AIA 5528

Calibration (field or vendor) Vendor

Casing diameter 8"

Casing stickup 6.5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 5.04', end 5.01'

Logging speed 1.5 ft/min.

Logging Direction(s) up

Repeat-log interval (usually 100ft) No repeat

Logs appear reasonable yes

File Name(s) ABI_U_974-092514

Notes

**Probe specific Comments:**

Confirm time gates

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

| Suggested sample rates | Azimuthal | Vertical |
|---|---|---|
| | 144 | 4.4mm (0.014') |
| | 288 | 2.2mm (0.007') |

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (heat pulse flow meter)

Well ID GW-974

Date 10/01/14

Location (site and/or geographic) ~~GW~~ EMDF

Logging Geophysicist GM

Client Observer Mark Maki

Power source

Probe model and S/N HFP-2293 S/N: 3465

Calibration (field or vendor) Vendor

Casing diameter 8"

Casing stickup 6.5"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 2.64', end 2.58'

Logging speed NA

Logging Direction(s) NA

Repeat-log interval (usually 100ft)

Logs appear reasonable

File Name(s) HFP_974-1001a

Notes ~~Attempted~~ to induce flow by removing (bailing) 5gal at 35' and 40'. No improvement in flow measurement.

**Probe specific Comments:**

Use proper diverter size (large for 8" hole)

Performance check should include firing the heat grid & moving the probe up and down to simulate flow.

Diagram if necessary

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (Fluid temperature & resistivity)

Well ID Gw 976

Date 9/23/14

Location (site and/or geographic) FMDF

Logging Geophysicist GM

Client Observer Mark Mak

Power source Generator – switched to Sinewave inverter

Probe model and S/N 2PFA 3587

Calibration (field or vendor) Vendor

Casing diameter 10"

Casing stickup 9"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 1.31' end 1.30'

Logging speed 6 ft/min

Logging Direction(s) Down

Repeat-log interval (usually 100ft)

Logs appear reasonable yes

File Name(s) PFA_D_976-0923a (45.16 to 55.29), PFA_D_976-0923b

Notes Lowered Probe to 45.16' to equilibrate in borehole fluid

Diagram if necessary

**Probe specific Comments:**

2PFA-1000 Length is 20.6 inches (52 cm)
Should be first probe run
✓ Warm-up electronics in hole until stabilized
Recommended max logging speed is 10-15 fpm
✓ Log down (subsequent logs may not be repeatable)
FR 0-100 ohm-m, T -20-80 C (scale 48-55 F, 8-13 C)
***Power off prior to connecting or disconnecting***

URS

## Log QA/QC Checklist (3-arm caliper)

Well ID GW976

Date 9/23/14

Location (site and/or geographic) EMDF

Logging Geophysicist Gill

Client Observer Mark Maki

Power source Sine wave inverter

Probe model and S/N 2PCA 4824

Calibration (field or vendor) field

Casing diameter 10"

Casing stickup 9"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 4.79', end 4.81' / Start 4.79', end 4.80'

Logging speed 9 ft/min

Logging Direction(s) Up

Repeat-log interval (usually 100ft) Up from 50'

Logs appear reasonable Yes

File Name(s) PCA_U_976-0923a, PCA_U-976-0923b (repeat)

Notes Up from 101.18'

**Probe specific Comments:**

Length is 59.5 inches (151 cm)
Probe current light remains on while opening or closing
Recommended max logging speed is 15-20 fpm
Log up only
*Unless you need to calibrate the tool or are at the bottom of the desired logging interval **DO NOT press the Tool Power On button or the Arms will begin to open.**
***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (Natural Gamma, SP, SPR)

Well ID GW 976

Date 9/23/14

Location (site and/or geographic) E11DF

Logging Geophysicist G.M

Client Observer Mark Maki

Power source Sine wave inverter

Probe model and S/N 2PGA 4884

Calibration (field or vendor) vendor (API)

Casing diameter 10"

Casing stickup 9"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) start 1.84' end 1.85' / start 1.84' end 1.81'

Logging speed ~12.5 ft/min / SP 5ft/min

Logging Direction(s) Down γ, up SP, down SP (repeat) to 80' then repeat γ up from there

Repeat-log interval (usually 100ft)

Logs appear reasonable yes

File Name(s) P6A-D-976-0923a, P6A_U_SP_976-0923a, P6A-D-SP_976-0923a (Repeat)

Notes total of 5 errors minimal, SP up from 101.12' to 101.07' / P6A_U_976-0923a (Repeat)

**Probe specific Comments:**

SP & SPR down, gamma up if not connected to 2PEA

Confirm distance to scintillation counter

Electrical tape probe top to at least 2' above measure electrode

SP & SPR require mud plug placement

~620 ohms between center conductor (probe top) & electrode

***Probe is susceptible to physical shock damage***

**handle with care**

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (optical televiewer)

Well ID GW-976

Date 9/29/14

Location (site and/or geographic) EMDF

Logging Geophysicist GM

Client Observer Mark Muki

Power source Generator

Probe model and S/N 2OIA-4389

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 9"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Start 4.99', end 4.93'

Logging speed ~2.5 ft/min

Logging Direction(s) down / up (repeat)

Repeat-log interval (usually 100ft) OIA_U_976-0929a

Logs appear reasonable Yes

File Name(s) OIA_D_976-0929a

Notes

**Probe specific Comments:**

Exposure, aperature, etc. should be set to auto

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

Suggested sample rates

| Azimuthal | Vertical |
|---|---|
| 180 | 3.5mm (0.012') |
| (360) | 1.77mm (0.006') |
| 720* | 0.89mm (0.003') |

*Logging speed will be <3ft/min

Diagram if necessary

***Power off prior to connecting or disconnecting**

URS

## Log QA/QC Checklist (acoustic televiewer)

Well ID GW-976

Date 9/29/14

Location (site and/or geographic) EMDF

Logging Geophysicist Gm

Client Observer Mark Maki

Power source Generator

Probe model and S/N 2AIA5528

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 9"

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) start 4.83', end 4.73'

Logging speed ~1.8ft/min

Logging Direction(s) UP

Repeat-log interval (usually 100ft) from 55' to 45'

Logs appear reasonable

File Name(s) ABI_GW976-0929a, ABI_GW-976-0929b (Repeat)

Notes

**Probe specific Comments:**

Confirm time gates

Proper centalization is critical - compression ring on top

Probe head is extremely delicate - handle with care

| Suggested sample rates | Azimuthal | Vertical |
|---|---|---|
| | 144 | 4.4mm (0.014') |
| | (288) | 2.2mm (0.007') |

***Power off prior to connecting or disconnecting**

Diagram if necessary

URS

## Log QA/QC Checklist (heat pulse flow meter)

Well ID GU2-976

Date 10/01/14

Location (site and/or geographic) EMPE

Logging Geophysicist G.M

Client Observer Richard Stout

Power source Generator

Probe model and S/N HFP-2293 S/N: 3465

Calibration (field or vendor) vendor

Casing diameter 10"

Casing stickup 9'

Depth Reference ground surface

Depth Reference return discrepancy (+ or -) Stout 2.43', end 2.38'

Logging speed NA

Logging Direction(s) NA

Repeat-log interval (usually 100ft)

Logs appear reasonable

File Name(s) HFP_976-1001a

Notes

**Probe specific Comments:**

Use proper diverter size (large for 8" hole)

Performance check should include firing the heat grid & moving the probe up and down to simulate flow.

Diagram if necessary

***Power off prior to connecting or disconnecting**

**APPENDIX D**

**(Electronic only)**

☆U.S.GPO:1996—751-640

# HEALTH PHYSICS
# MATERIAL TRANSFER CLEARANCE

TAG NUMBER
GT 303921

## SURVEY INFORMATION

| BUILDING | ROOM NO. |
|---|---|
| Y-12 | Drill Site |

| REQUESTED BY | DIVISION |
|---|---|
| Alliant | |

## DESCRIPTION OF MATERIAL/REMARKS

Gamma log Probe SN# 4884
Plug Case / Conductivity
Probe SN# 3587 / Caliper
Probe SN# 4824 Case

## SURFACE CONTAMINATION

CHECK IF NONE DETECTED

| | | |
|---|---|---|
| MAX. FIXED+REMOVABLE ALPHA | dpm/100cm$^2$ | ☑ |
| REMOVABLE ALPHA | dpm/100cm$^2$ | ☑ |
| MAX. FIXED+REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | ☑ |
| REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | ☑ |

## HEALTH PHYSICS INSTRUMENTS USED

| Alpha Instrument I.D. | Beta/Gamma Instrument I.D. |
|---|---|
| 855/1069 | 853/913 |

## SURVEY COMPLETED

| DATE | BY (NAME and BADGE NUMBER) |
|---|---|
| 9/24/14 | Howard 140777 |

VOID AFTER
90 DAYS

UCN-14B (123 7-94)

☆U.S.GPO:1996–751-640

# HEALTH PHYSICS
# MATERIAL TRANSFER CLEARANCE

TAG NUMBER
GT 303923

## SURVEY INFORMATION

| BUILDING | ROOM NO. |
|---|---|
| EMDF | 1/14 |

| REQUESTED BY | DIVISION |
|---|---|
| Aliant | |

## DESCRIPTION OF MATERIAL/REMARKS

Center Probe, Acoustic Calibrator Case, Televiewer Probe, Televiewer Controller Case

## SURFACE CONTAMINATION

CHECK IF NONE DETECTED

| | | |
|---|---|---|
| MAX. FIXED+REMOVABLE ALPHA | dpm/100cm$^2$ | ☑ |
| REMOVABLE ALPHA | dpm/100cm$^2$ | ☑ |
| MAX. FIXED+REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | ☑ |
| REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | ☑ |

## HEALTH PHYSICS INSTRUMENTS USED

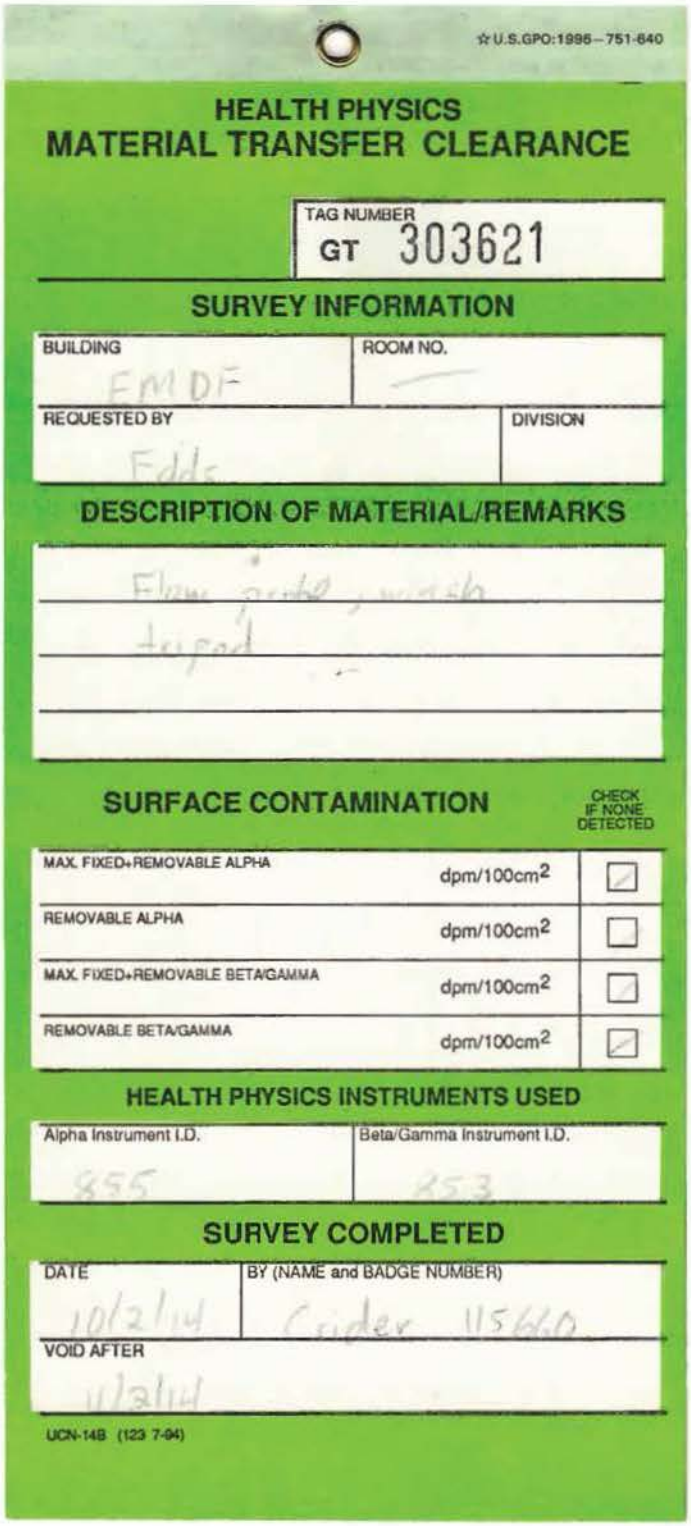
| Alpha Instrument I.D. | Beta/Gamma Instrument I.D. |
|---|---|
| 855/669 | 853/913 |

## SURVEY COMPLETED

| DATE | BY (NAME and BADGE NUMBER) |
|---|---|
| 10/1/14 | Howard 140777 |

VOID AFTER
90 DAYS

UCN-148 (123 7-94)



☆U.S.GPO:1996—751-640

# HEALTH PHYSICS
# MATERIAL TRANSFER CLEARANCE

TAG NUMBER
GT 303621

## SURVEY INFORMATION

| BUILDING | ROOM NO. |
|---|---|
| EMDF | — |

| REQUESTED BY | DIVISION |
|---|---|
| Fdds | |

## DESCRIPTION OF MATERIAL/REMARKS

Flow guide, wash
tripod

## SURFACE CONTAMINATION

| | | CHECK IF NONE DETECTED |
|---|---|---|
| MAX. FIXED+REMOVABLE ALPHA | dpm/100cm$^2$ | ☑ |
| REMOVABLE ALPHA | dpm/100cm$^2$ | ☐ |
| MAX. FIXED+REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | ☑ |
| REMOVABLE BETA/GAMMA | dpm/100cm$^2$ | ☑ |

## HEALTH PHYSICS INSTRUMENTS USED

| Alpha Instrument I.D. | Beta/Gamma Instrument I.D. |
|---|---|
| 855 | 853 |

## SURVEY COMPLETED

| DATE | BY (NAME and BADGE NUMBER) |
|---|---|
| 10/2/14 | Cuder 11560 |

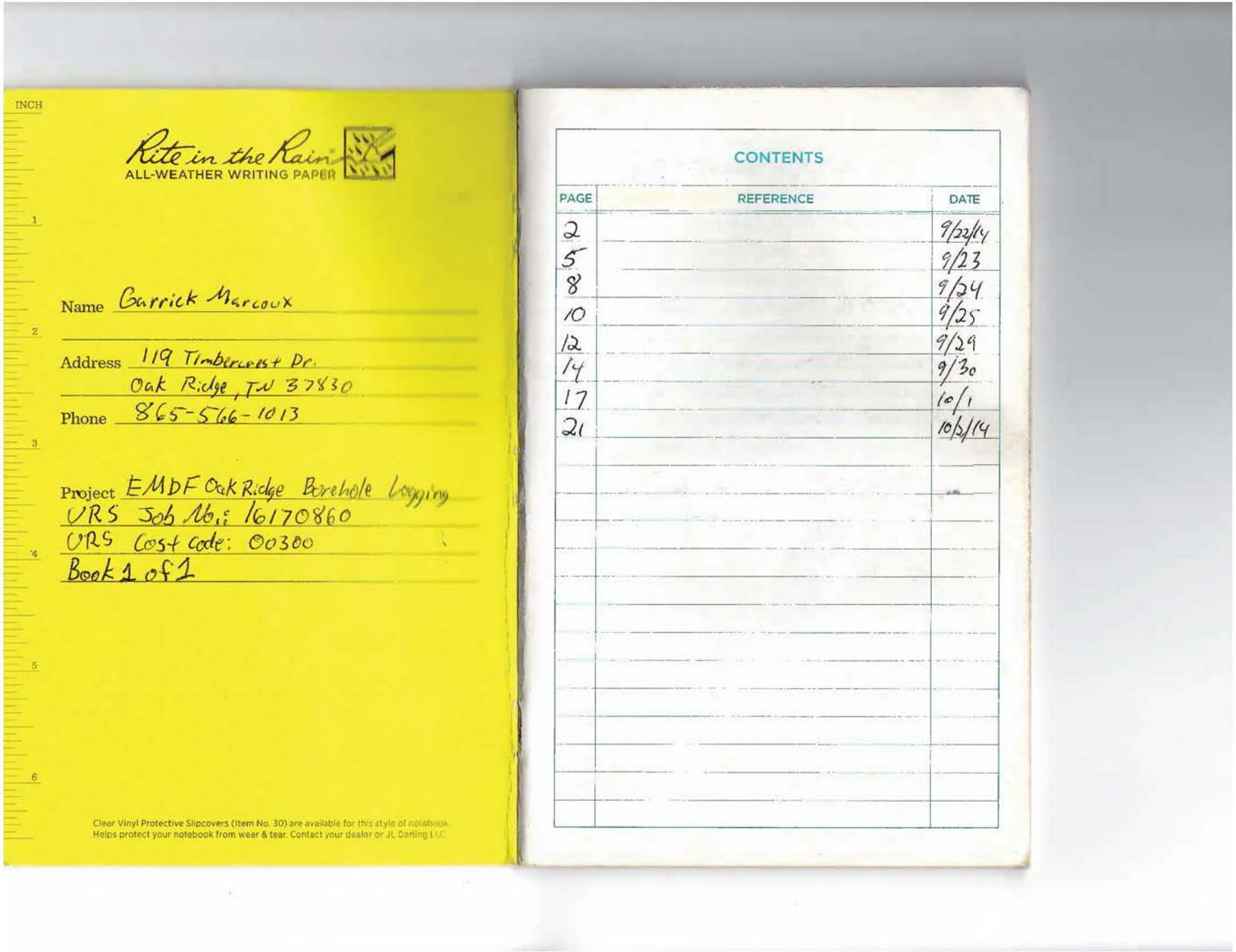
VOID AFTER
11/2/14

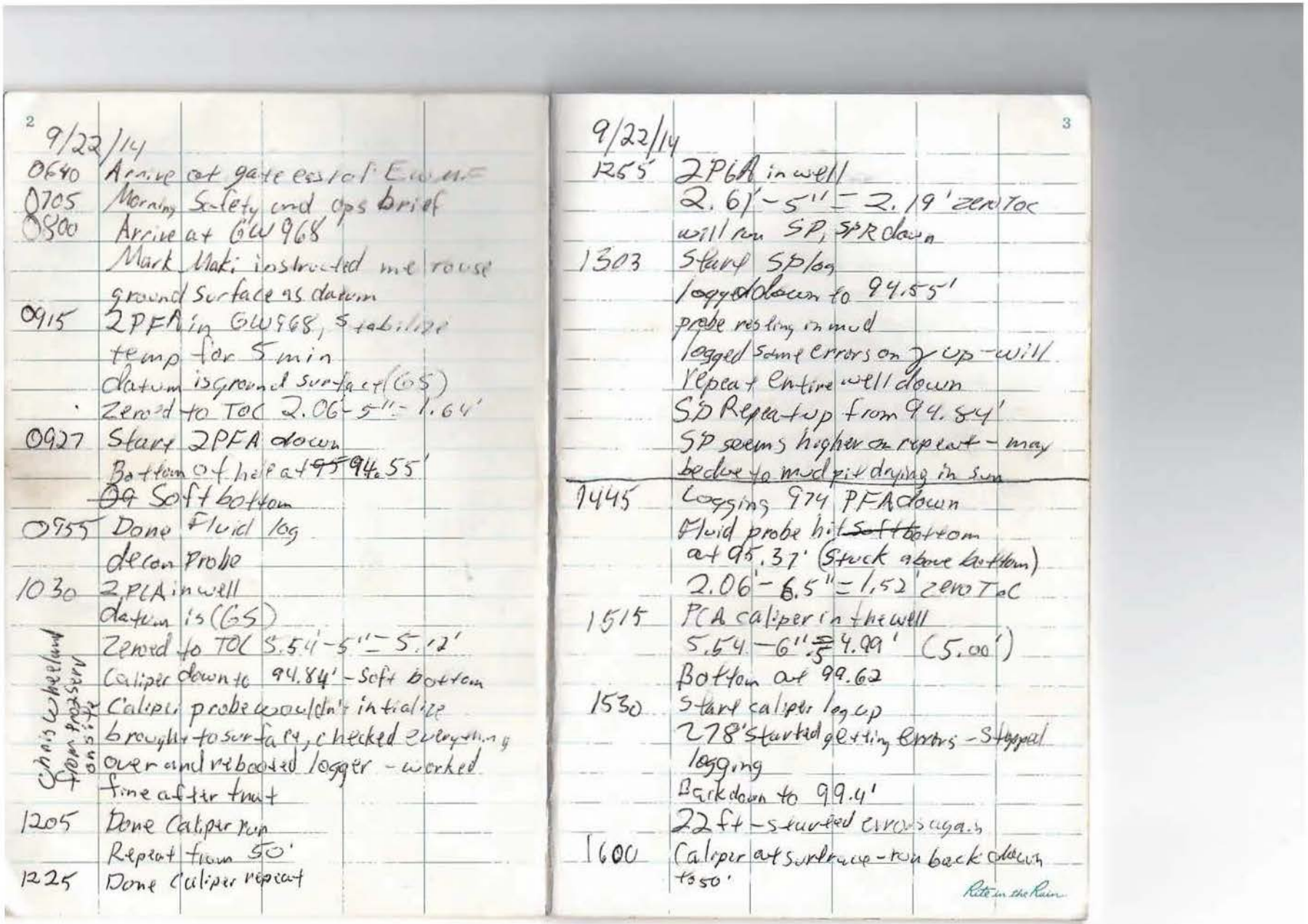
UCN-148 (123 7-94)

**APPENDIX E**

**(Electronic only)**

EMDF 1
Rite in the Rain
ALL-WEATHER
LEVEL
№ 311


Rite in the Rain
ALL-WEATHER WRITING PAPER
Name Garrick Marcoux
Address 119 Timbercrest Dr.
Oak Ridge, TN 37830
Phone 865-566-1013
Project EMDF Oak Ridge Borehole Logging
URS Job No.: 16170860
URS Cost code: 00300
Book 1 of 1
Clear Vinyl Protective Slipcovers (Item No. 30) are available for this style of notebook.
Helps protect your notebook from wear & tear. Contact your dealer or JL Darling LLC
CONTENTS
PAGE
REFERENCE
DATE
2 9/22/14
5 9/23
8 9/24
10 9/25
12 9/29
14 9/30
17 10/1
21 10/2/14



2

9/22/14

0640 Arrive at gate escort Ewing

0705 Morning Safety and ops brief

0800 Arrive at GW968
Mark Maki instructed me reuse ground surface as datum

0915 2PFA in GW968, stabilize temp for 5 min
datum is ground surface (GS)
Zeroed to TOC 2.06 - 5" = 1.64'

0927 Start 2PFA down
Bottom of help at ~~95~~ 94.55'
~~09~~ Soft bottom

0955 Done Fluid log
decon probe

1030 2PCA in well
datum is (GS)
Zeroed to TOC 5.54 - 5" = 5.12'
Caliper down to 94.84' - Soft bottom
Caliper probe wouldn't initialize
brought to surface, checked everything over and rebooted logger - worked fine after that

1205 Done Caliper run
Repeat from 50'

1225 Done Caliper repeat

Chris Wheeland from transducer

3

9/22/14

1255 2PCA in well
2.61' - 5" = 2.19' zero TOC
will run SP, SPR down

1303 Start SP log
logged down to 94.55'
probe resting in mud
logged some errors on way up - will repeat entire well down
SP Repeat up from 94.84'
SP seems higher on repeat - may be due to mud pit drying in sun

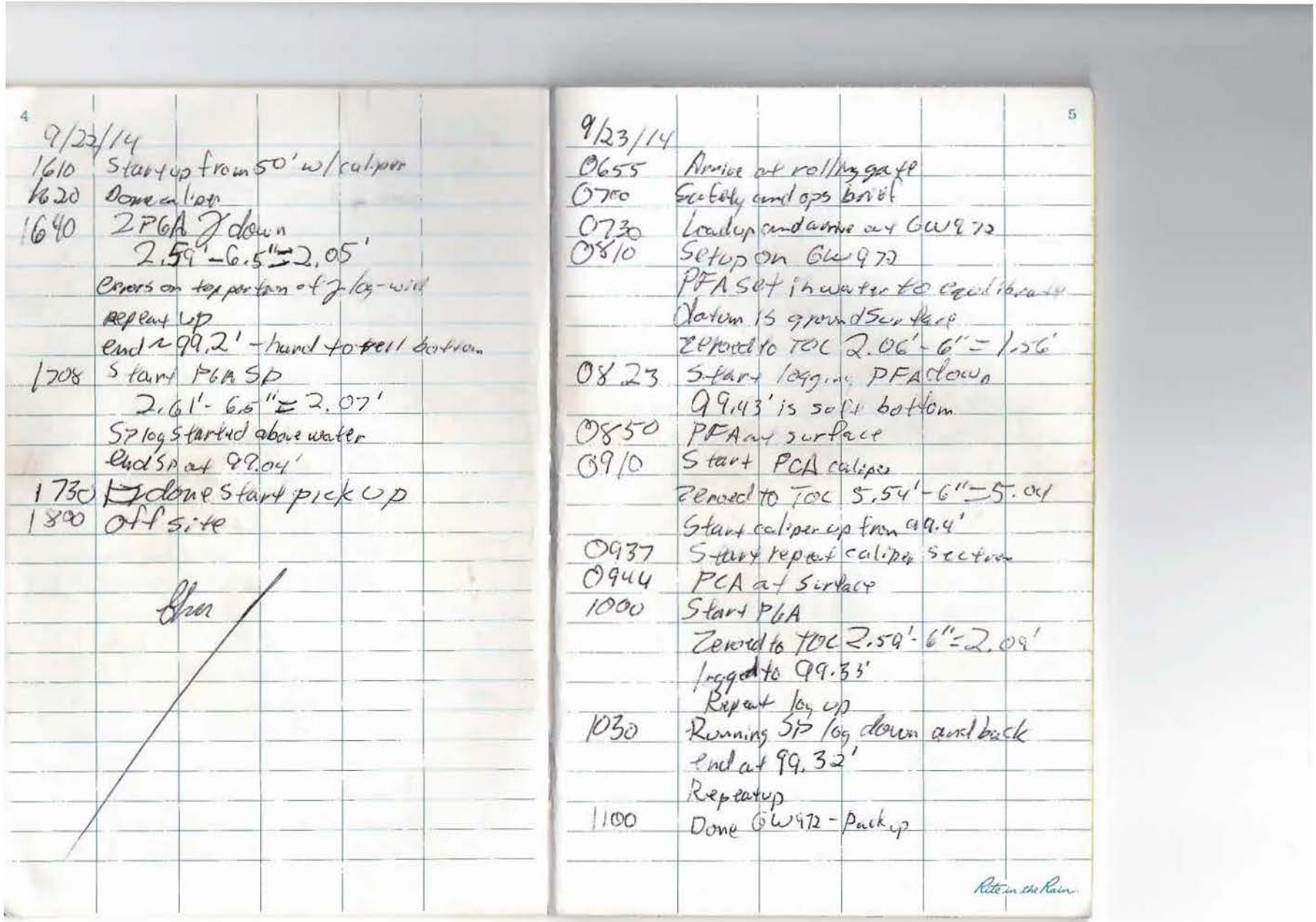
1445 Logging 974 PFA down
Fluid probe hit ~~soft bottom~~ at 95.37' (Stuck above bottom)
2.06' - 6.5" = 1.52' zero TOC

1515 PCA caliper in the well
5.54 - 6" = 4.99' (5.00')
Bottom at 99.62

1530 Start caliper log up
278' started getting errors - stopped logging
Back down to 99.4'
22 ft - started errors again

1600 Caliper at surface - run back down to 50'

Rite in the Rain



4

9/23/14
1610 Start up from 50' w/ caliper
1620 Done caliper
1640 2PGA J down
2.59' - 6.5" = 2.05'
Covers on top portion of J-leg - will
repeat up
end ~99.2' - hard to tell bottom
1708 Start PGA SP
2.61' - 6.5" = 2.07'
SP log started above water
end SP at 99.04'
1730 done start pick up
1800 off site

5

9/23/14
0655 Arrive at rolling gate
0700 Safety and ops brief
0730 Load up and arrive at GW972
0810 Setup on GW972
PFA set in water to equilibrate
Datum is ground surface
Zeroed to TOC 2.06' - 6" = 1.56'
0823 Start logging PFA down
99.43' is soft bottom
0850 PFA at surface
0910 Start PCA caliper
Zeroed to TOC 5.54' - 6" = 5.04
Start caliper up from 99.4'
0937 Start repeat caliper section
0944 PCA at surface
1000 Start PGA
Zeroed to TOC 2.59' - 6" = 2.09'
Logged to 99.33'
Repeat log up
1030 Running SP log down and back
end at 99.32'
Repeat up
1100 Done GW972 - Pack up

Rite in the Rain

6

9/23/14

1145 Arrive at GW976 to set up

1200 Sending 2PFA down to water to equilibrate

Zero to TOC 2.06' - 9" = 1.31'

1220 Start 2PFA down from 45.16'

Stopped at 55.29' because more errors, whill switch to inverter

Spoke to Mount Soprisand they will send a new matrix box out tomorrow

Stopped logging at 101.15 when probe got into mud

1246 Done Fluid log

Zero to TOC 5.54' - 9" = 4.79'

1315 Caliper at bottom (soft) 101.18'

1400 Start PGA γ down

Zero to TOC 2.59' - 9" = 1.84'

end at 101.2'

1416 SP up from 101.12'

Repeat SP down, but started recording above the water (delete dry portion)

ended at 80', Repeat γ up from 80'

1515 Breaking down and moving to 970

1550 Setup on GW970

1608 2PFA in water to equilibrate

7

9/23/14

Zero to TOC 2.06' - 2" = 1.89'

1619 Start 2PFA down

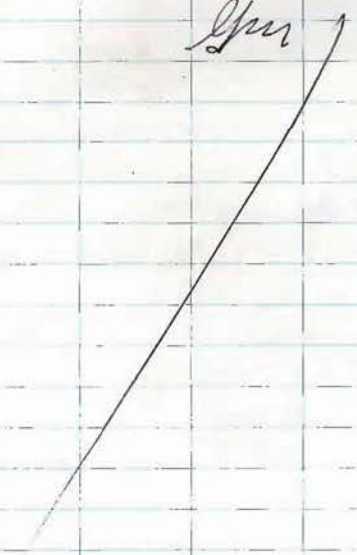
Note 2 spikes in temp between 73 and 75. Will need to delete

Spike at 90' also.

Stopped at 97.76' in the mud

1641 done logging, breakdown

1700 Off Site



Rite in the Rain

8

9/24/14
0700 Safety/ops brief
0810 Setup with caliper on 970
Zero to TOC 5.54'-2"=5.37'
0815 Start PCA down hole
Caliper at 50 ft bottom at 101.1'
0850 done primary run, start down for repeat
0857 Start Repeat
0905 Done caliper log
Deconed caliper
0930 PGA in well
Zero to TOC 2.50'-2"=2.42'
probe stopped at 100.18'
0947 Start PGA SP up from 100.18'
1005 Start SP Repeat down
1022 done w/970, start clean/pack to move
1045 Leave site to get Telesmarts
1240 Back on site at well GW968, start to setup OBI - Replacement matrix box
1340 OBI is at top of GW968
Centralized to 28.3" w/ Centralizer
Spacing of 17 13/16"
Zeroed to TOC 5.74'-5'=5.32'
Too tight - changed Centralizers to 17 7/8"

Chris Wheeland on site

9

9/24/14
1511 To OBI head into the mud at ~89.2'
Start up hole
1530 OBI at top of hole
prepare to switch to ATV
1600 ABI in hole, start testing
Zeroed to TOC 5.09'-5'=4.67'
1800 ABI 92.91' - Start up
Too much mud, had to come up to 88.53' to get clear of the mud and see the tubes echo
1810 done ABI
1830 leave site

Rite in the Rain

10

9/25/14

0700 Safety OPS Brief

0805 Set upon GW 974 (Rutledge)

0850 OIA in hole - centralized for 8"
(17 4/16" collar separation)
Zeroed to TOC 5, 74' - 6.5" = 5,20'
First 2 files (candle) were trying
to get light intensity right
Daniel EDDs brough green tags out for
PCA, PGA, and FFA probes

0950 Stopped OIA at mud 98'

1037 Set up ABI
17 15/16" collar separation
Zeroed to TOC 5.58' - 6.5" = 5.04'

1055 ABI at a 7.85' (can't see target echo
below this depth due to mud)

1228 Done ABI log

1230-1300 Lunch Break
pumped down well to run a section
of OIA tool in dry section

1445 Pumped water down to ~60'
Started OIA up from that depth
final file here 'e' was run at mcm.res
w/ logging speed 1 ft/min

1530 Done repeat tests in GW 974

11

9/25/14

1700 Leave site to go to Fedex

1730 Leave Fedex

~~Zeroed to TOC 5~~

Rite in the Rain

12

9/24/14
0700 Safety/ops brief
0820 Setup on well 972 (Pumkin Valley)
Start logging setup
Depth to water 9'5" from TOC
Zeroed to TOC 5.74-6"=5.24'
Sticky from ~37' to 48.53'
Could not get probe past 97.88'
End log here
Repeat small section from 97.83'-90'
to and 60'-30'
1015 done OTV
1037 ATV at top of hole
Zeroed to TOC 5.58'-6"=5.08'
ABI down to 97.46' - could not get further down hole
Got to 99' on Repeat - looks like probe is in the mud
1215 Done ABI in 972 - Start breakdown
1325 Setup OBI on Gw 976
Zeroed to TOC 5.94'-9"=4.99'
Start logging down at 25' (in casing)
Water level at 45'
Probe in mud at 100.38'
Repeat up from 50' to casing

13

9/29/14
1435 Done OBI on Gw 976
1450 Setup ABI at top of hole
Zeroed to TOC 5.58'-9"=4.83'
Stopped probe at 100.17' to avoid going in to mud.
Stopped just above water level
Repeat from 55' to 45'
1618 ABI at top of hole - start breakdown
1700 Leave Site

Rite in the Rain

14

9/30/14

0700 Safety and ops brief
0835 Set upon GW970
0940 OBI in GW970
Centralizers spaced to 7⅝", 17 3/32" spacer separation
Zeroed to TOC 5.74' - 2" - 5.57'
water level down ~15' from TOC
Started log ~32'
97.5' into the mud, end log
1100 ABI is at top of hole
Zeroed to TOC 5.58' - 2" = 5.41'
Chris Weiland, Bill Wiland visit site
1115 Start logging up from 97.5'
1225 done with ATV, start breakdown
1300 Back to off load at GW968
Left site for gel HPFM
1450 Start functional checks of HPFM
water level in GW-968 is 2" below TOC
Driller pumped shallow well that's 20' to the west during lunch time
propose sample intervals: 13, 17, 25, 30 35 42, ~~50~~ 55 (Pulse)
→ 12, 17, 25, 35, 42, 50 purge 69 (68, 71)

15

9/30/14

Tool calibrations confirmed / Fluid conductivity checked
zeroed to TOC 3.18' - 5" = 2.76'

| Depth | Pick time | Flow | # shots | Comments |
|---|---|---|---|---|
| 12 | 17.90 | 0.019 | 1 | |
| 12 | 16.50 | 0.020 | 2 | |
| 17.01 | 15.45 | 0.022 | 1 | |
| 17.01 | 15.05 | 0.023 | 2 | |
| 25 | No flow measured | | | |
| 26 | 20.65 | 0.016 | 1 | |
| 26 | 23.65 | 0.014 | 2 | Maybe packer seal |
| 27 | 13.20 | ~~13.20~~ 0.026 | 1 | |
| 27 | 21.75 | 0.015 | 2 | |
| 27 | 15.4 | 0.022 | 3 | |
| 27 | 23.0 | 0.014 | 4 | |
| 35.01 | No flow | | 1 | Probably Noise |
| 35.01 | 25.60 | 0.013 | 2 | Noise |
| 35.01 | 25.85 | 0.013 | 3 | |
| 42 | 13.25 | 0.026 | 1 | |
| 42 | 19.25 | 0.017 | 2 | |
| 42 | 23.40 | 0.014 | 3 | |
| 42 | 27.10 | 0.014 | 3 | |
| 50 | No flow | | 1 | |
| 50 | No flow | | 2 | |
| 68 | 16.25 | 0.021 | 1 | |
| 68 | 24.05 | 0.014 | 2 | |

Rite in the Rain

16

9/30/14

| Depth | P. time | Flow | # shots | Comments |
|---|---|---|---|---|
| 68 | 23.30 | 0.014 | 3 | |
| 68 | No flow | | 4 | |
| 71 | 12.80 | 0.024 | 1 | |
| 71 | No flow | | 2 | |
| 71 | No flow | | 3 | |
| 38 | 21.60 | 0.015 | 1 | |
| 38 | No flow | | 2 | |
| 38 | No flow | | | |
| 1730 | Done - packup | | | |
| 1800 | Leave Site | | | |

17

10/1/14

0700 Safety/opsbrief

0820 Set up on Gate-972

Review logs for HPFM intervals

proposed 30, 45, 51, ~~60.5~~ 61.5, 70, 76

Water level is 9'6" below TOC

Zeroed to TOC 3.18241 - 6" = 2.68241

| Depth | P. time | Flow | # shot | Comments |
|---|---|---|---|---|
| all systems nominal after warmup | | | | |
| 30.01 | 22.75 | 0.015 | 1 | |
| 30.01 | No flow | | 2 | |
| 40.00 | No flow | | 1 | |
| 40.00 | No flow | | 2 | |
| 45.00 | No flow | | 1 | |
| 45.00 | No flow | | 2 | |
| 51.00 | No flow | | 1 | |
| 51.00 | No Flow | | 2 | |
| 61.50 | No Flow | | 1 | |
| 61.50 | No Flow | | 2 | |
| 70.00 | 14.14 | 0.024 | 1 | |
| 70.00 | 12.50 | 0.027 | 2 | |
| 70.00 | No Flow | | 3 | |
| 70.00 | No flow | | 4 | |
| 76.00 | 14.55 | 0.023 | 1 | |
| 76.00 | No Flow | | 2 | |
| 76.00 | No Flow | | 3 | |

Kite in the Rain

18

10/1/14

GW-972 continued

| Depth | P. time | Flow | # Shot | Comments |
|---|---|---|---|---|
| 26.00 | No flow | | | |
| 26.00 | No Flow | | | |

1150 Setup HPFM on GW-974

proposed sample intervals 20, 26, 35, 40 64, 46.50, 76

Zeroed to TOC 3.18' - 6.5" = 2.64

water depth at 8'7" to TOC

| Depth | P. time | Flow | # Shot | comments |
|---|---|---|---|---|
| 20.01 | No flow | | | |
| 26.02 | NO Flow | | | |
| 35.01 | 23.95 | 0.014 | 1 | Tubing on bottom |
| 35.01 | 14.30 | 0.024 | 2 | |
| 35.01 | No flow | | 3 | |
| 40.02 | 20.80 | 0.016 | 1 | |
| 40.02 | No flow | | 2 | |
| 40.02 | No Flow | | 3 | |
| 46.5 | No Flow | | 1 | |
| 50.0 | No Flow | | 1 | |
| 64.0 | No flow | | 1 | |

Will come up to 40' and 35' to induce Flow

19

10/1/14

| Depth | P. type | Flow | # Shot | Comments |
|---|---|---|---|---|
| 39.99 | No Flow | | | Bailed 5 gal and waited 3 minutes water came up 20.06' |
| | Took another 5 gal out | | | |
| 34.99 | 26.75 | 0.012 | 1 | up 20.05' |
| 34.99 | 25.55 | 0.013 | 2 | |
| 34.99 | No Flow | | 3 | |

GW-976

Proposed sample intervals: 50, 62.5, 67, 75 80.5, 88.5 Bill w. Ider helped pick

1540 Start HPFM down GW-976

Zeroed to TOC 3.18 - 9" = 2.43'

| Depth | P. time | Flow | # Shot | Comments |
|---|---|---|---|---|
| 50 | No flow | | 1 | |
| 62.5 | No Flow | | 1 | |
| 67.0 | NO Flow | | 1 | |
| 75.0 | 12.20 | -0.028 | 1 | could see rise |
| 75 | 17.34 | -0.02 | 2 | |
| 75 | No flow | | 3 | |
| 75 | No Flow | | 4 | Rite in the Rain |

10/01/14

GW-976 continued

| Depth | p.time | Flow | #shot | Comments |
|---|---|---|---|---|
| 80.5 | 8.75 | 0.040 | 1 | |
| 80.5 | No Flow | | 2 | |
| 80.5 | ~~20.55~~ ~~-0.016~~ No Flow | | 3 | |
| 88.5 | 20.55 | -0.016 | 1 | |
| 88.5 | No Flow | | | |
| 93.01 | No Flow | | | down |
| 80.50 | 18.40 | 0.018 | 1 | Retry |
| 80.50 | 14.25 | 0.024 | 2 | up |
| 80.50 | 13.55 | 0.025 | 3 | Depth Recorded as 78.93 because I moved before adding trace |
| 75.00 | 11.30 | 0.031 | 1 | |
| 75.00 | 9.55 | 0.037 | 2 | |
| 75.00 | 10.33 | 0.034 | 3 | |
| will Repeat at 50' | | | | |
| 50.00 | No flow | | | |

1755 Start breakdown
1830 Offsite to Fedex
1900 Leave Fedex



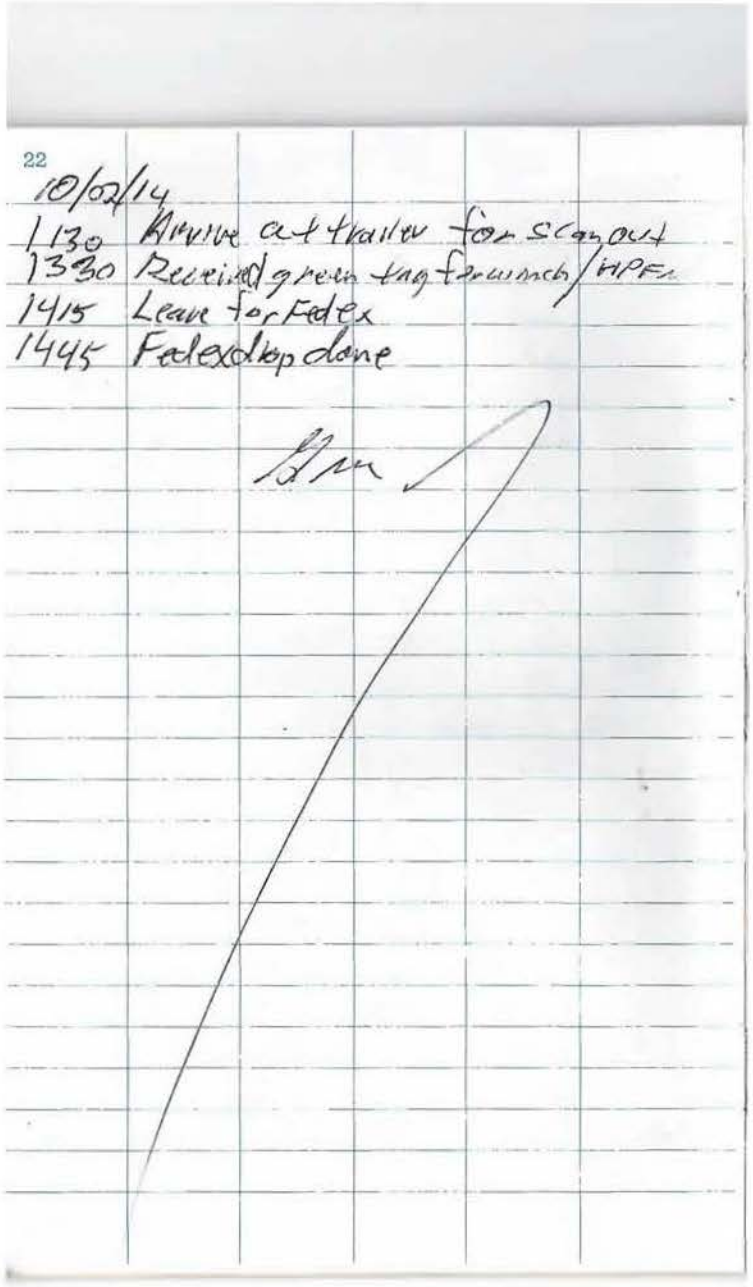
10/02/14

~~0800~~ Safety and Ops brief
0825 Setup on GW-970
proposed sample intervals: 45, 50, 57, 70, 77, 90
Zeroed to TOC 3.18' - 2" = 3.02'

| Depth | p.time | Flow | #shot | Comments |
|---|---|---|---|---|
| 45.01 | No flow | | 1 | |
| 45.01 | 5.40 | 0.070 | 2 | Flipped pistols |
| 45.01 | 6.25 | 0.054 | 3 | |
| 50.00 | 15.00 | 0.023 | 1 | |
| 50.00 | 6.90 | 0.053 | 2 | Flipped pistols |
| 50.00 | 8.50 | 0.042 | 3 | |
| Trip to depth and sample up | | | | |
| 90.00 | No flow | | | |
| 77.00 | No Flow | | | |
| 70.00 | 16.05 | 0.021 | | |
| 70.00 | 24.55 | 0.013 | | |
| 70.00 | 21.50 | 0.015 | | |
| 57.00 | 11.45 | 0.030 | | |
| 57.00 | 10.80 | 0.032 | | |
| 57.00 | 11.10 | 0.031 | | |
| Done testing - start up hole | | | | |

1045 Probe cuts surface, start breakdown/decon

Rite in the Rain


22
10/02/14
1130 Arrive at trailer for scan out
1330 Received green tag for unch/HPF
1415 Leave for Fedex
1445 Fedex drop done

# EXHIBIT A.9:
# PACKER TEST DOCUMENTATION

This page intentionally left blank.

**PACKER TEST SUMMARY SHEET**
**EMDF PHASE 1 SITE CHARACTERIZATION**

| Open Bedrock Borehole (8-inch diameter) | Date of Test | Test Interval (ft) | Pressure (psi) with range in brackets | Hydraulic Conductivity - K (cm/sec) | Average Hydraulic Conductivity - K For Tested Interval (cm/sec) | Comments |
|---|---|---|---|---|---|---|
| GW-968 | 10/20/2014 | 23-33 | 15 | 3.12E-05 | 3.1E-05 | No 30 or 45 psi tests |
| GW-970 | 10/22/2014 | 44-54 | 15 [15-16] | 1.70E-04 | 1.5E-04 | |
| | | | 30 | 1.34E-04 | | |
| | 10/22/2014 | 52-62 | 15 [15-16] | 3.17E-05 | 3.1E-05 | No 45 psi test |
| | | | 30 [29-30] | 2.94E-05 | | |
| | 10/22/2014 | 65-75 | 15 | 1.59E-05 | 1.4E-05 | |
| | | | 30 | 1.36E-05 | | |
| | | | 45 | 1.35E-05 | | |
| GW-972 | 10/16/2014 | 65-75 | 15 [14-18] | No or limited/erratic flow - K indeterminate | K indeterminate | |
| | | | 30 [30-35] | No or limited/erratic flow - K indeterminate | | |
| | | | 45 | No or limited/erratic flow - K indeterminate | | |
| | 10/15/2014 | 75-85 | 15 | No or limited/erratic flow - K indeterminate | K indeterminate | Bottom packer failed to seat |
| | | | 45 | No or limited/erratic flow - K indeterminate | | No 30 PSI test. No flow after initial 1.0 gal |
| GW-974 | 10/16/2014 | 33-43 | 15 | No or limited/erratic flow - K indeterminate | K indeterminate | No flow after initial 0.5 gal |
| | | | 30 | No or limited/erratic flow - K indeterminate | | |
| | | | 45 | No or limited/erratic flow - K indeterminate | | |
| GW-976 | 10/21/2014 | 49.5-59.5 | 15 | 4.99E-05 | 5.6E-05 | |
| | | | 30 [26-29] | 5.75E-05 | | |
| | | | 45 [40-41] | 5.93E-05 | | |
| | 10/21/2014 | 68-78 | 15 | No consistent flow/K indeterminate | K indeterminate | |
| | | | 30 | 1.21E-05 | 1.2E-05 | |
| | | | 45 | 1.16E-05 | | |

## Wilder, Bill

**From:** Mark Maki [mmaki@alliantcorp.com]
**Sent:** Monday, March 16, 2015 10:32 AM
**To:** Wilder, Bill; Richard Stout
**Cc:** Henry, Brian; Wieland, Christopher; Jamie Raymer
**Subject:** RE: EMDF Ph I - Alliant revised packer test submittals
**Attachments:** Comments & Responses Table_Rev2.docx; 976-68-78_Packer Test Calc Sheet_03042015.xls

This information was provided on the CD's Alliant submitted to DOE last Thursday.

The Pro2Serve comments and Alliant responses were provided on the CD as the Comments and Responses Table attached as an MSWord file. This was located in the Packer Testing Results folder on the CD.

All pressure transducer data for each test was included in the raw data files. The names of those files are included in the Packer Test Calculation Sheet for each well test. For example on the tests at Well GW976 from 68 ft to 78 ft below ground surface (bgs) at 1220 PM (file attached), the pressure transducer raw file is name is shown on Row 39 of the sheet, and for this test it is labeled as 976-68-78-1220p-2,-3,-4,-5. Due to space limitations, this stands for the packer test raw data log files in Win-Situ format (.wls format), exported to MSExcel (.csv format). These files are in the sub-folder "GW-976 Packer Tests – Raw Data & Exports. Each pressure transducer has a serial number and an address. The address is the -2 through 5 designation after the serial number, and is shown below.

- -2 is the Baro Troll for atmospheric correction,
- -3 is the top pressure transducer (above the packers),
- -4 is the pressure transducer between the packers at the injection zone, and
- -5 is the lower pressure transducer below the packers.

This serial number and address information cross reference is provided on the test calculation sheet on Rows 34 through 37, and as shown below:

| | |
|---|---|
| Barometric sensor S/N and address: | 190601-2 |
| Top sensor S/N and address: | 332540-3 |
| Packer zone sensor S/N and address: | 142142-4 |
| Lower sensor S/N and address: | 174036-5 |

In addition, in response to Pro2Serve comments, Alliant provided graphs of the transducers responses during each test. These files are .pdf format, and for the GW-976 test from 68 to 78 ft bgs, it is titled: GW-976 (68-78 ft bgs) GRAPH-15, 30 & 45psi.

Please contact us if there are any additional questions or comments.

**Packer Test Review Comments and Responses**
**EMDF Phase 1 Site Characterization**

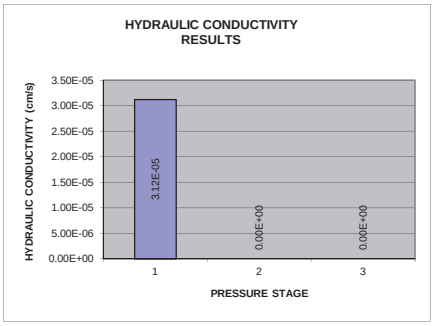
| Item No. | Comment | Response |
|---|---|---|
| 1. | Alliant needs to provide all the In-situ Troll pressure transducer data from the four transducers used in each test. Preferably, the data would be displayed in and x-y graphical form as pressure over time and linked and clearly labeled directly to the timing/duration of each test and test increments at different pressures | Raw data and exported data from each of the four pressure transducers that were used in the packer tests will be provided as requested. The data will be provided in a separate file for each well (e.g., GW-968 Packer Tests - Raw Data & Exports). Additionally, Alliant will provide Pro2Serve with graphs of the data (i.e., pressure over time) in PDF format. The files will be named to clearly identify the locations, depths, and pressures of each test. |
| 2. | An explanation needs to be provided for how the pressure transducer data (in psi) were converted to the Total Head data (in ft) used in the excel spreadsheet calculations and reports for each test interval. | Alliant deployed three non-vented (absolute) pressure transducers downhole, and a table top Baro Troll (recorded barometric pressure values) during each packer test. Alliant used Win-Situ® BaroMerge® Software to post-correct the level sensor data and eliminate barometric pressure effects from the downhole measurements using the barometric pressure data obtained from the table top transducer. The software includes three options for post-correcting the data: fixed correction; manual entry; and BaroTroll log file. Alliant used the BaroTroll log file option to individually correct the majority of the data points. For the packer tests conducted from 49.5 to 59.5 ft in GW-976, Alliant used the manual entry option. The manual entry option was used because the Baro Troll did not collect data during a portion of the tests at GW-976 due to being inadvertently disconnected. |
| 3. | The explanation should also address atmospheric pressures measured at the surface during each test and how those were accounted for/corrected for in determining the Total Head data used in the excel calculations. | Please see the attached In-Situ document *In-Situ Technical Note Using Baro Merge Software, Post-Correction of Absolute (non-vented) Level Sensor Data* for a complete explanation of this process used by Alliant. |
| 4. | Alliant needs to provide an explanation for the "Maximum Total Test Pressure (excess plus static in psi)" located in Row 33 of the header in the Excel spreadsheets. This is a new line item added by URS/Alliant. Also needed is an explanation of how and why this pressure was calculated and used in the packer testing, and potential relationships between this and the Total Head determinations per comment 2/3 above. This information was not provided in Alliant's Packer testing SOP and is needed for reporting purposes. | The Maximum Total Test Pressure located in Row 33 is the sum of the not to exceed excess injection pressure plus the static pressure of the water column at the depth of the middle transducer. The formula may be translated thusly:<br>= H32+(((H26-(0.5*H28))-H27)*0.43353), where<br>H32 = Maximum Excess Injection Pressure (psi);<br>(H26-(0.5*H28) = the midway point between the packers (i.e.,location of the middle transducer);<br>H27 = the water level in the well<br>0.43353 = psi/ft $H_2O$<br><br>Alliant added this calculation at the request of Pro2Serve to provide an estimate of the not to exceed pressure to avoid the possibility of hydro-fracturing the formation during the packer test injection process. |
| 5. | Alliant should provide a revised summary table for packer test results based on corrections and a final QA/QC on all data and algorithms used in the excel spreadsheets for each test. | The revised summary table will be provided as requested. Additionally, a final QA/QC check will be conducted on the packer test results before being submitted. |

# FINAL PACKER TEST RESULTS

EMDF Phase I Site Characterization

Y-12 National Security Complex, Oak Ridge, Tennessee

| | |
|---|---|
| **Borehole ID#:** | GW-968 |
| **Test Interval (ft):** | 23-33 |
| **Description of material(s) tested/lithologic interval:** | Assumed shale, weathered shale |
| **Test Date:** | 10/20/2014 |
| **Packer arrangement (single or double):** | Double |
| **Test time - start & finish:** | 1147-1159 |
| **Weather:** | Cool and clear |
| **~ Temp (ºF):** | 62 |
| **Field Geologist/Engineer:** | R. Stout (Alliant) |
| **Drilling Co. Personnel:** | M. Sturdevant (M&W Drilling) |
| **Others Present:** | J. Scott (M&W Drilling) |
| **Injection Water Source:** | Water tank |
| **Top of ground elevation (ft MSL):** | 1070.21 |
| **Depth Datum:** | Top of casing |
| **Casing stickup at time of test (ft):** | 0.41 |
| **Depth of borehole at test time (ft):** | 93.5 |
| **Depth to bottom of top packer (ft):** | 23.00 |
| **Depth to top of bottom packer (ft):** | 33.00 |
| **Depth of piezometric level (ft):** | 0.0 |
| **Length of test section, L (ft):** | 10 |
| **Radius of borehole, r (ft):** | 0.33 |
| **L/r (dimensionless):** | 30 |
| **Length of packers (ft):** | 3.00 |
| **Maximum Excess Injection Pressure (psi):** | 15.96 |
| **Maximum Total Test Pressure (excess plus static in psi):** | 28.10 |
| **Barometric sensor S/N and address:** | 190601-2 |
| **Top sensor S/N and address:** | 332540-3 |
| **Packer zone sensor S/N and address:** | 142142-4 |
| **Lower sensor S/N and address:** | 174036-5 |
| **Data Site (WinSitu5):** | EMDF |
| **Data log (raw data file *.wsl):** | 968-23-33-1000a-2,-3,-4,-5 |
| **Barometric post-corrected file (*.wsl):** | 968-23-33-1000a-4-BaroMerge |
| **ASCII exported file (*.csv):** | 968-23-33-1000a-2,-3,-4,-5 |




| | |
|---|---|
| **MEAN HYDRAULIC CONDUCTIVITY FOR TEST PRESSURE RANGE (cm/s)** | **3.1E-05** * |

| Pressure Stage No. | Mean Stabilized Flow Rate (gpm) | Mean Total Head (ft) | Mean Hydraulic Conductivity (cm/sec) |
|---|---|---|---|
| 1 | 0.625 | 73.69 | 3.12E-05 |
| 2 | 0.000 | 0.00 | 0.00E+00 |
| 3 | 0.000 | 0.00 | 0.00E+00 |

| | Pressure Stage No. | Actual Time (min.) | Elapsed Time (min.) | Flow Meter Reading (gal.) | Water Volume Injected (gal.) | Flow Rate, Q (gpm) | Total Head, H (ft) | 2πLH (sf) | ln (L/r) | Hydraulic Conductivity, k (cm/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 PSI | 1 | 0 | 0 | 124752 | 0 | 0 | 73.57 | 4623 | 3.401 | 0.00E+00 |
| | 1 | 1 | 1 | 124753.5 | 1.500 | 1.500 | 74.08 | 4654 | 3.401 | 7.45E-05 |
| | 1 | 2 | 1 | 124754 | 0.500 | 0.500 | 73.92 | 4645 | 3.401 | 2.49E-05 |
| | 1 | 3 | 1 | 124754.5 | 0.500 | 0.500 | 73.95 | 4647 | 3.401 | 2.49E-05 |
| | 1 | 4 | 1 | 124755 | 0.500 | 0.500 | 73.65 | 4628 | 3.401 | 2.50E-05 |
| | 1 | 5 | 1 | 124755.5 | 0.500 | 0.500 | 74.44 | 4677 | 3.401 | 2.47E-05 |
| | 1 | 6 | 1 | 124756 | 0.500 | 0.500 | 73.72 | 4632 | 3.401 | 2.50E-05 |
| | 1 | 7 | 1 | 124756.5 | 0.500 | 0.500 | 72.79 | 4574 | 3.401 | 2.53E-05 |
| | 1 | 8 | 1 | 124756.5 | 0.000 | 0.000 | 73.18 | 4598 | 3.401 | 0.00E+00 |
| | 1 | 9 | 1 | 124756.5 | 0.000 | 0.000 | 72.87 | 4579 | 3.401 | 0.00E+00 |
| | 1 | 10 | 1 | 124756.5 | 0.000 | 0.000 | 73.38 | 4611 | 3.401 | 0.00E+00 |
| | 1 | 11 | 1 | 124757 | 0.500 | 0.500 | 73.00 | 4586 | 3.401 | 2.52E-05 |
| | 1 | 12 | 1 | 124757 | 0.000 | 0.000 | 71.97 | 4522 | 3.401 | 0.00E+00 |
| 30 PSI | 2 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 1 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| NOT CONDUCTED. WOULD HAVE EXCEEDED MAX PRESSURE OF 16 PSI | 2 | 2 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 3 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 4 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 5 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 6 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 7 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 8 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 9 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 2 | 10 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | | | | | | | | | 0 | |
| 45 PSI | 3 | 0 | 0 | 0.0 | 0 | 0 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 1 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| NOT CONDUCTED. WOULD HAVE EXCEEDED MAX PRESSURE OF 16 PSI | 3 | 2 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 3 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 4 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 5 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 6 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 7 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 8 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 9 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 10 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |

| | |
|---|---|
| ***FOR DESIGN USE:** | **3.1E-05** |

Test Method: USBR Earth Manual 2nd edition (1974) Appendix E-18

prepared by: R. Stout date: 2/13/2015
checked by: B. Price date:
edited by: GM date: 10/14/2014

GW 968 23-33 15psi

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GW 968 | Depth of borehole at test time | |
| Test Date | 10-20-2014 | Depth to bottom of top packer | 23' |
| Test Time - Start & Finish | | Depth to top of bottom packer | 33' |
| Weather | Cool & clear | Depth & Elevation of piezometric level | |
| ~ Temp (F) | 61 | Length of test section | 10' |
| Field geologist/engineer: | A. Stout / M. Mdsi | Radius of borehole | 8 in |
| Drilling Co Personnel: | [illegible] / M. Stuvvedant | Length of packer(s) | 5 ft |
| Others present: | | Height of pressure gage above ground surface | 2.2 ft |
| Injection Water Source: | | Height of water swivel above ground surface | 2.2 ft |
| | | Description of material(s) tested/lithologic interval | Shale [illegible] |

**PRE-TEST DATA**

Leak check completed (Y/N):

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 15 psi Test | | | |

124752 [illegible]

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| | 0 | — | 124752 | — 0 | 0 At top of casing |
| 1150 | 1 | 1.5 | 753.5 | 15 | |
| | 2 | 0.5 | 754 | 15 | |
| | 3 | 0.5 | 754.5 | 15 | |
| | 4 | 0.5 | 755 | 15 | |
| | 5 | 0.5 | 755.5 | 15 | |
| | 6 | 0.5 | 756 | 15 | |
| | 7 | 0.5 | 756.5 | 15 | |
| | 8 | 0.0 | 756.5 | 15 | |
| | 9 | 0.0 | 756.5 | 15 | |
| 1200 | 10 | 0.0 | 756.5 | 15 | |
| | 11 | 0.5 | 757 | 15 | |
| 1202 | 12 | 0.0 | 757 | 15 | Bleed off Pressure |
| 12 | | | | | |

Comments/Notes:

PackerTestFieldForm.xls

Page 1 of 1

# GW-968 PACKER TEST RESULTS (23-33 FT BGS) - 15 PSI

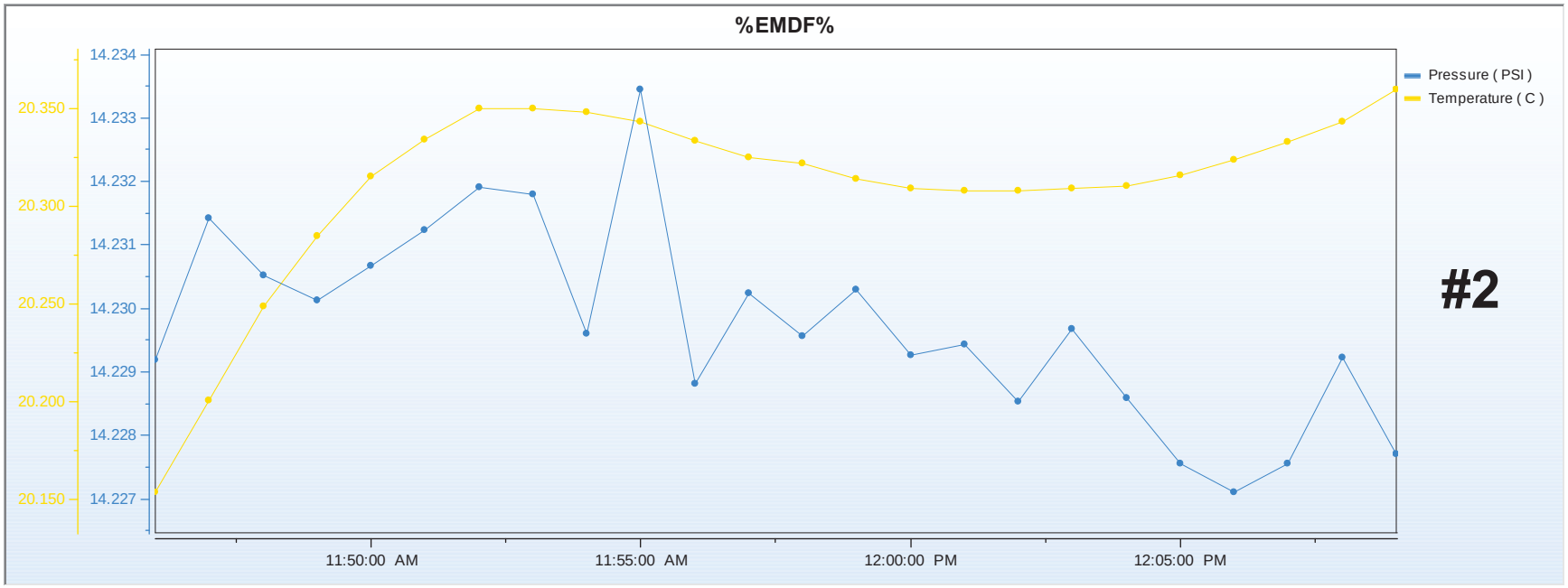
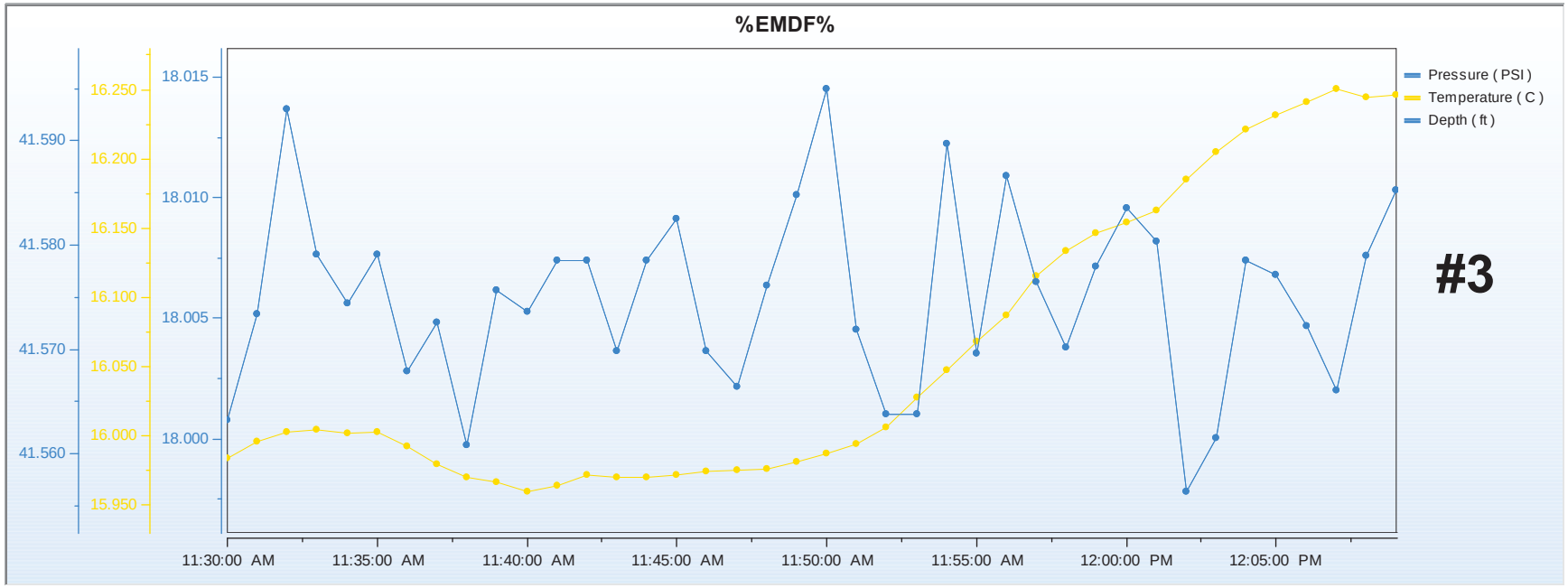


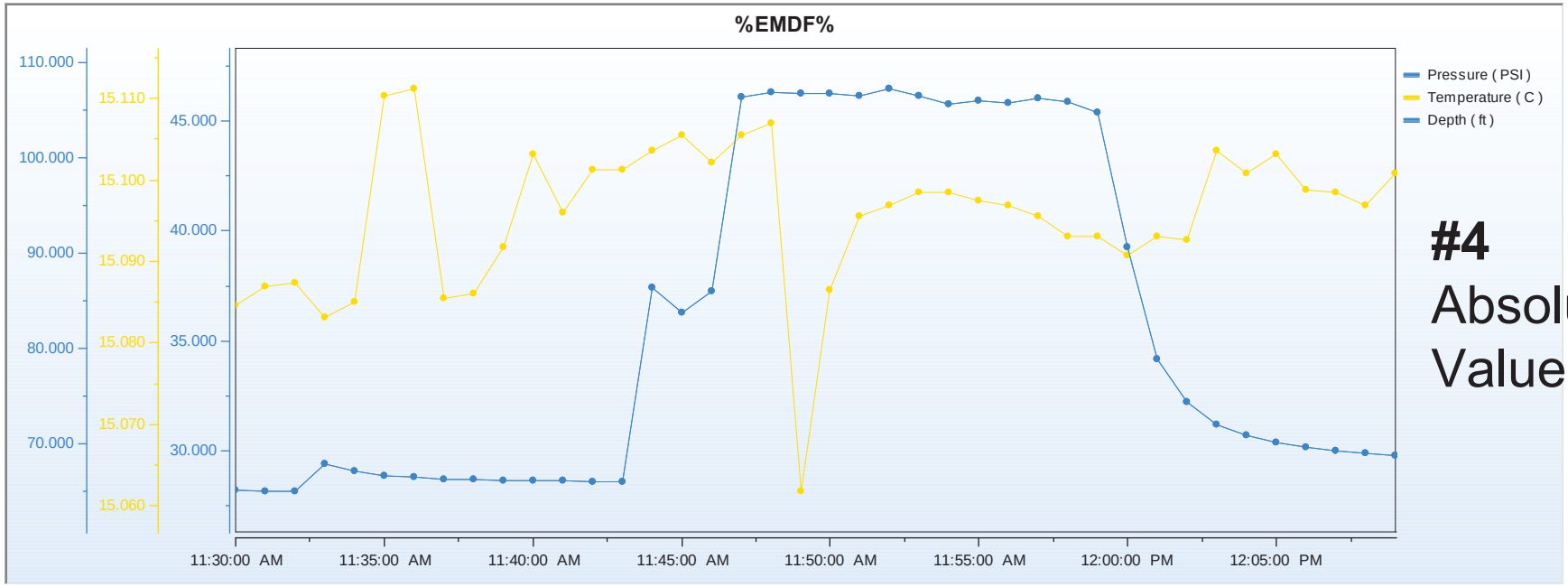

Table Top Baro Troll Data (Address #2)

# GW-968 PACKER TEST RESULTS (23-33 FT BGS) - 15 PSI




Upper Zone (Top) Transducer Data (Address #3)

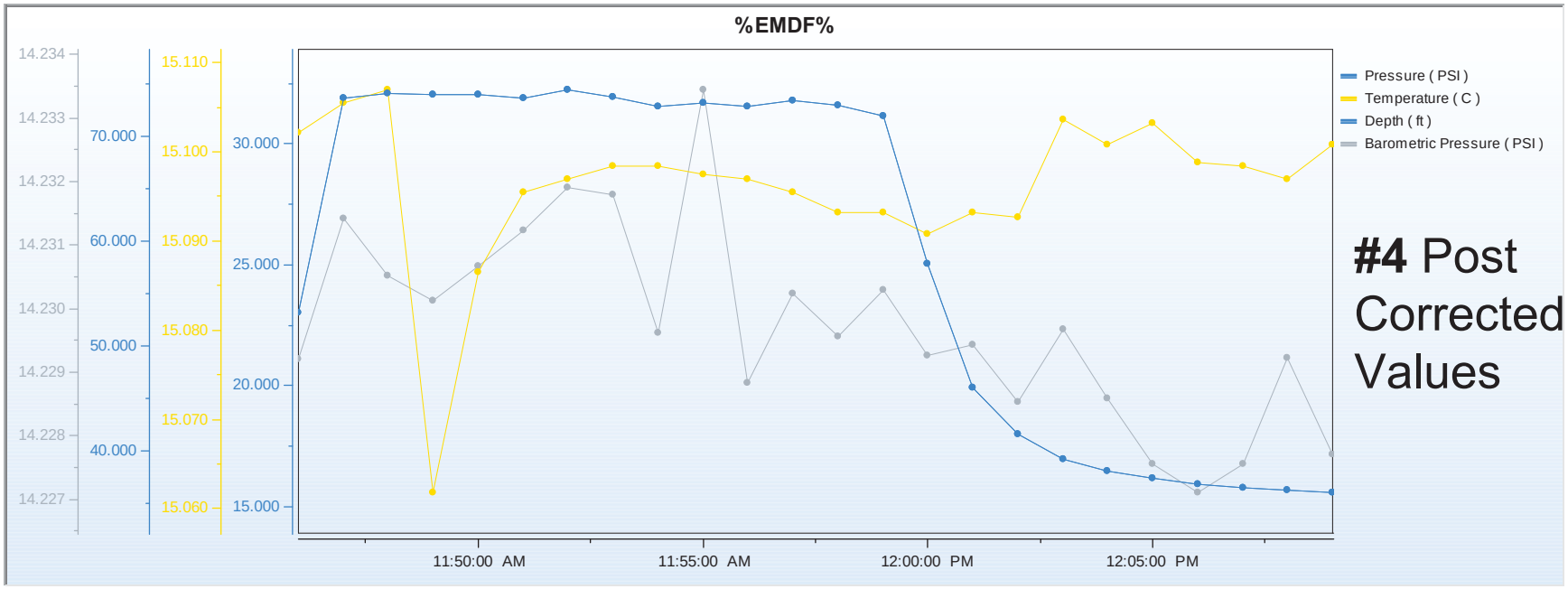
# GW-968 PACKER TEST RESULTS (23-33 FT BGS) - 15 PSI




**#4**
Absolute
Values

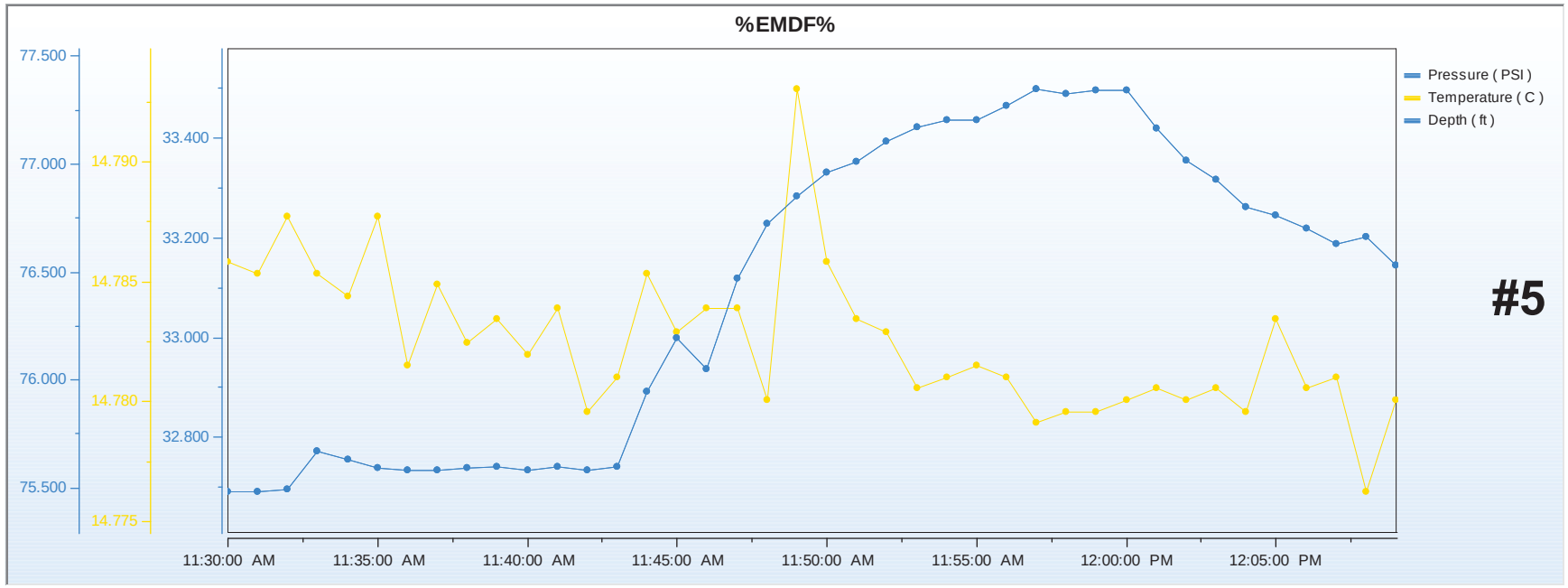
Packer Zone (Middle) Transducer Data (Address #4)

# GW-968 PACKER TEST RESULTS (23-33 FT BGS) - 15 PSI




Packer Zone (Middle) Transducer Data (Address #4) - Post Corrected (BaroMerge) Data

# GW-968 PACKER TEST RESULTS (23-33 FT BGS) - 15 PSI




Lower Zone (Bottom) Transducer Data (Address #5)

| | |
|---|---|
| Report Date: | 10/23/2014 15:22 |
| Report User Name: | richardstout |
| Report Computer Name: | D4ZR1HC1 |
| Application: | WinSitu.exe |
| Application Version: | 5.6.25.0 |

Log File Properties

| | |
|---|---|
| File Name | 968-23-33-1000a- |
| Create Date | 10/23/2014 15:19 |

Device Properties

| | | | | |
|---|---|---|---|---|
| Device | Level TROLL 700 | | | |
| Site | 968 | | | |
| Device Name | | | | |
| Serial Number | 142142 | | | |
| Firmware Version | 2.09 | | | |
| Hardware Version | 3 | | | |
| Device Address | 4 | | | |
| Device Comm Cfg | 19200 | 8 | Even | 1 (Modbus-RTU) |
| Used Memory | 15 | | | |
| Used Battery | 35 | | | |

Log Configuration

| | |
|---|---|
| Log Name | 968-23-33-1000a-4 |
| Created By | richardstout |
| Computer Name | D4ZR1HC1 |
| Application | WinSitu.exe |
| Application Version | 5.6.25.0 |
| Create Date | 10/20/2014 8:10:52 AM Eastern Daylight Time |
| Log Setup Time Zone | Eastern Daylight Time |
| Notes Size(bytes) | 4096 |
| Overwrite when full | Enabled |
| Scheduled Start Time | 10/20/2014 10:00:00 AM Eastern Daylight Time |
| Scheduled Stop Time | 10/20/2014 7:00:00 PM Eastern Daylight Time |
| Type | Linear |
| Duration | Days: 0 hrs: 09 mins: 00 secs: 00 |
| Interval | Days: 0 hrs: 00 mins: 01 secs: 00 |

Level Reference Settings At Log Creation

| | |
|---|---|
| Level Measurement Mode | Depth |
| Specific Gravity | 0.999 |

Other Log Settings

| | |
|---|---|
| Depth of Probe: | 69.52 (ft) |
| Head Pressure: | 30.1087 (PSI) |
| Temperature: | 14.4954 (C) |

Log Notes:

| Date | Time | Note |
|---|---|---|
| 10/20/2014 | 8:10:54 AM | Sensor SN: 142142 Factory calibration has expired.: 9/11/2014 12:18:23 PM |
| 10/20/2014 | 8:10:54 AM | Used Battery: 35% Used Memory: 18% User Name: richardstout |
| 10/20/2014 | 12:15:57 PM | Used Battery: |

| | | |
|---|---|---|
| 10/20/2014 | 12:15:58 PM | Manual Stop |
| 10/23/2014 | 3:19:54 PM | User Note: "Pressure & Level adjusted by baro data from: "968-23-33-1000a- |

Log Data:

| | | | |
|---|---|---|---|
| Record Count | 24 | | |
| Sensors | 2 | | |
| | 1 | 142142 | Pressure/Temp 300 PSIA (200.7m/658.7ft) |
| | 2 | 0 | Baro-Adjustment Calc |

Time Zone: Eastern Daylight Time

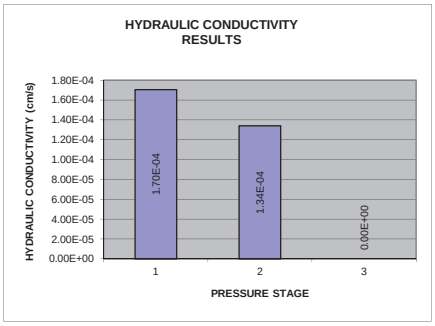
| Date | Time | Elapsed Time Minutes | Sensor: Pres(A) 658.7ft SN#: 142142 Corrected Pressure (PSI) | Sensor: Pres(A) 658.7ft SN#: 142142 Temperature (C) | Sensor: Pres(A) 658.7ft SN#: 142142 Corrected Depth (ft) | Sensor: Baro-Adj Calc SN#: 000000 Barometric Pressure (PSI) |
|---|---|---|---|---|---|---|
| 10/20/2014 | 11:46:00 AM | 0 | 23.046 | 15.102 | 53.212 | 14.229 |
| 10/20/2014 | 11:47:00 AM | 1 | 31.863 | 15.106 | 73.572 | 14.231 |
| 10/20/2014 | 11:48:00 AM | 2 | 32.083 | 15.107 | 74.078 | 14.231 |
| 10/20/2014 | 11:49:00 AM | 2.998 | 32.015 | 15.062 | 73.921 | 14.23 |
| 10/20/2014 | 11:50:00 AM | 3.998 | 32.029 | 15.086 | 73.954 | 14.231 |
| 10/20/2014 | 11:51:00 AM | 4.998 | 31.898 | 15.096 | 73.652 | 14.231 |
| 10/20/2014 | 11:52:00 AM | 5.998 | 32.238 | 15.097 | 74.436 | 14.232 |
| 10/20/2014 | 11:53:00 AM | 6.998 | 31.925 | 15.098 | 73.715 | 14.232 |
| 10/20/2014 | 11:54:00 AM | 7.998 | 31.525 | 15.098 | 72.79 | 14.23 |
| 10/20/2014 | 11:55:00 AM | 8.998 | 31.692 | 15.097 | 73.175 | 14.233 |
| 10/20/2014 | 11:56:00 AM | 9.998 | 31.557 | 15.097 | 72.865 | 14.229 |
| 10/20/2014 | 11:57:00 AM | 10.998 | 31.781 | 15.096 | 73.382 | 14.23 |
| 10/20/2014 | 11:58:00 AM | 11.998 | 31.613 | 15.093 | 72.995 | 14.23 |
| 10/20/2014 | 11:59:00 AM | 13 | 31.171 | 15.093 | 71.973 | 14.23 |
| 10/20/2014 | 12:00:00 PM | 14 | 25.042 | 15.091 | 57.822 | 14.229 |
| 10/20/2014 | 12:01:00 PM | 14.999 | 19.926 | 15.093 | 46.008 | 14.229 |
| 10/20/2014 | 12:02:00 PM | 16 | 17.985 | 15.093 | 41.526 | 14.229 |
| 10/20/2014 | 12:03:00 PM | 16.997 | 16.993 | 15.104 | 39.235 | 14.23 |
| 10/20/2014 | 12:04:00 PM | 17.997 | 16.49 | 15.101 | 38.075 | 14.229 |
| 10/20/2014 | 12:05:00 PM | 18.997 | 16.176 | 15.103 | 37.349 | 14.228 |
| 10/20/2014 | 12:06:00 PM | 19.998 | 15.949 | 15.099 | 36.825 | 14.227 |
| 10/20/2014 | 12:07:00 PM | 20.997 | 15.792 | 15.098 | 36.464 | 14.228 |
| 10/20/2014 | 12:08:00 PM | 21.997 | 15.681 | 15.097 | 36.207 | 14.229 |
| 10/20/2014 | 12:09:00 PM | 22.997 | 15.585 | 15.101 | 35.986 | 14.228 |

# FINAL PACKER TEST RESULTS

EMDF Phase I Site Characterization

Y-12 National Security Complex, Oak Ridge, Tennessee

| | |
|---|---|
| **Borehole ID#:** | GW-970 |
| **Test Interval (ft):** | 44-54 |
| **Description of material(s) tested/lithologic interval:** | Assumed shale, weathered shale |
| **Test Date:** | 10/22/2014 |
| **Packer arrangement (single or double):** | Double |
| **Test time - start & finish:** | 1000-1026 |
| **Weather:** | Clear, dry w/ light breeze |
| **~ Temp (ºF):** | 50 |
| **Field Geologist/Engineer:** | R. Stout (Alliant) |
| **Drilling Co. Personnel:** | M. Sturdevant (M&W Drilling) |
| **Others Present:** | J. Scott (M&W Drilling) |
| **Injection Water Source:** | Water tank |
| **Top of ground elevation (ft MSL):** | 1040.93 |
| **Depth Datum:** | Top of casing |
| **Casing stickup at time of test (ft):** | 0.16 |
| **Depth of borehole at test time (ft):** | 99.5 |
| **Depth to bottom of top packer (ft):** | 44.00 |
| **Depth to top of bottom packer (ft):** | 54.00 |
| **Depth of piezometric level (ft):** | 7.97 |
| **Length of test section, L (ft):** | 10 |
| **Radius of borehole, r (ft):** | 0.33 |
| **L/r (dimensionless):** | 30 |
| **Length of packers (ft):** | 3.00 |
| **Maximum Excess Injection Pressure (psi):** | 31.36 |
| **Maximum Total Test Pressure (excess plus static in psi):** | 49.14 |
| **Barometric sensor S/N and address:** | 190601-2 |
| **Top sensor S/N and address:** | 332540-3 |
| **Packer zone sensor S/N and address:** | 142142-4 |
| **Lower sensor S/N and address:** | 174036-5 |
| **Data Site (WinSitu5):** | EMDF |
| **Data log (raw data file *.wsl):** | 970-44-54-1000a-2,-3,-4,-5 |
| **Barometric post-corrected file (*.wsl):** | 970-44-54-1000a-4-BaroMerge |
| **ASCII exported file (*.csv):** | 970-44-54-1000a-2,-3,-4,-5 |




| | |
|---|---|
| **MEAN HYDRAULIC CONDUCTIVITY FOR TEST PRESSURE RANGE (cm/s)** | **1.5E-04** * |

| Pressure Stage No. | Mean Stabilized Flow Rate (gpm) | Mean Total Head (ft) | Mean Hydraulic Conductivity (cm/sec) |
|---|---|---|---|
| 1 | 4.545 | 98.09 | 1.70E-04 |
| 2 | 4.727 | 129.63 | 1.34E-04 |
| 3 | 0.000 | 0.00 | 0.00E+00 |

| | Pressure Stage No. | Actual Time (min.) | Elapsed Time (min.) | Flow Meter Reading (gal.) | Water Volume Injected (gal.) | Flow Rate, Q (gpm) | Total Head, H (ft) | 2πLH (sf) | ln (L/r) | Hydraulic Conductivity, k (cm/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 15-16 PSI | 1 | 0 | 0 | 124880 | 0 | 0 | 69.36 | 4358 | 3.401 | 0.00E+00 |
| | 1 | 1 | 1 | 124885 | 5.000 | 5.000 | 96.91 | 6089 | 3.401 | 1.90E-04 |
| | 1 | 2 | 1 | 124890 | 5.000 | 5.000 | 97.71 | 6139 | 3.401 | 1.88E-04 |
| | 1 | 3 | 1 | 124895 | 5.000 | 5.000 | 98.26 | 6174 | 3.401 | 1.87E-04 |
| | 1 | 4 | 1 | 124900 | 5.000 | 5.000 | 98.09 | 6163 | 3.401 | 1.88E-04 |
| | 1 | 5 | 1 | 124904 | 4.000 | 4.000 | 98.24 | 6173 | 3.401 | 1.50E-04 |
| | 1 | 6 | 1 | 124908 | 4.000 | 4.000 | 98.80 | 6208 | 3.401 | 1.49E-04 |
| | 1 | 7 | 1 | 124912 | 4.000 | 4.000 | 98.35 | 6179 | 3.401 | 1.50E-04 |
| | 1 | 8 | 1 | 124917 | 5.000 | 5.000 | 98.65 | 6198 | 3.401 | 1.86E-04 |
| | 1 | 9 | 1 | 124921 | 4.000 | 4.000 | 97.96 | 6155 | 3.401 | 1.50E-04 |
| | 1 | 10 | 1 | 124926 | 5.000 | 5.000 | 98.27 | 6175 | 3.401 | 1.87E-04 |
| | 1 | 11 | 1 | 124930 | 4.000 | 4.000 | 97.80 | 6145 | 3.401 | 1.50E-04 |
| 30 PSI | 2 | 0 | 0 | 124937 | 0 | 0 | 139.45 | 8762 | 3.401 | 0.00E+00 |
| | 2 | 1 | 1 | 124943 | 6.000 | 6.000 | 129.47 | 8135 | 3.401 | 1.71E-04 |
| | 2 | 2 | 1 | 124948 | 5.000 | 5.000 | 130.69 | 8211 | 3.401 | 1.41E-04 |
| | 2 | 3 | 1 | 124952 | 4.000 | 4.000 | 130.76 | 8216 | 3.401 | 1.13E-04 |
| | 2 | 4 | 1 | 124957 | 5.000 | 5.000 | 130.69 | 8212 | 3.401 | 1.41E-04 |
| | 2 | 5 | 1 | 124962 | 5.000 | 5.000 | 130.94 | 8227 | 3.401 | 1.40E-04 |
| | 2 | 6 | 1 | 124967 | 5.000 | 5.000 | 128.98 | 8104 | 3.401 | 1.43E-04 |
| | 2 | 7 | 1 | 124972 | 5.000 | 5.000 | 129.20 | 8118 | 3.401 | 1.42E-04 |
| | 2 | 8 | 1 | 124975 | 3.000 | 3.000 | 129.14 | 8114 | 3.401 | 8.55E-05 |
| | 2 | 9 | 1 | 124980 | 5.000 | 5.000 | 128.61 | 8081 | 3.401 | 1.43E-04 |
| | 2 | 10 | 1 | 124984 | 4.000 | 4.000 | 129.10 | 8111 | 3.401 | 1.14E-04 |
| | 2 | 11 | 1 | 124989 | 5.000 | 5.000 | 128.36 | 8065 | 3.401 | 1.43E-04 |
| 45 PSI | 3 | 0 | 0 | 0.0 | 0 | 0 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 1 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| NOT CONDUCTED. WOULD HAVE EXCEEDED MAX PRESSURE OF 31 PSI. | 3 | 2 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 3 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 4 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 5 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 6 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 7 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 8 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 9 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 10 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |

***FOR DESIGN USE: 1.5E-04**

Test Method: USBR Earth Manual 2nd edition (1974) Appendix E-18

prepared by: R. Stout date: 2/13/2015
checked by: B. Price date:
edited by: GM date: 10/14/2014

GW-970

GW 970 44-54 15 psi

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GW 970 | Depth of borehole at test time | 100 ft |
| Test Date | 10-22-14 | Depth to bottom of top packer | 44 ft |
| Test Time - Start & Finish | 1003 / 1017 | Depth to top of bottom packer | 54 ft |
| Weather | Clear, dry, 1-4 breeze | Depth & Elevation of piezometric level | 7.9 ft |
| ~ Temp (F) | 46 F | Length of test section | 10 ft |
| Field geologist/engineer: | N. Stant / M. Maki | Radius of borehole | 4 in. |
| Drilling Co Personnel: | M&W / M. Studebaker | Length of packer(s) | 5 ft. |
| Others present: | | Height of pressure gage above ground surface | 3.2 ft |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 3.2 ft |
| | | Description of material(s) tested/lithologic interval | Shale (Pumpkin Valley Fm) |

PRE-TEST DATA

Leak check completed (Y/N): Yes

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 15 psi test | | | |

TEST DATA

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| 1003 | 0 | - | 124880 | 0 | 7.9 ft. |
| 1006 | 1 | 5 | 124885 | 15 | |
| | 2 | 5 | 124890 | 16 | |
| | 3 | 5 | 124895 | 16 | |
| 1010 | 4 | 5 | 124900 | 16 | |
| | 5 | 4 | 124904 | 16 | |
| | 6 | 4 | 124908 | 16 | |
| | 7 | 4 | 124913 | 16 | |
| | 8 | 5 | 124917 | 16 | |
| | 9 | 4 | 124921 | 16 | |
| 1016 | 10 | 5 | 124926 | 16 | |
| 1017 | 11 | 4 | 124930 | 16 | |
| | 12 | | | | |

Comments/Notes: Good flow test at 15 psi

PackerTestFieldForm.xls

Page 1 of 1

GW-970

GW 970 4/4-54 30psi

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GW-970 | Depth of borehole at test time | 100 ft |
| Test Date | 10/22/2014 | Depth to bottom of top packer | 44 ft |
| Test Time - Start & Finish | 1018 / 1029 | Depth to top of bottom packer | 54 ft |
| Weather | Clear, dry, breezy | Depth & Elevation of piezometric level | 7.9 ft / 6.53 at end of test after inflation of packers. |
| ~ Temp (F) | 46°F | Length of test section | 10 ft |
| Field geologist/engineer: | R Stout / [illegible] | Radius of borehole | ~~5 in~~ 4 in. |
| Drilling Co Personnel: | M&W Drilling | Length of packer(s) | 5 ft |
| Others present: | | Height of pressure gage above ground surface | 3.2 ft |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 3.2 ft |
| | | Description of material(s) tested/lithologic interval | Shale (Pumpkin Valley Fm) |

**PRE-TEST DATA**

Leak check completed (Y/N):

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 30 psi | | | |

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| | 0 | — | 124937 | — | |
| 1018 | 1 | 6 | 124943 | 30 | 7.9 |
| | 2 | 5 | 124948 | 30 | |
| | 3 | 4 | 124952 | 30 | |
| 1022 | 4 | 5 | 124957 | 30 | |
| | 5 | 5 | 124962 | 30 | |
| | 6 | 5 | 124967 | 30 | |
| | 7 | 5 | 124972 | 30 | |
| | 8 | 3 | 124975 | 30 | |
| | 9 | 5 | 124980 | 30 | |
| 1028 | 10 | 4 | 124984 | 30 | |
| 1029 | 11 | 5 | 124989 | 30 | 6.53 |

Comments/Notes:

Good flow of injection water @ 30 psi test. Water level rose above packer. Start shut in test @ 1029. Pressure bled off within 10 secs. No test @ 45 psi due to low gradient.

PackerTestFieldForm.xls

Page 1 of 1

# GW-970 PACKER TEST RESULTS (44-54 ft) - 15 & 30 PSI

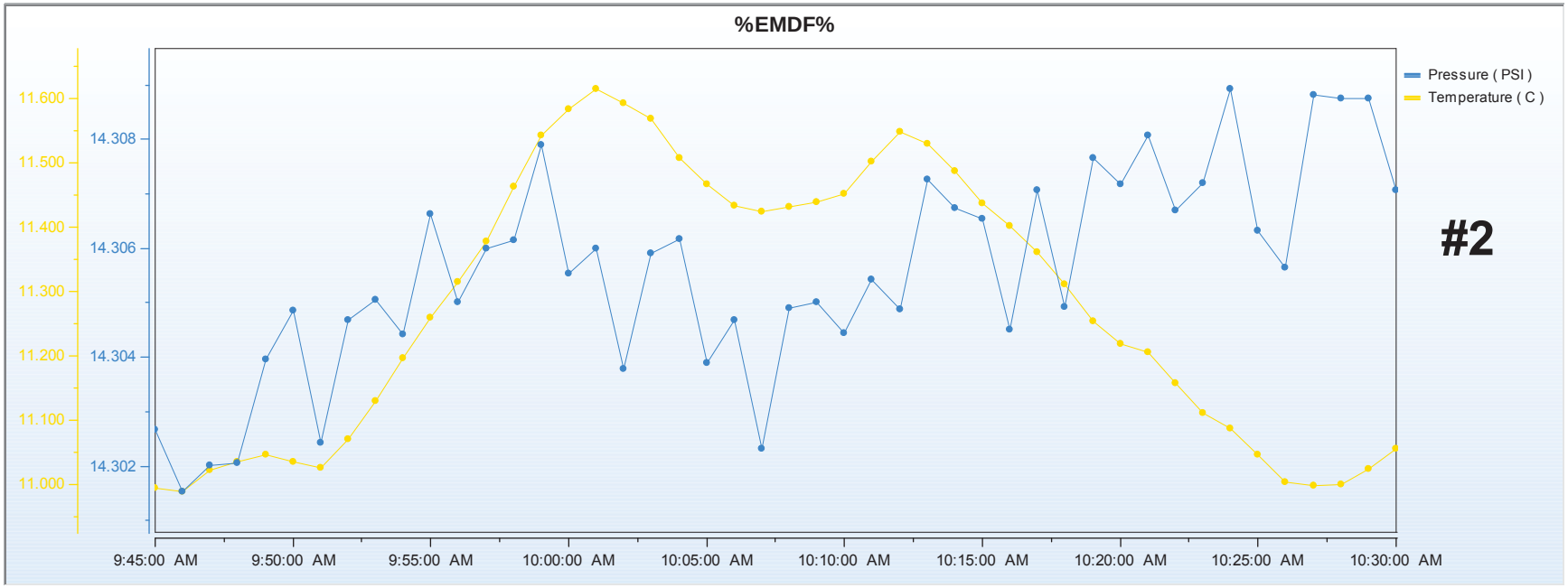
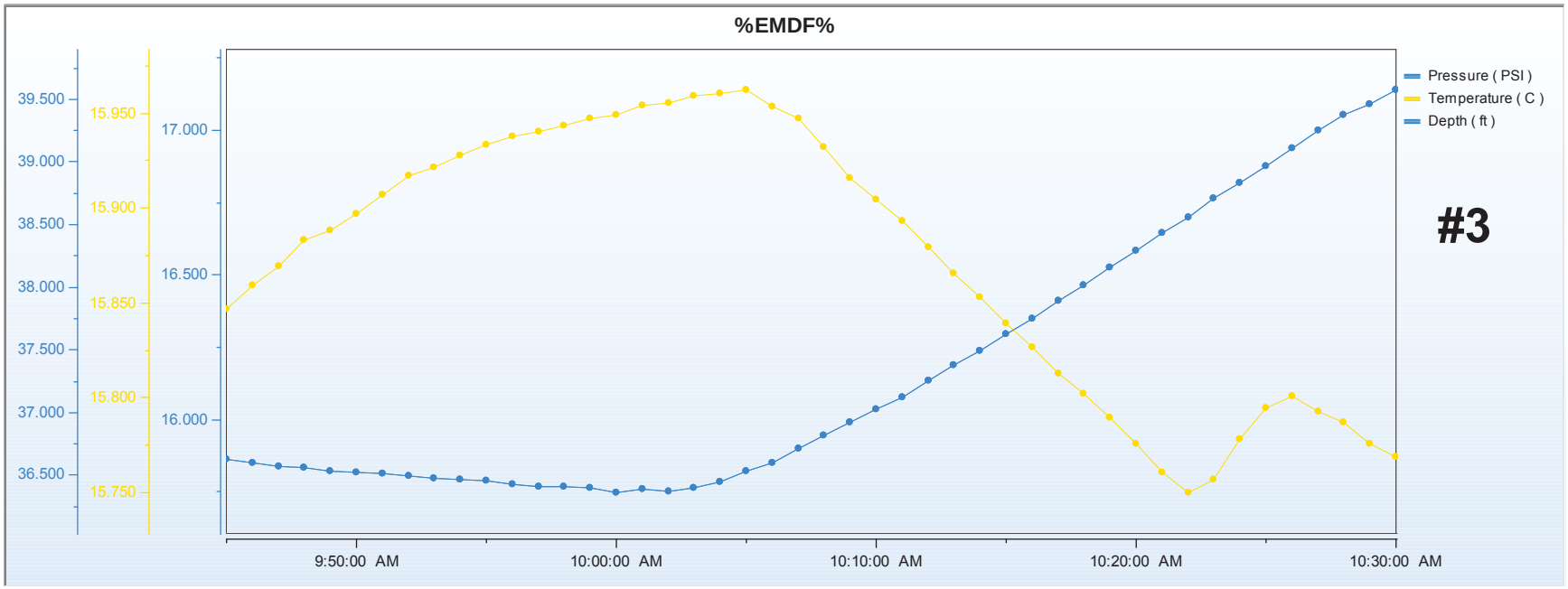


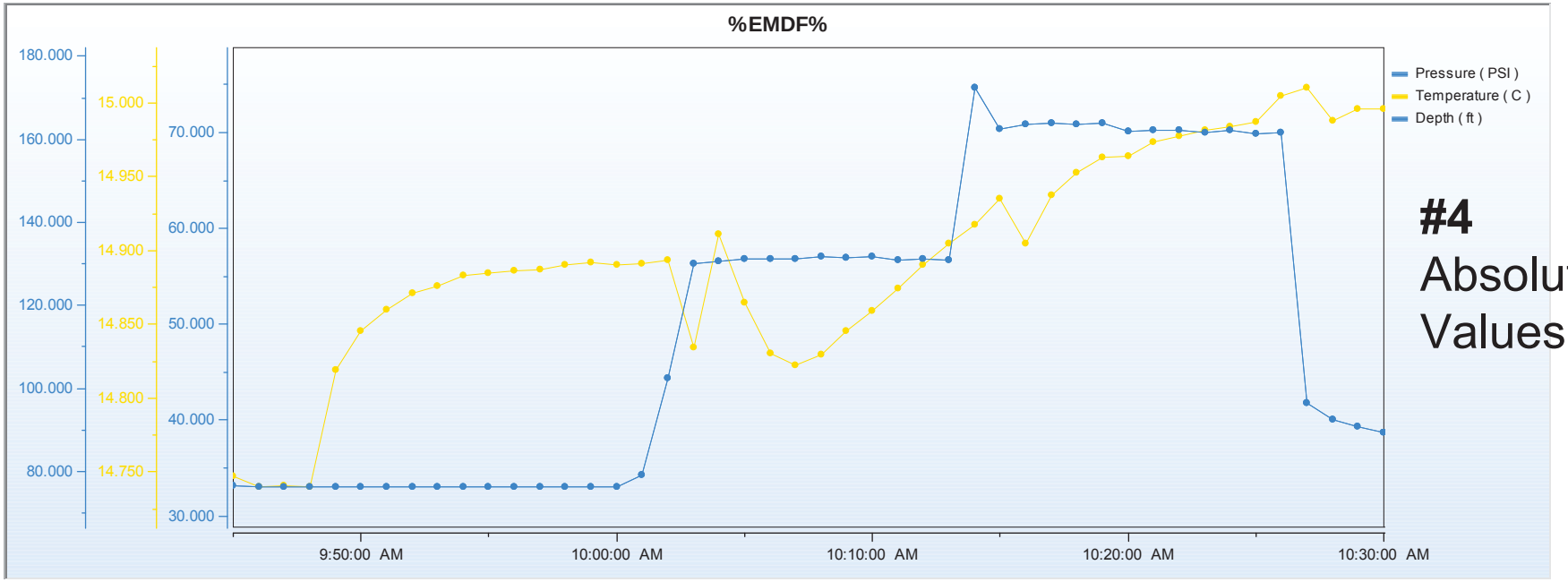

Table Top Baro Troll Data (Address #2)

# GW-970 PACKER TEST RESULTS (44-54 ft) - 15 & 30 PSI



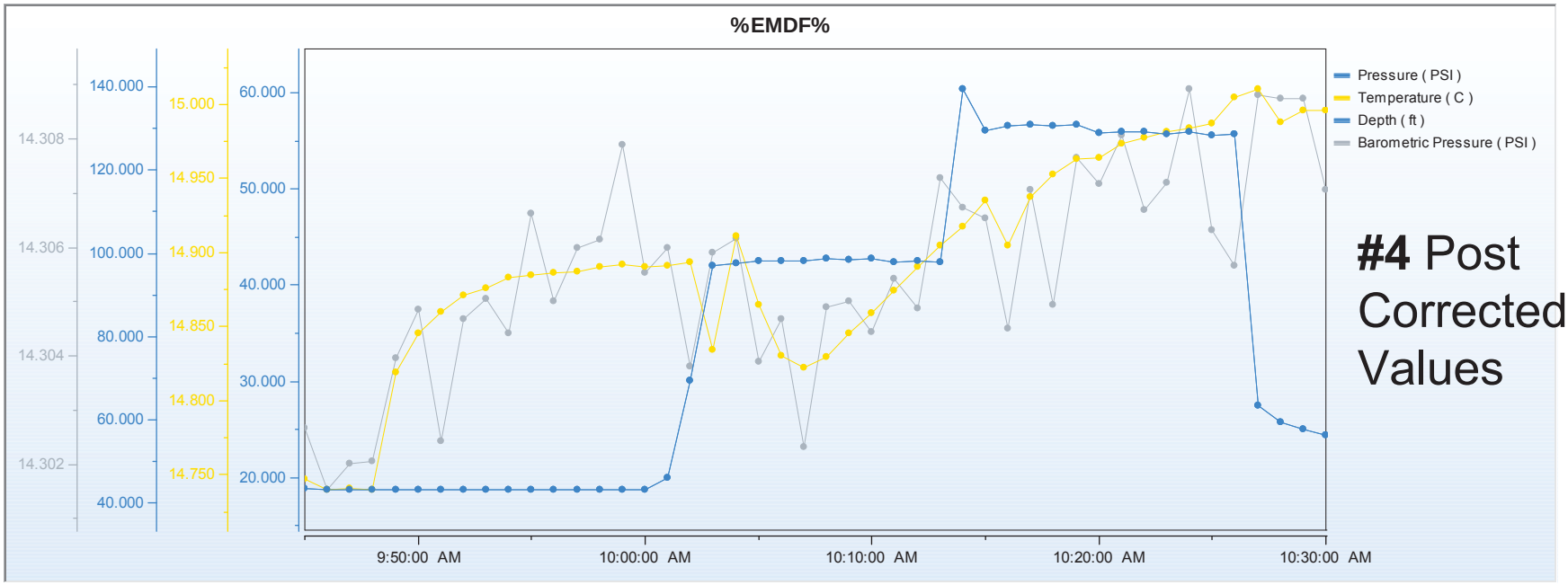

Upper Zone (Top) Transducer Data (Address #3)

# GW-970 PACKER TEST RESULTS (44-54 ft) - 15 & 30 PSI



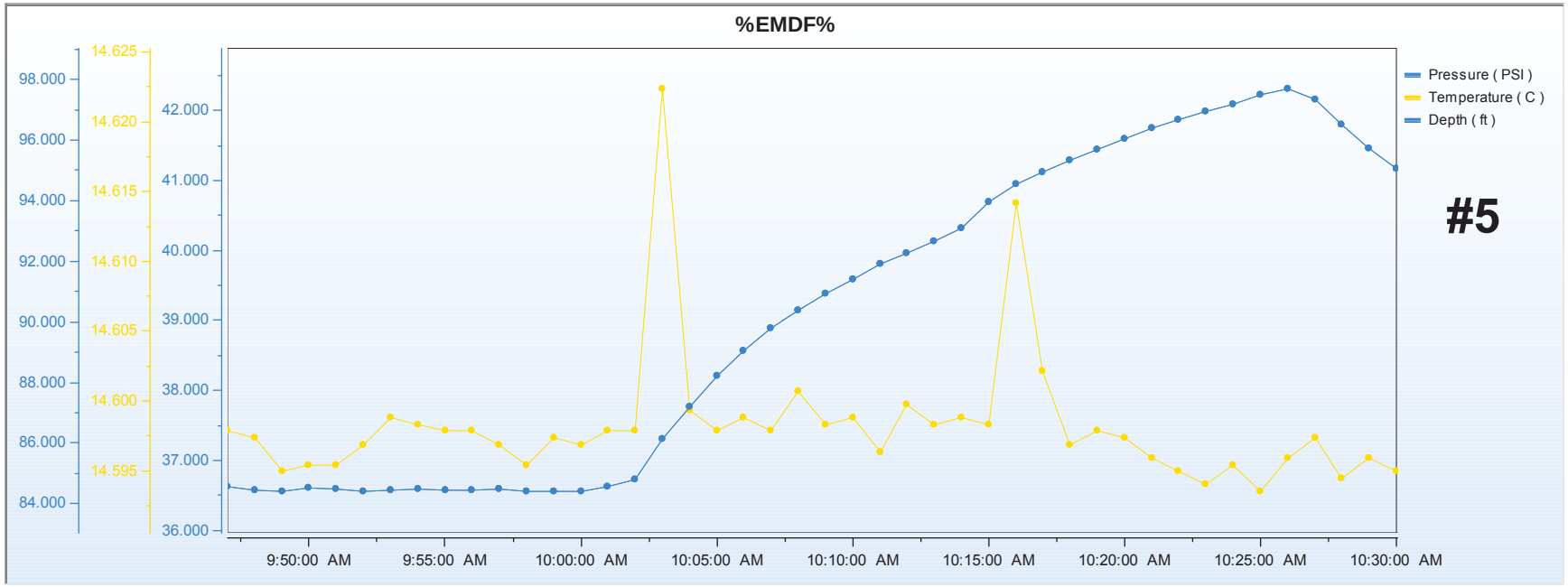

Packer Zone (Middle) Transducer Data (Address #4)

# GW-970 PACKER TEST RESULTS (44-54 ft) - 15 & 30 PSI




Packer Zone (Middle) Transducer Data (Address #4) - Post Corrected (BaroMerge) Data

# GW-970 PACKER TEST RESULTS (44-54 ft) - 15 & 30 PSI




Lower Zone (Bottom) Transducer Data (Address #5)

Report Date: 10/23/2014 16:05
Report User Na richardstout
Report Comput D4ZR1HC1
Application: WinSitu.exe
Application Ver 5.6.25.0

Log File Properties
File Name 970-44-54-0945a-4_2014-10-22_10-33-25-203-BaroMerge.wsl
Create Date 10/23/2014 16:04

Device Properties

| | | | | |
|---|---|---|---|---|
| Device | Level TROLL 700 | | | |
| Site | 970 | | | |
| Device Name | | | | |
| Serial Number | 142142 | | | |
| Firmware Versi | 2.09 | | | |
| Hardware Versi | 3 | | | |
| Device Address | 4 | | | |
| Device Comm C | 19200 | 8 Even | | 1 (Modbus-RTU) |
| Used Memory | 28 | | | |
| Used Battery | 36 | | | |

Log Configuration

| | |
|---|---|
| Log Name | 970-44-54-0945a-4 |
| Created By | richardstout |
| Computer Name | D4ZR1HC1 |
| Application | WinSitu.exe |
| Application Version | 5.6.25.0 |
| Create Date | 10/22/2014 9:43:58 AM Eastern Daylight Time |
| Log Setup Time Zone | Eastern Daylight Time |
| Notes Size(bytes) | 4096 |
| Overwrite when full | Enabled |
| Scheduled Start Time | 10/22/2014 9:45:00 AM Eastern Daylight Time |
| Scheduled Stop Time | 10/22/2014 10:00:00 PM Eastern Daylight Time |
| Type | Linear |
| Duration | Days: 0 hrs: 12 mins: 15 secs: 00 |
| Interval | Days: 0 hrs: 00 mins: 01 secs: 00 |

Level Reference Settings At Log Creation

| | |
|---|---|
| Level Measurement Mode | Depth |
| Specific Gravity | 0.999 |

Other Log Settings

| | |
|---|---|
| Depth of Probe: | 76.3123 (ft) |
| Head Pressure: | 33.0504 (PSI) |
| Temperature: | 14.7725 (C) |

Log Notes:

| Date | Time | Note |
|---|---|---|
| 10/22/2014 | 9:44:02 AM | Sensor SN: 142142 Factory calibration has expired.: 9/11/2014 12:18:23 PM |
| 10/22/2014 | 9:44:03 AM | Used Battery: 36% Used Memory: 31% User Name: richardstout |
| 10/22/2014 | 10:33:02 AM | Used Battery: 36% Used Memory: 31% User Name: richardstout |
| 10/22/2014 | 10:33:03 AM | Manual Stop Command |
| 10/23/2014 | 4:04:24 PM | User Note: "Pressure & Level adjusted by baro data from: "970-44-54-0945a-2_2014-10-22_10-31-47-843.wsl"" |

Log Data:
Record Count 46

| | | | |
|---|---|---|---|
| Sensors | 2 | | |
| | 1 | 142142 | Pressure/Temp 300 PSIA (200.7m/658.7ft) |
| | 2 | 0 | Baro-Adjustment Calc |

Time Zone: Eastern Daylight Time

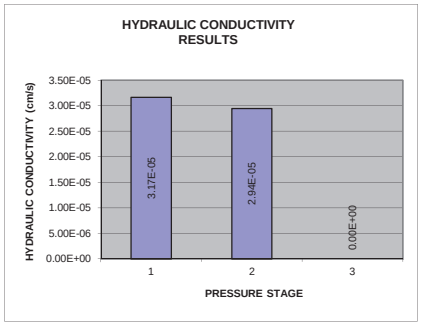
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Sensor: Pres(A) 658.7ft SN#: 142142 | Sensor: Pres(A) 658.7ft SN#: 142142 | Sensor: Pres(A) 658.7ft SN#: 142142 | Sensor: Baro-Adj Calc SN#: 000000 |
| | | | Elapsed Time | Corrected | | Corrected | |
| Date | Time | | Minutes | Pressure (PSI) | Temperature (C) | Depth (ft) | Barometric Pressure (PSI) |
| 10/22/2014 | 9:45:00 AM | | 0 | 18.81 | 14.747 | 43.432 | 14.303 |
| 10/22/2014 | 9:46:00 AM | | 1 | 18.772 | 14.74 | 43.344 | 14.302 |
| 10/22/2014 | 9:47:00 AM | | 2 | 18.793 | 14.741 | 43.391 | 14.302 |
| 10/22/2014 | 9:48:00 AM | | 3 | 18.77 | 14.74 | 43.339 | 14.302 |
| 10/22/2014 | 9:49:00 AM | | 4.001 | 18.747 | 14.819 | 43.286 | 14.304 |
| 10/22/2014 | 9:50:00 AM | | 5 | 18.757 | 14.846 | 43.309 | 14.305 |
| 10/22/2014 | 9:51:00 AM | | 6 | 18.758 | 14.86 | 43.313 | 14.302 |
| 10/22/2014 | 9:52:00 AM | | 7 | 18.757 | 14.871 | 43.309 | 14.305 |
| 10/22/2014 | 9:53:00 AM | | 8 | 18.733 | 14.876 | 43.254 | 14.305 |
| 10/22/2014 | 9:54:00 AM | | 9 | 18.738 | 14.883 | 43.265 | 14.304 |
| 10/22/2014 | 9:55:00 AM | | 10 | 18.716 | 14.884 | 43.216 | 14.307 |
| 10/22/2014 | 9:56:00 AM | | 11 | 18.716 | 14.886 | 43.214 | 14.305 |
| 10/22/2014 | 9:57:00 AM | | 12 | 18.726 | 14.887 | 43.238 | 14.306 |
| 10/22/2014 | 9:58:00 AM | | 13.002 | 18.733 | 14.89 | 43.253 | 14.306 |
| 10/22/2014 | 9:59:00 AM | | 14.002 | 18.713 | 14.892 | 43.207 | 14.308 |
| 10/22/2014 | 10:00:00 AM | | 15.002 | 18.713 | 14.89 | 43.207 | 14.306 |
| 10/22/2014 | 10:01:00 AM | | 16.002 | 19.966 | 14.891 | 46.101 | 14.306 |
| 10/22/2014 | 10:02:00 AM | | 17.002 | 30.041 | 14.893 | 69.364 | 14.304 |
| 10/22/2014 | 10:03:00 AM | | 18 | 41.972 | 14.834 | 96.912 | 14.306 |
| 10/22/2014 | 10:04:00 AM | | 19 | 42.318 | 14.911 | 97.711 | 14.306 |
| 10/22/2014 | 10:05:00 AM | | 20.002 | 42.555 | 14.864 | 98.258 | 14.304 |
| 10/22/2014 | 10:06:00 AM | | 21.002 | 42.483 | 14.83 | 98.093 | 14.305 |
| 10/22/2014 | 10:07:00 AM | | 22.002 | 42.547 | 14.822 | 98.241 | 14.302 |
| 10/22/2014 | 10:08:00 AM | | 23.002 | 42.791 | 14.829 | 98.803 | 14.305 |
| 10/22/2014 | 10:09:00 AM | | 24 | 42.594 | 14.846 | 98.349 | 14.305 |
| 10/22/2014 | 10:10:00 AM | | 25 | 42.723 | 14.859 | 98.646 | 14.304 |
| 10/22/2014 | 10:11:00 AM | | 26 | 42.424 | 14.874 | 97.955 | 14.305 |
| 10/22/2014 | 10:12:00 AM | | 27 | 42.562 | 14.89 | 98.273 | 14.305 |
| 10/22/2014 | 10:13:00 AM | | 28 | 42.357 | 14.904 | 97.802 | 14.307 |
| 10/22/2014 | 10:14:00 AM | | 29 | 60.395 | 14.917 | 139.451 | 14.307 |
| 10/22/2014 | 10:15:00 AM | | 30 | 56.072 | 14.935 | 129.468 | 14.307 |
| 10/22/2014 | 10:16:00 AM | | 31.001 | 56.6 | 14.904 | 130.687 | 14.305 |
| 10/22/2014 | 10:17:00 AM | | 32.001 | 56.629 | 14.938 | 130.755 | 14.307 |
| 10/22/2014 | 10:18:00 AM | | 33.001 | 56.603 | 14.952 | 130.694 | 14.305 |
| 10/22/2014 | 10:19:00 AM | | 34.001 | 56.709 | 14.963 | 130.939 | 14.308 |
| 10/22/2014 | 10:20:00 AM | | 35.001 | 55.861 | 14.964 | 128.981 | 14.307 |
| 10/22/2014 | 10:21:00 AM | | 36.001 | 55.955 | 14.974 | 129.198 | 14.308 |
| 10/22/2014 | 10:22:00 AM | | 37.001 | 55.931 | 14.977 | 129.143 | 14.307 |
| 10/22/2014 | 10:23:00 AM | | 38.001 | 55.7 | 14.981 | 128.61 | 14.307 |
| 10/22/2014 | 10:24:00 AM | | 39.001 | 55.91 | 14.984 | 129.095 | 14.309 |
| 10/22/2014 | 10:25:00 AM | | 40.001 | 55.591 | 14.987 | 128.357 | 14.306 |
| 10/22/2014 | 10:26:00 AM | | 41.002 | 55.654 | 15.005 | 128.504 | 14.306 |
| 10/22/2014 | 10:27:00 AM | | 42.002 | 27.5 | 15.01 | 63.497 | 14.309 |
| 10/22/2014 | 10:28:00 AM | | 43 | 25.79 | 14.988 | 59.549 | 14.309 |
| 10/22/2014 | 10:29:00 AM | | 44 | 25.004 | 14.996 | 57.733 | 14.309 |
| 10/22/2014 | 10:30:00 AM | | 45 | 24.461 | 14.996 | 56.479 | 14.307 |

# FINAL PACKER TEST RESULTS

EMDF Phase I Site Characterization

Y-12 National Security Complex, Oak Ridge, Tennessee

| | |
|---|---|
| **Borehole ID#:** | GW-970 |
| **Test Interval (ft):** | 52-62 |
| **Description of material(s) tested/lithologic interval:** | Assumed shale, weathered shale |
| **Test Date:** | 10/22/2014 |
| **Packer arrangement (single or double):** | Double |
| **Test time - start & finish:** | 1159-1236 |
| **Weather:** | Clear and breezy |
| **~ Temp (ºF):** | 46 |
| **Field Geologist/Engineer:** | R. Stout (Alliant) |
| **Drilling Co. Personnel:** | M. Sturdevant (M&W Drilling) |
| **Others Present:** | J. Scott (M&W Drilling) |
| **Injection Water Source:** | Water tank |
| **Top of ground elevation (ft MSL):** | 1040.93 |
| **Depth Datum:** | Top of Casing |
| **Casing stickup at time of test (ft):** | 0.16 |
| **Depth of borehole at test time (ft):** | 99.5 |
| **Depth to bottom of top packer (ft):** | 52.00 |
| **Depth to top of bottom packer (ft):** | 62.00 |
| **Depth of piezometric level (ft):** | 6.3 |
| **Length of test section, L (ft):** | 10 |
| **Radius of borehole, r (ft):** | 0.33 |
| **L/r (dimensionless):** | 30 |
| **Length of packers (ft):** | 3.00 |
| **Maximum Excess Injection Pressure (psi):** | 35.20 |
| **Maximum Total Test Pressure (excess plus static in psi):** | 57.18 |
| **Barometric sensor S/N and address:** | 190601-2 |
| **Top sensor S/N and address:** | 332540-3 |
| **Packer zone sensor S/N and address:** | 142142-4 |
| **Lower sensor S/N and address:** | 174036-5 |
| **Data Site (WinSitu5):** | EMDF |
| **Data log (raw data file *.wsl):** | 970-52-62-1100a-2,-3,-4,-5 |
| **Barometric post-corrected file (*.wsl):** | 970-52-62-1100a-4-BaroMerge |
| **ASCII exported file (*.csv):** | 970-52-62-1100a-2,-3,-4,-5 |




| | |
|---|---|
| **MEAN HYDRAULIC CONDUCTIVITY FOR TEST PRESSURE RANGE (cm/s)** | **3.1E-05** * |

| Pressure Stage No. | Mean Stabilized Flow Rate (gpm) | Mean Total Head (ft) | Mean Hydraulic Conductivity (cm/sec) |
|---|---|---|---|
| 1 | 0.909 | 105.66 | 3.17E-05 |
| 2 | 1.091 | 136.30 | 2.94E-05 |
| 3 | 0.000 | 0.00 | 0.00E+00 |

| | Pressure Stage No. | Actual Time (min.) | Elapsed Time (min.) | Flow Meter Reading (gal.) | Water Volume Injected (gal.) | Flow Rate, Q (gpm) | Total Head, H (ft) | 2πLH (sf) | ln (L/r) | Hydraulic Conductivity, k (cm/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 15-16 PSI | 1 | 0 | 0 | 124994 | 0 | 0 | 54.20 | 3405 | 3.401 | 0.00E+00 |
| | 1 | 1 | 1 | 124995 | 1.000 | 1.000 | 107.95 | 6783 | 3.401 | 3.41E-05 |
| | 1 | 2 | 1 | 124996 | 1.000 | 1.000 | 106.19 | 6672 | 3.401 | 3.46E-05 |
| | 1 | 3 | 1 | 124997 | 1.000 | 1.000 | 105.12 | 6605 | 3.401 | 3.50E-05 |
| | 1 | 4 | 1 | 124998.5 | 1.500 | 1.500 | 105.80 | 6648 | 3.401 | 5.22E-05 |
| | 1 | 5 | 1 | 124999 | 0.500 | 0.500 | 105.89 | 6654 | 3.401 | 1.74E-05 |
| | 1 | 6 | 1 | 125000 | 1.000 | 1.000 | 104.93 | 6593 | 3.401 | 3.51E-05 |
| | 1 | 7 | 1 | 125001 | 1.000 | 1.000 | 106.37 | 6683 | 3.401 | 3.46E-05 |
| | 1 | 8 | 1 | 125002 | 1.000 | 1.000 | 105.59 | 6634 | 3.401 | 3.48E-05 |
| | 1 | 9 | 1 | 125002.5 | 0.500 | 0.500 | 105.36 | 6620 | 3.401 | 1.75E-05 |
| | 1 | 10 | 1 | 125003 | 0.500 | 0.500 | 105.47 | 6627 | 3.401 | 1.74E-05 |
| | 1 | 11 | 1 | 125004 | 1.000 | 1.000 | 103.56 | 6507 | 3.401 | 3.55E-05 |
| 29-30 PSI | 2 | 0 | 0 | 125004 | 0 | 0 | 142.94 | 8981 | 3.401 | 0.00E+00 |
| | 2 | 1 | 1 | 125005.5 | 1.500 | 1.500 | 143.12 | 8993 | 3.401 | 3.86E-05 |
| | 2 | 2 | 1 | 125007.0 | 1.500 | 1.500 | 138.62 | 8710 | 3.401 | 3.98E-05 |
| | 2 | 3 | 1 | 125008 | 1.000 | 1.000 | 137.09 | 8613 | 3.401 | 2.68E-05 |
| | 2 | 4 | 1 | 125009 | 1.000 | 1.000 | 137.31 | 8627 | 3.401 | 2.68E-05 |
| | 2 | 5 | 1 | 125010 | 1.000 | 1.000 | 135.75 | 8529 | 3.401 | 2.71E-05 |
| | 2 | 6 | 1 | 125011 | 1.000 | 1.000 | 136.09 | 8551 | 3.401 | 2.70E-05 |
| | 2 | 7 | 1 | 125012 | 1.000 | 1.000 | 134.22 | 8433 | 3.401 | 2.74E-05 |
| | 2 | 8 | 1 | 125013 | 1.000 | 1.000 | 135.84 | 8535 | 3.401 | 2.71E-05 |
| | 2 | 9 | 1 | 125014 | 1.000 | 1.000 | 133.42 | 8383 | 3.401 | 2.76E-05 |
| | 2 | 10 | 1 | 125015 | 1.000 | 1.000 | 134.02 | 8420 | 3.401 | 2.75E-05 |
| | 2 | 11 | 1 | 125016 | 1.000 | 1.000 | 133.80 | 8407 | 3.401 | 2.75E-05 |
| 45 PSI | 3 | 0 | 0 | 0.0 | 0 | 0 | 0.00 | 0 | 0.000 | 0.00E+00 |
| **NOT CONDUCTED. WOULD HAVE EXCEEDED MAX PRESSURE OF 35 PSI.** | 3 | 1 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 2 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 3 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 4 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 5 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 6 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 7 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 8 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 9 | 1 | 0.0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |
| | 3 | 10 | 1 | 0 | 0.000 | 0.000 | 0.00 | 0 | 0.000 | 0.00E+00 |

| | |
|---|---|
| ***FOR DESIGN USE:** | **3.1E-05** |

Test Method: USBR Earth Manual 2nd edition (1974) Appendix E-18

prepared by: R. Stout date: 2/17/2015
checked by: B. Price date:
edited by: GM date: 10/14/2014

GW-970

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GW-970 | Depth of borehole at test time | 100 ft. |
| Test Date | 10/22/2014 | Depth to bottom of top packer | 52 ft. |
| Test Time - Start & Finish | 1216 / 1227 | Depth to top of bottom packer | 62 ft. |
| Weather | clear dry breezy | Depth & Elevation of piezometric level | 6.30 ft 4 inflated packers |
| ~ Temp (F) | 52°F | Length of test section | 10 ft. |
| Field geologist/engineer: | M. Stark / M. Malci | Radius of borehole | ~~8 in. mm~~ 4 in. |
| Drilling Co Personnel: | M&W / M. Sturdeant | Length of packer(s) | 5 ft. |
| Others present: | | Height of pressure gage above ground surface | 3.8 ft. |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 3.8 ft. |
| | | Description of material(s) tested/lithologic interval | Pumpkin Valley FM (Shale) |

**PRE-TEST DATA**

Leak check completed (Y/N): No

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| -15 psi Test | | | |

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| 1216 | 0 | 0. | 124994 | — | |
| | 1 | 1.0 | 124995 | 15 | |
| | 2 | 1.0 | 124996 | 16 | |
| | 3 | 1.0 | 124997 | 16 | |
| | 4 | 1.5 | 124998 1/2 | 16 | 124998 1/2 |
| | 5 | 0.5 | 124999 | 16 | |
| 1222 | 6 | 1.0 | 125000 | 16 | |
| | 7 | 1.0 | 125001 | 16 | |
| | 8 | 1.0 | 125002 | 16 | |
| | 9 | 0.5 | 125002 1/2 | 16 | |
| | 10 | 0.5 | 125003 | 16 | |
| 1227 | 11. | 1.0 | 125004 | 16 | |

Comments/Notes:
No 45 psi test to avoid fracturing formation.
Flow rate of 0.5 to 1 Gpm during test.

PackerTestFieldForm.xls

Page 1 of 1

GU-970

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GU-970 | Depth of borehole at test time | 100 ft |
| Test Date | 10/22/2014 | Depth to bottom of top packer | 52 ft. |
| Test Time - Start & Finish | 1228 | Depth to top of bottom packer | 62 ft. |
| Weather | clear dry, breezy | Depth & Elevation of piezometric level | 6.30 ft w/ packers inflated |
| ~ Temp (F) | 52F | Length of test section | 10 ft. |
| Field geologist/engineer: | N. Stout / M. Malsi | Radius of borehole | ~~5 in~~ 4 in. |
| Drilling Co Personnel: | M&W / M. Sturdevant | Length of packer(s) | 5 ft. |
| Others present: | | Height of pressure gage above ground surface | 3.8 ft. |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 3.8 ft. |
| | | Description of material(s) tested/lithologic interval | Pumpkin Valley Fm. (Shale) |

**PRE-TEST DATA**

Leak check completed (Y/N):

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 30 PSI Test | | | |

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| 1228 | 0 | — | 125004 | — | |
| | 1 | 1.5 | 125005 1/2 | 31 | |
| | 2 | 1.5 | 125007 | 30 | |
| | 3 | 1.0 | 125008 | 30 | |
| | 4 | 1.0 | 125009 | 30 | |
| | 5 | 1.0 | 125010 | 30 | 125010 gals |
| 1234 | 6 | 1.0 | 125011 | 30 | |
| | 7 | 1.0 | 125012 | 30 | |
| | 8 | 1.0 | 125013 | 29 | |
| | 9 | 1.0 | 125014 | 29 | |
| | 10 | 1.0 | 125015 | 29 | |
| 1239 | 11 | 1.0 | 125016 | 29 | |

Comments/Notes:

Some pressure adjustments in first test min.
Steady injection rate of 1.0 GPM

PackerTestFieldForm.xls

Page 1 of 1

# GW-970 PACKER TEST RESULTS (52-62 ft) - 15 & 30 PSI

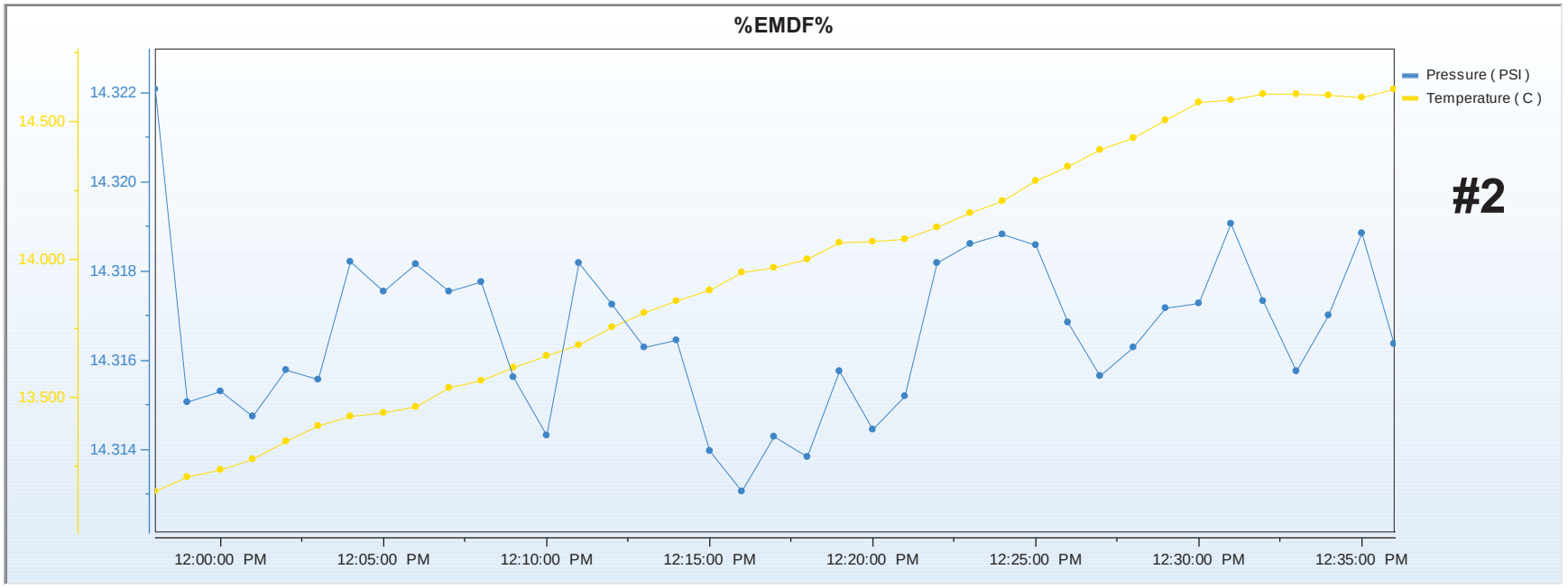
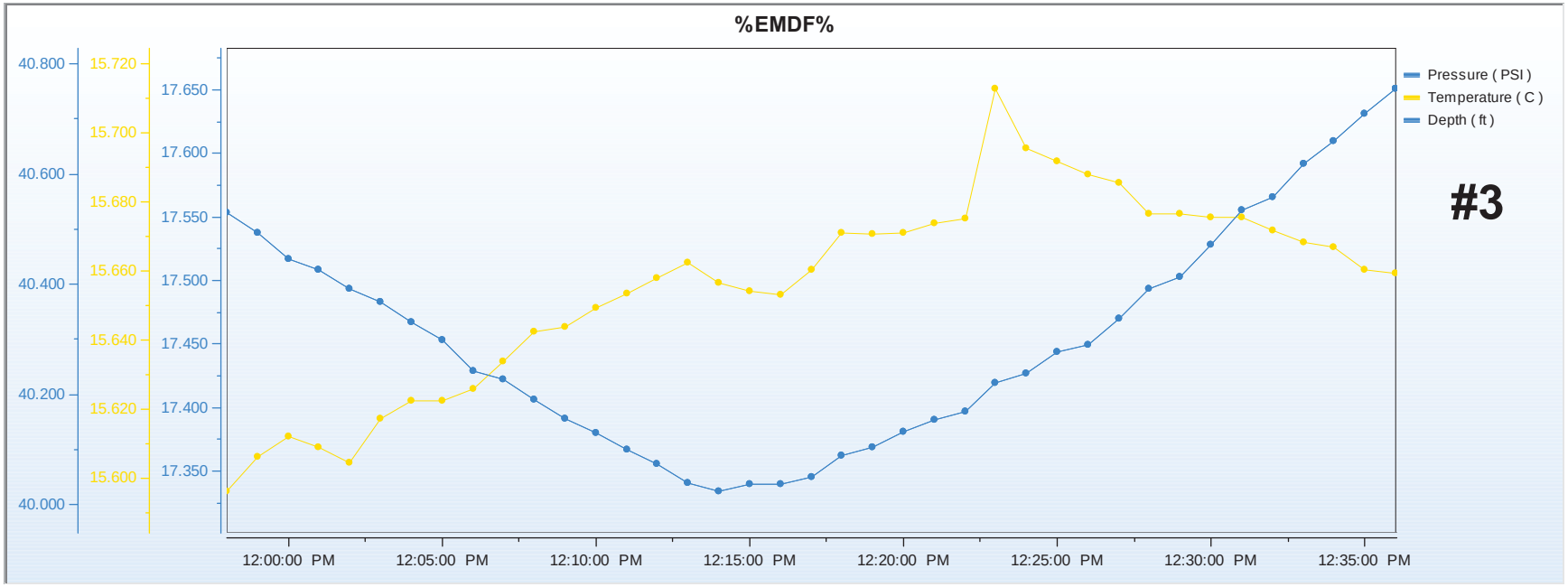


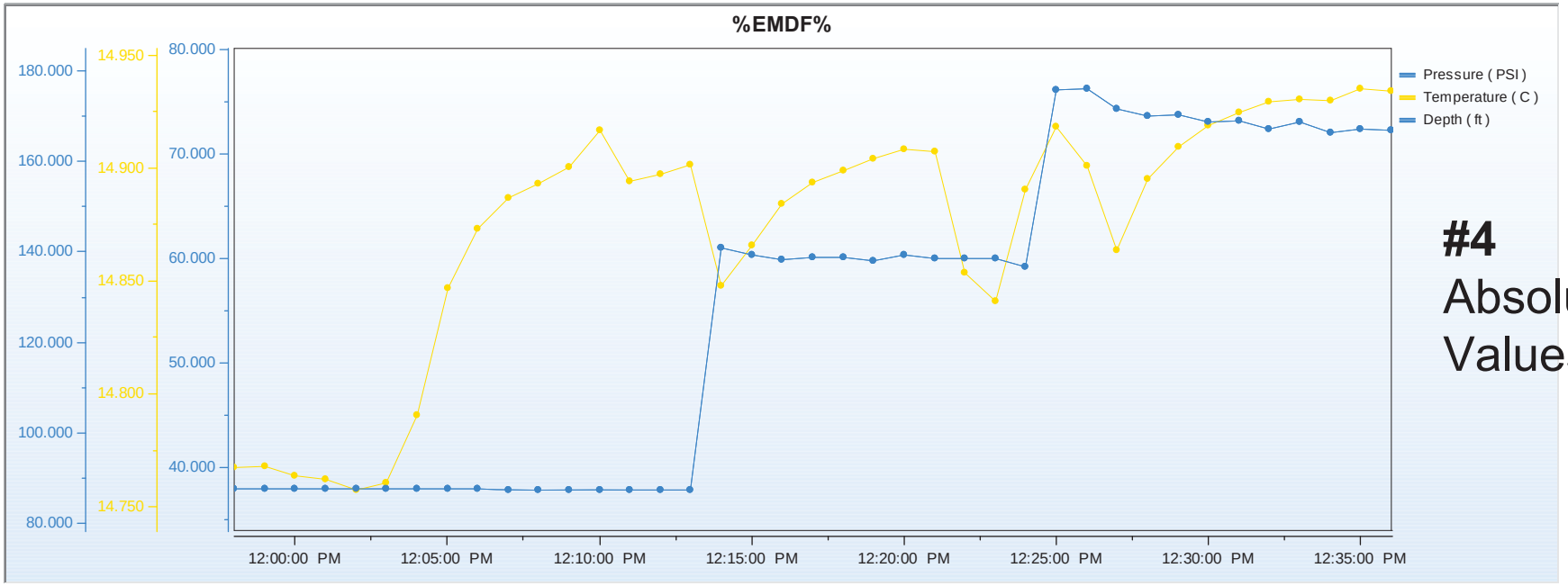

Table Top Baro Troll Data (Address #2)

# GW-970 PACKER TEST RESULTS (52-62 ft) - 15 & 30 PSI




Upper Zone (Top) Transducer Data (Address #3)

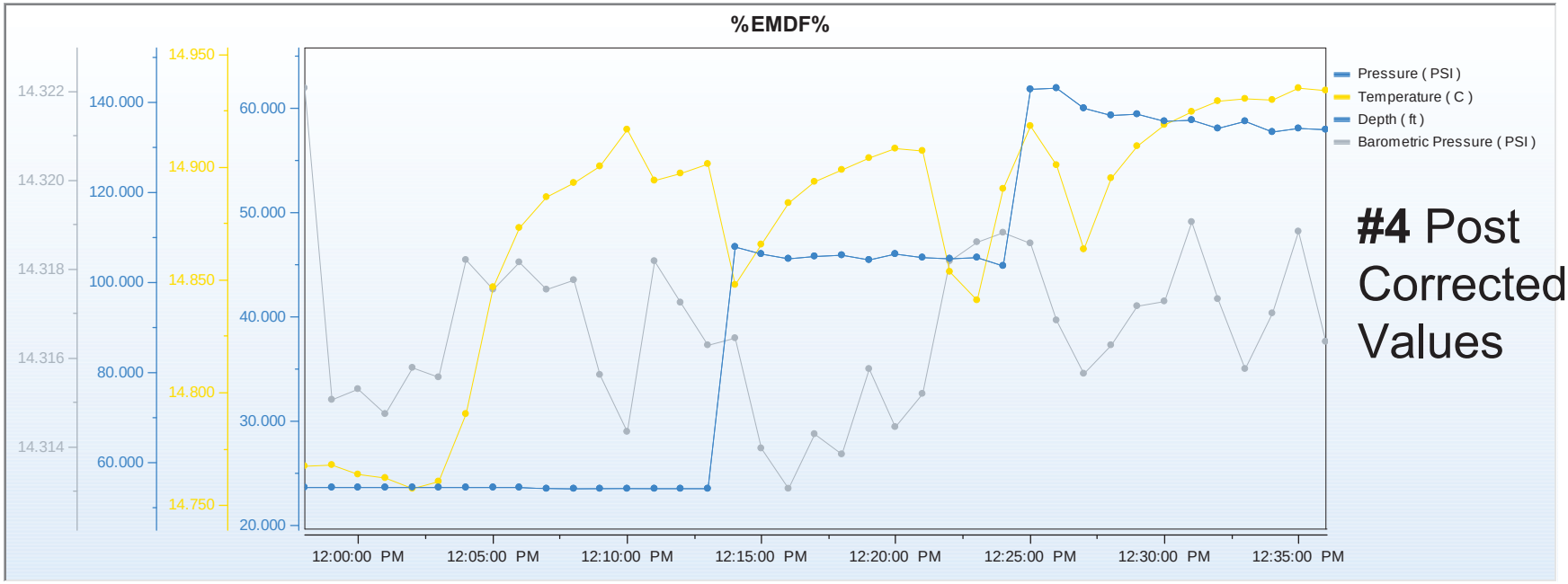
# GW-970 PACKER TEST RESULTS (52-62 ft) - 15 & 30 PSI




**#4**
Absolute
Values

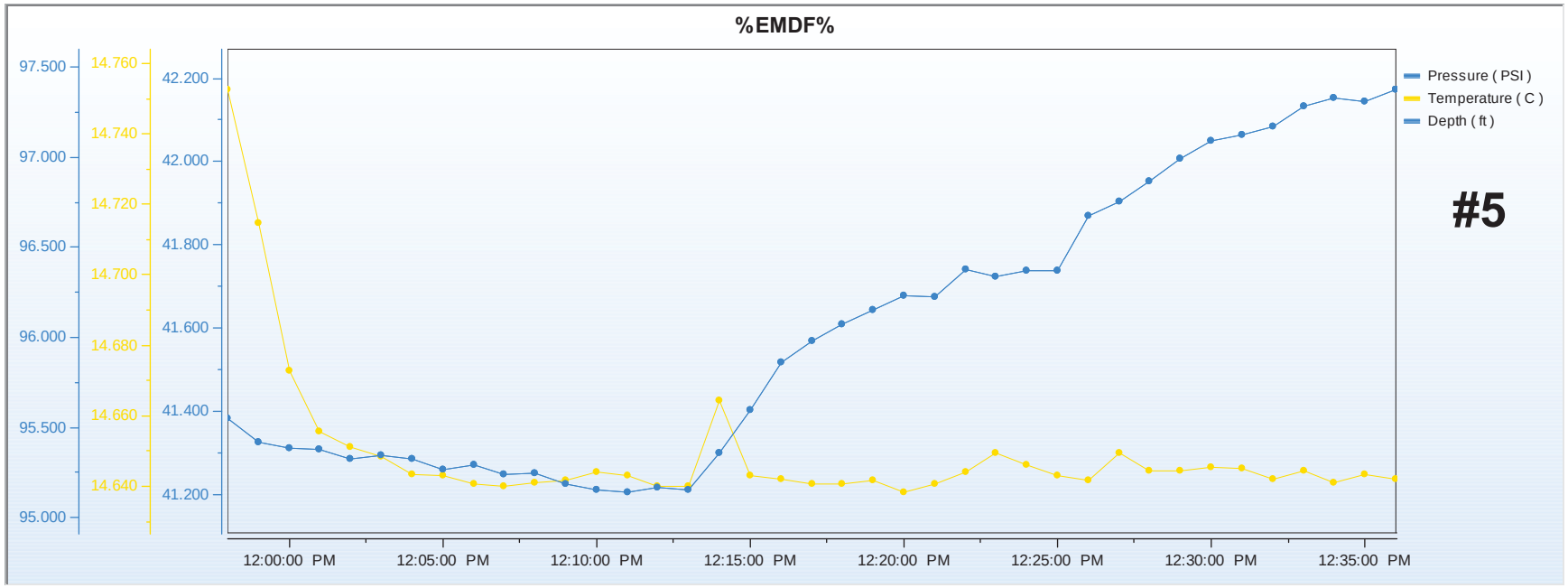
Packer Zone (Middle) Transducer Data (Address #4)

# GW-970 PACKER TEST RESULTS (52-62 ft) - 15 & 30 PSI




Packer Zone (Middle) Transducer Data (Address #4) - Post Corrected (BaroMerge) Data

# GW-970 PACKER TEST RESULTS (52-62 ft) - 15 & 30 PSI




Lower Zone (Bottom) Transducer Data (Address #5)

Report Date: 10/23/2014 16:05
Report User Nar richardstout
Report Compute D4ZR1HC1
Application: WinSitu.exe
Application Vers 5.6.25.0

Log File Properties
File Name 970-52-62-1200p-4_2014-10-22_12-39-55-593-BaroMerge.wsl
Create Date 10/23/2014 16:04

Device Properties

| | | | | |
|---|---|---|---|---|
| Device | Level TROLL 700 | | | |
| Site | 970 | | | |
| Device Name | | | | |
| Serial Number | 142142 | | | |
| Firmware Versic | 2.09 | | | |
| Hardware Versi | 3 | | | |
| Device Address | 4 | | | |
| Device Comm C | 19200 | 8 Even | 1 | (Modbus-RTU) |
| Used Memory | 31 | | | |
| Used Battery | 36 | | | |

Log Configuration

| | |
|---|---|
| Log Name | 970-52-62-1200p-4 |
| Created By | richardstout |
| Computer Name | D4ZR1HC1 |
| Application | WinSitu.exe |
| Application Version | 5.6.25.0 |
| Create Date | 10/22/2014 11:53:16 AM Eastern Daylight Time |
| Log Setup Time Zone | Eastern Daylight Time |
| Notes Size(bytes) | 4096 |
| Overwrite when full | Enabled |
| Scheduled Start Tim | 10/22/2014 11:58:00 AM Eastern Daylight Time |
| Scheduled Stop Time | 10/22/2014 10:00:00 PM Eastern Daylight Time |
| Type | Linear |
| Duration | Days: 0 hrs: 10 mins: 02 secs: 00 |
| Interval | Days: 0 hrs: 00 mins: 01 secs: 00 |

Level Reference Settings At Log Creation

| | |
|---|---|
| Level Measuren | Depth |
| Specific Grav | 0.999 |

Other Log Settings

| | |
|---|---|
| Depth of Probe: | 87.6268 (ft) |
| Head Pressure: | 37.9506 (PSI) |
| Temperature: | 14.8049 (C) |

Log Notes:

| Date | Time | Note |
|---|---|---|
| | | Sensor SN: 142142 Factory calibration has expired.: 9/11/2014 |
| 10/22/2014 | 11:53:16 AM | 12:18:23 PM |
| 10/22/2014 | 11:53:17 AM | Used Battery: 36% Used Memory: 34% User Name: richardstout |
| 10/22/2014 | 12:39:29 PM | Used Battery: 36% Used Memory: 34% User Name: richardstout |
| 10/22/2014 | 12:39:29 PM | Manual Stop Command |
| 10/23/2014 | 4:04:52 PM | User Note: "Pressure & Level adjusted by baro data from: "970-52-62-1200p-2_2014-10-22_12-38-05-968.wsl"" |

Log Data:

| | | | |
|---|---|---|---|
| Record Count | 39 | | |
| Sensors | 2 | | |
| | 1 | 142142 | Pressure/Temp 300 PSIA (200.7m/658.7ft) |
| | 2 | 0 | Baro-Adjustment Calc |

Time Zone: Eastern Daylight Time

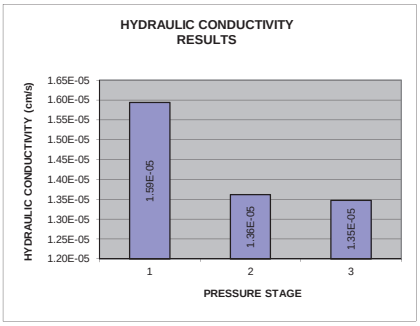
| Date | Time | Elapsed Time Minutes | Sensor: Pres(A) 658.7ft SN#: 142142 Corrected Pressure (PSI) | Sensor: Pres(A) 658.7ft SN#: 142142 Temperature (C) | Sensor: Pres(A) 658.7ft SN#: 142142 Corrected Depth (ft) | Sensor: Baro-Adj Calc SN#: 000000 Barometric Pressure (PSI) |
|---|---|---|---|---|---|---|
| 10/22/2014 | 11:58:00 AM | 0 | 23.624 | 14.767 | 54.547 | 14.322 |
| 10/22/2014 | 11:59:00 AM | 1 | 23.636 | 14.768 | 54.574 | 14.315 |
| 10/22/2014 | 12:00:00 PM | 2 | 23.608 | 14.764 | 54.51 | 14.315 |
| 10/22/2014 | 12:01:00 PM | 3 | 23.603 | 14.762 | 54.499 | 14.315 |
| 10/22/2014 | 12:02:00 PM | 4 | 23.594 | 14.757 | 54.477 | 14.316 |
| 10/22/2014 | 12:03:00 PM | 5 | 23.597 | 14.761 | 54.484 | 14.316 |
| 10/22/2014 | 12:04:00 PM | 6 | 23.557 | 14.791 | 54.392 | 14.318 |
| 10/22/2014 | 12:05:00 PM | 7.003 | 23.558 | 14.847 | 54.395 | 14.318 |
| 10/22/2014 | 12:06:00 PM | 8.003 | 23.549 | 14.873 | 54.375 | 14.318 |
| 10/22/2014 | 12:07:00 PM | 9.003 | 23.539 | 14.887 | 54.352 | 14.318 |
| 10/22/2014 | 12:08:00 PM | 10.003 | 23.525 | 14.893 | 54.318 | 14.318 |
| 10/22/2014 | 12:09:00 PM | 11.003 | 23.505 | 14.9 | 54.272 | 14.316 |
| 10/22/2014 | 12:10:00 PM | 12.002 | 23.486 | 14.917 | 54.227 | 14.314 |
| 10/22/2014 | 12:11:00 PM | 13 | 23.495 | 14.894 | 54.248 | 14.318 |
| 10/22/2014 | 12:12:00 PM | 14 | 23.489 | 14.897 | 54.235 | 14.317 |
| 10/22/2014 | 12:13:00 PM | 15 | 23.473 | 14.901 | 54.2 | 14.316 |
| 10/22/2014 | 12:14:00 PM | 16 | 46.753 | 14.848 | 107.95 | 14.316 |
| 10/22/2014 | 12:15:00 PM | 17 | 45.991 | 14.866 | 106.192 | 14.314 |
| 10/22/2014 | 12:16:00 PM | 18 | 45.529 | 14.884 | 105.124 | 14.313 |
| 10/22/2014 | 12:17:00 PM | 19 | 45.821 | 14.893 | 105.8 | 14.314 |
| 10/22/2014 | 12:18:00 PM | 20 | 45.862 | 14.899 | 105.894 | 14.314 |
| 10/22/2014 | 12:19:00 PM | 21 | 45.442 | 14.904 | 104.925 | 14.316 |
| 10/22/2014 | 12:20:00 PM | 22 | 46.067 | 14.909 | 106.367 | 14.314 |
| 10/22/2014 | 12:21:00 PM | 23 | 45.73 | 14.907 | 105.588 | 14.315 |
| 10/22/2014 | 12:22:00 PM | 24 | 45.632 | 14.854 | 105.363 | 14.318 |
| 10/22/2014 | 12:23:00 PM | 25.003 | 45.68 | 14.841 | 105.473 | 14.319 |
| 10/22/2014 | 12:24:00 PM | 26.003 | 44.852 | 14.89 | 103.561 | 14.319 |
| 10/22/2014 | 12:25:00 PM | 27 | 61.906 | 14.918 | 142.938 | 14.319 |
| 10/22/2014 | 12:26:00 PM | 28 | 61.986 | 14.901 | 143.123 | 14.317 |
| 10/22/2014 | 12:27:00 PM | 29 | 60.036 | 14.863 | 138.621 | 14.316 |
| 10/22/2014 | 12:28:00 PM | 30 | 59.372 | 14.895 | 137.088 | 14.316 |
| 10/22/2014 | 12:29:00 PM | 31 | 59.467 | 14.909 | 137.307 | 14.317 |
| 10/22/2014 | 12:30:00 PM | 32 | 58.793 | 14.919 | 135.751 | 14.317 |
| 10/22/2014 | 12:31:00 PM | 33 | 58.938 | 14.925 | 136.086 | 14.319 |
| 10/22/2014 | 12:32:00 PM | 34 | 58.129 | 14.929 | 134.217 | 14.317 |
| 10/22/2014 | 12:33:00 PM | 35 | 58.832 | 14.93 | 135.842 | 14.316 |
| 10/22/2014 | 12:34:00 PM | 36 | 57.785 | 14.93 | 133.424 | 14.317 |
| 10/22/2014 | 12:35:00 PM | 37 | 58.042 | 14.935 | 134.016 | 14.319 |
| 10/22/2014 | 12:36:00 PM | 38 | 57.947 | 14.934 | 133.797 | 14.316 |

# FINAL PACKER TEST RESULTS

EMDF Phase I Site Characterization

Y-12 National Security Complex, Oak Ridge, Tennessee

| | |
|---|---|
| **Borehole ID#:** | GW-970 |
| **Test Interval (ft):** | 65-75 |
| **Description of material(s) tested/lithologic interval:** | Assumed shale, weathered shale |
| **Test Date:** | 10/22/2014 |
| **Packer arrangement (single or double):** | Double |
| **Test time - start & finish:** | 1332-1422 |
| **Weather:** | Clear, dry and light breeze |
| **~ Temp (ºF):** | 54 |
| **Field Geologist/Engineer:** | R. Stout (Alliant) |
| **Drilling Co. Personnel:** | M. Sterdavent (M&W Drilling) |
| **Others Present:** | J. Scott (M&W Drilling) |
| **Injection Water Source:** | Water tank |
| **Top of ground elevation (ft MSL):** | 1040.93 |
| **Depth Datum:** | Top of Casing |
| **Casing stickup at time of test (ft):** | 0.16 |
| **Depth of borehole at test time (ft):** | 100.2 |
| **Depth to bottom of top packer (ft):** | 65.00 |
| **Depth to top of bottom packer (ft):** | 75.00 |
| **Depth of piezometric level (ft):** | 7.97 |
| **Length of test section, L (ft):** | 10 |
| **Radius of borehole, r (ft):** | 0.33 |
| **L/r (dimensionless):** | 30 |
| **Length of packers (ft):** | 3.00 |
| **Maximum Excess Injection Pressure (psi):** | 43.33 |
| **Maximum Total Test Pressure (excess plus static in psi):** | 70.22 |
| **Barometric sensor S/N and address:** | 190601-2 |
| **Top sensor S/N and address:** | 332540-3 |
| **Packer zone sensor S/N and address:** | 142142-4 |
| **Lower sensor S/N and address:** | 174036-5 |
| **Data Site (WinSitu5):** | EMDF |
| **Data log (raw data file *.wsl):** | 970-65-75-1300p-2,-3,-4,-5 |
| **Barometric post-corrected file (*.wsl):** | 970-65-75-1300p-4-BaroMerge |
| **ASCII exported file (*.csv):** | 970-65-75-1300p-2,-3,-4,-5 |




| | |
|---|---|
| **MEAN HYDRAULIC CONDUCTIVITY FOR TEST PRESSURE RANGE (cm/s)** | **1.4E-05** * |

| Pressure Stage No. | Mean Stabilized Flow Rate (gpm) | Mean Total Head (ft) | Mean Hydraulic Conductivity (cm/sec) |
|---|---|---|---|
| 1 | 0.500 | 115.45 | 1.59E-05 |
| 2 | 0.545 | 147.40 | 1.36E-05 |
| 3 | 0.682 | 186.25 | 1.35E-05 |

| | Pressure Stage No. | Actual Time (min.) | Elapsed Time (min.) | Flow Meter Reading (gal.) | Water Volume Injected (gal.) | Flow Rate, Q (gpm) | Total Head, H (ft) | 2πLH (sf) | ln (L/r) | Hydraulic Conductivity, k (cm/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 PSI | 1 | 0 | 0 | 125019 | 0 | 0 | 116.53 | 7322 | 3.401 | 0.00E+00 |
| | 1 | 1 | 1 | 125019.5 | 0.500 | 0.500 | 115.64 | 7266 | 3.401 | 1.59E-05 |
| | 1 | 2 | 1 | 125020 | 0.500 | 0.500 | 115.25 | 7241 | 3.401 | 1.60E-05 |
| | 1 | 3 | 1 | 125020 | 0.000 | 0.000 | 114.72 | 7208 | 0.000 | 0.00E+00 |
| | 1 | 4 | 1 | 125020 | 0.000 | 0.000 | 114.85 | 7216 | 0.000 | 0.00E+00 |
| | 1 | 5 | 1 | 125020 | 0.000 | 0.000 | 114.79 | 7212 | 0.000 | 0.00E+00 |
| | 1 | 6 | 1 | 125020 | 0.000 | 0.000 | 113.95 | 7160 | 0.000 | 0.00E+00 |
| | 1 | 7 | 1 | 125020 | 0.000 | 0.000 | 114.19 | 7175 | 0.000 | 0.00E+00 |
| | 1 | 8 | 1 | 125020 | 0.000 | 0.000 | 114.06 | 7167 | 0.000 | 0.00E+00 |
| | 1 | 9 | 1 | 125020 | 0.000 | 0.000 | 113.75 | 7147 | 0.000 | 0.00E+00 |
| | 1 | 10 | 1 | 125020 | 0.000 | 0.000 | 113.66 | 7141 | 0.000 | 0.00E+00 |
| 30 PSI | 2 | 0 | 0 | 125020 | 0 | 0 | 148.80 | 9350 | 3.401 | 0.00E+00 |
| | 2 | 1 | 1 | 125021.0 | 1.000 | 1.000 | 148.91 | 9357 | 3.401 | 2.47E-05 |
| | 2 | 2 | 1 | 125022.0 | 1.000 | 1.000 | 148.59 | 9336 | 3.401 | 2.48E-05 |
| | 2 | 3 | 1 | 125022 | 0.000 | 0.000 | 148.35 | 9321 | 3.401 | 0.00E+00 |
| | 2 | 4 | 1 | 125022.5 | 0.500 | 0.500 | 147.96 | 9297 | 3.401 | 1.24E-05 |
| | 2 | 5 | 1 | 125023 | 0.500 | 0.500 | 147.62 | 9275 | 3.401 | 1.25E-05 |
| | 2 | 6 | 1 | 125023.5 | 0.500 | 0.500 | 147.33 | 9257 | 3.401 | 1.25E-05 |
| | 2 | 7 | 1 | 125024 | 0.500 | 0.500 | 147.04 | 9239 | 3.401 | 1.25E-05 |
| | 2 | 8 | 1 | 125024.5 | 0.500 | 0.500 | 146.75 | 9221 | 3.401 | 1.25E-05 |
| | 2 | 9 | 1 | 125025 | 0.500 | 0.500 | 146.16 | 9183 | 3.401 | 1.26E-05 |
| | 2 | 10 | 1 | 125025.5 | 0.500 | 0.500 | 146.54 | 9208 | 3.401 | 1.26E-05 |
| | 2 | 11 | 1 | 125026 | 0.500 | 0.500 | 146.16 | 9184 | 3.401 | 1.26E-05 |
| 45 PSI | 3 | 0 | 0 | 125026 | 0 | 0 | 189.24 | 11890 | 3.401 | 0.00E+00 |
| | 3 | 1 | 1 | 125027 | 1.000 | 1.000 | 187.73 | 11795 | 3.401 | 1.96E-05 |
| | 3 | 2 | 1 | 125028 | 1.000 | 1.000 | 187.38 | 11774 | 3.401 | 1.96E-05 |
| | 3 | 3 | 1 | 125029 | 1.000 | 1.000 | 187.51 | 11782 | 3.401 | 1.96E-05 |
| | 3 | 4 | 1 | 125029.5 | 0.500 | 0.500 | 187.40 | 11775 | 3.401 | 9.82E-06 |
| | 3 | 5 | 1 | 125030 | 0.500 | 0.500 | 187.28 | 11767 | 3.401 | 9.82E-06 |
| | 3 | 6 | 1 | 125031 | 1.000 | 1.000 | 185.68 | 11667 | 3.401 | 1.98E-05 |
| | 3 | 7 | 1 | 125031.5 | 0.500 | 0.500 | 186.15 | 11696 | 3.401 | 9.88E-06 |
| | 3 | 8 | 1 | 125032.0 | 0.500 | 0.500 | 185.38 | 11648 | 3.401 | 9.92E-06 |
| | 3 | 9 | 1 | 125032.5 | 0.500 | 0.500 | 184.64 | 11601 | 3.401 | 9.96E-06 |
| | 3 | 10 | 1 | 125033 | 0.500 | 0.500 | 184.95 | 11620 | 3.401 | 9.95E-06 |
| | 3 | 11 | 1 | 125033.5 | 0.500 | 0.500 | 184.62 | 11600 | 3.401 | 9.96E-06 |

| | |
|---|---|
| ***FOR DESIGN USE:** | **1.4E-05** |

Test Method: USBR Earth Manual 2nd edition (1974) Appendix E-18

prepared by: R. Stout date: 2/17/2015
checked by: B. Price date:
edited by: GM date: 10/14/2014

GW-970 65-75

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GW-970 | Depth of borehole at test time | 100 ft |
| Test Date | 10/22/2014 | Depth to bottom of top packer | 65 ft |
| Test Time - Start & Finish | 1345 / 1355 | Depth to top of bottom packer | 75 ft |
| Weather | Clear dry, light breeze | Depth & Elevation of piezometric level | 7.33 ft after packers inflated |
| ~ Temp (F) | 54F 30.26 in Hg | Length of test section | 10 ft |
| Field geologist/engineer: | R. Stout / M. Mulcy | Radius of borehole | ~~8 in~~ 4 in (8 in diam.) |
| Drilling Co Personnel: | M&W / M. Sturdevant | Length of packer(s) | 5 ft. |
| Others present: | | Height of pressure gage above ground surface | 2 ft. |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 2 ft. |
| | | Description of material(s) tested/lithologic interval | Pumkinvalley Shale |

**PRE-TEST DATA**

Leak check completed (Y/N):

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 15 PSI Test | | | |

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| 1345 | 0 | — | 125019 | — | |
| | 1 | 0.5 | 125019 1/2 | 15 | |
| | 2 | 0.5 | 125020 | 15 | |
| | 3 | 0 | 125020 | 15 | |
| | 4 | 0 | 125020 | 15 | |
| 1350 | 5 | 0 | 125020 | 15 | |
| | 6 | 0 | 125020 | 15 | |
| | 7 | 0 | 125020 | 15 | |
| | 8 | 0 | 125020 | 15 | |
| | 9 | 0 | 125020 | 15 | |
| 1400 | 10 | 0 | 125020 | 15 | |

Comments/Notes: No flow to Very low flow after first 2 min.

PackerTestFieldForm.xls

Page 1 of 1

GU-970 65-75 30psi

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GU-970 | Depth of borehole at test time | 100 ft |
| Test Date | 10/22/2014 | Depth to bottom of top packer | 60 ft |
| Test Time - Start & Finish | 1400 | Depth to top of bottom packer | 75 ft |
| Weather | Clear, dry, light breeze | Depth & Elevation of piezometric level | 7.33 ft after packer inflation |
| ~ Temp (F) | 54°F | Length of test section | 10 ft |
| Field geologist/engineer: | R. Stout / M. Malyi | Radius of borehole | 8.4 in |
| Drilling Co Personnel: | M&W / M. Stundevant | Length of packer(s) | 5 ft |
| Others present: | | Height of pressure gage above ground surface | 2 ft |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 2 ft |
| | | Description of material(s) tested/lithologic interval | Pumkinvalley Shale |

**PRE-TEST DATA**

Leak check completed (Y/N):

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 30 PSI Test | | | |

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| 1400 | 0 | — | 125020 | — | |
| | 1 | 1.0 | 125021 | 30 | |
| | 2 | 1.0 | 125022 | 30 | |
| | 3 | 0 | 125022 | 30 | |
| | 4 | 0.5 | 125022 1/2 | 30 | |
| 1405 | 5 | 0.5 | 125023 | 30 | |
| | 6 | 0.5 | 125023 1/2 | 30 | |
| | 7 | 0.5 | 125024 | 30 | |
| | 8 | 0.5 | 125024 1/2 | 30 | |
| | 9 | 0.5 | 125025 | 30 | |
| 1410 | 10 | 0.5 | 125025 1/2 | 30 | |
| | 11 | 0.5 | 125026 | 30 | |

Comments/Notes: Very slow injection rate of 0.5 GPM @ 30 PSI injection test.

PackerTestFieldForm.xls

Page 1 of 1

GW-970 65-75 45 psi

## PACKER TESTING DATA SHEET

*All depths are below ground surface (or as designated otherwise on this sheet)*

| | | | |
|---|---|---|---|
| Borehole ID# | GW-970 | Depth of borehole at test time | 100 ft |
| Test Date | 10/22/2014 | Depth to bottom of top packer | 65 ft |
| Test Time - Start & Finish | 1413 | Depth to top of bottom packer | 75 ft |
| Weather | Clear sunny, dry | Depth & Elevation of piezometric level | 7.33 ft after packers inflated 7.20 ft @ end of test. |
| ~ Temp (F) | 54 F | Length of test section | 10 ft |
| Field geologist/engineer: | R. Stout / M. Maki | Radius of borehole | 4 in. 4 in. |
| Drilling Co Personnel: | M&W / M. Sturdevant | Length of packer(s) | 5 ft. |
| Others present: | | Height of pressure gage above ground surface | 2 ft. |
| Injection Water Source: | UCOR | Height of water swivel above ground surface | 2 ft. |
| | | Description of material(s) tested/lithologic interval | Pumkin Valley Shale |

**PRE-TEST DATA**

Leak check completed (Y/N):

| Head Loss Curve | Test Interval(s) | Flow Rate(s) | Back Pressure(s) |
|---|---|---|---|
| 45 psi Test | | | |

**TEST DATA**

Test No.

| Actual Time | Elapsed Time (Min) | Flow Rate (gpm) | Cumulative Volume Injected | Injection Pressure (psi) | DTW in borehole above packer (Ft) |
|---|---|---|---|---|---|
| 1413 | 0 | — | 125026 | — | |
| | 1 | 1.0 1.0 | 125027 | 45 | |
| | 2 | 1.0 | 125028 | 45 | |
| | 3 | 1.0 | 125029 | 45 | |
| | 4 | 0.5 | 125029 1/2 | 45 | |
| | 5 | 0.5 | 125030 | 45 | |
| | 6 | 1.0 | 125031 | 45 | |
| | 7 | 0.5 | 125031 1/2 | 45 | |
| | 8 | 0.5 | 125032 | 45 | |
| | 9 | 0.5 | 125032 1/2 | 45 | |
| | 10 | 0.5 | 125033 | 45 | |
| | 11 | 0.5 | 125033 1/2 | 45 | |

Comments/Notes:

Water rose in boring 0.13 ft during test.

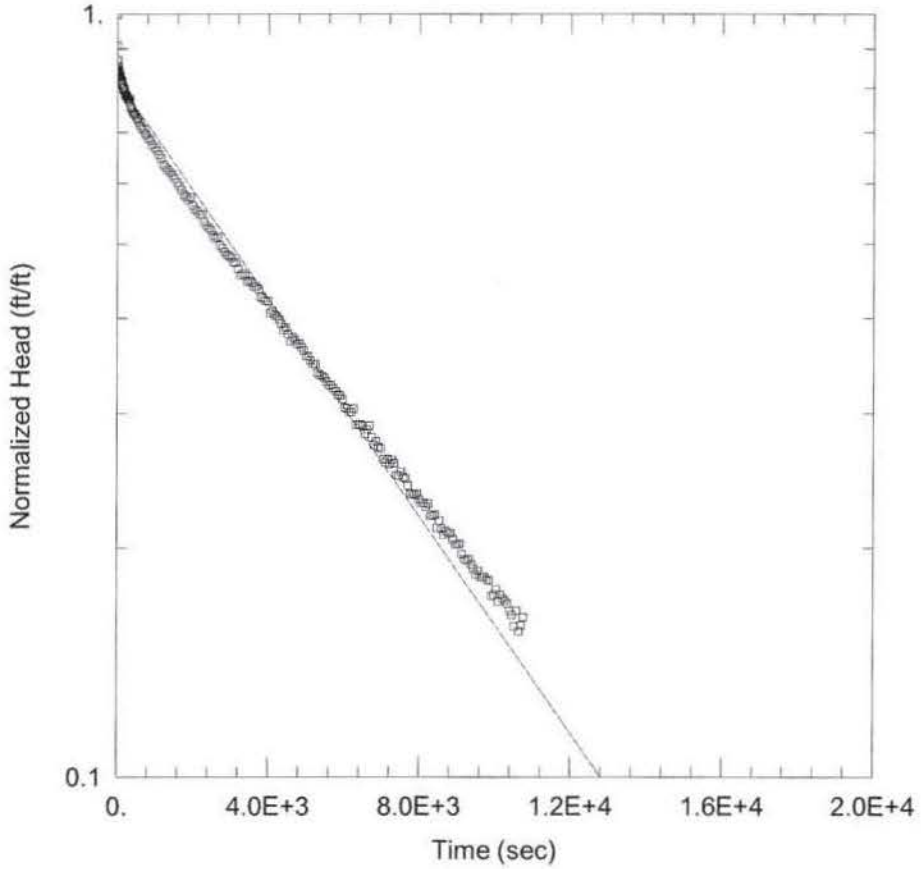
Low injection rate of 0.5 GPM during test.

PackerTestFieldForm.xls

Page ___ of ___

# EXHIBIT A.10:
# SLUG TEST DOCUMENTATIONS

This page intentionally left blank.




WELL TEST ANALYSIS

Data Set: P:\...\Falling Head GW 969.aqt
Date: 02/02/15 Time: 12:10:55

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-969
Test Date: 10/29/2014

AQUIFER DATA

Saturated Thickness: 13.18 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (969)

Initial Displacement: 2.523 ft
Total Well Penetration Depth: 13.18 ft
Casing Radius: 0.167 ft
Static Water Column Height: 13.18 ft
Screen Length: 5. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 7.65E-7 cm/sec
y0 = 2.06 ft

Data Set: P:\Project Files\2014\DOE EMDF Site Characterization\Phase I Field Data\Slug Testing Results\Slug
Date: 02/02/15
Time: 12:09:19

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/29/2014
Test Well: GW-969

AQUIFER DATA

Saturated Thickness: 13.18 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: 969

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.523 ft
Static Water Column Height: 13.18 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 5. ft
Total Well Penetration Depth: 13.18 ft

No. of Observations: 224

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 1. | 2.523 | 4098. | 1.031 |
| 3. | 2.293 | 4158. | 1.02 |
| 5. | 2.194 | 4218. | 1.014 |
| 7. | 2.124 | 4278. | 1.006 |
| 9. | 2.103 | 4338. | 0.993 |
| 11. | 2.197 | 4398. | 0.974 |
| 15. | 2.094 | 4458. | 0.981 |
| 17. | 2.155 | 4518. | 0.963 |
| 20. | 2.136 | 4578. | 0.942 |
| 23. | 2.137 | 4638. | 0.953 |
| 26. | 2.135 | 4698. | 0.947 |
| 30. | 2.131 | 4758. | 0.933 |
| 33. | 2.137 | 4818. | 0.935 |
| 37. | 2.119 | 4878. | 0.924 |
| 41. | 2.115 | 4938. | 0.916 |
| 45. | 2.112 | 4998. | 0.9 |
| 49. | 2.105 | 5058. | 0.9 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 54. | 2.101 | 5118. | 0.888 |
| 60. | 2.093 | 5178. | 0.879 |
| 64. | 2.099 | 5238. | 0.879 |
| 70. | 2.087 | 5298. | 0.856 |
| 76. | 2.091 | 5358. | 0.851 |
| 83. | 2.063 | 5418. | 0.848 |
| 89. | 2.069 | 5478. | 0.843 |
| 96. | 2.066 | 5538. | 0.834 |
| 104. | 2.064 | 5598. | 0.824 |
| 112. | 2.05 | 5658. | 0.825 |
| 120. | 2.06 | 5718. | 0.817 |
| 129. | 2.042 | 5778. | 0.81 |
| 139. | 2.032 | 5838. | 0.801 |
| 148. | 2.017 | 5898. | 0.799 |
| 159. | 2.005 | 5958. | 0.791 |
| 171. | 2.017 | 6018. | 0.771 |
| 183. | 2.007 | 6078. | 0.768 |
| 195. | 1.988 | 6138. | 0.76 |
| 208. | 1.973 | 6198. | 0.76 |
| 223. | 1.979 | 6258. | 0.768 |
| 238. | 1.969 | 6318. | 0.731 |
| 253. | 1.964 | 6378. | 0.733 |
| 270. | 1.957 | 6438. | 0.732 |
| 288. | 1.951 | 6498. | 0.73 |
| 307. | 1.937 | 6558. | 0.712 |
| 327. | 1.951 | 6618. | 0.722 |
| 348. | 1.907 | 6678. | 0.73 |
| 370. | 1.897 | 6738. | 0.705 |
| 394. | 1.885 | 6798. | 0.688 |
| 420. | 1.875 | 6858. | 0.696 |
| 446. | 1.866 | 6918. | 0.684 |
| 474. | 1.86 | 6978. | 0.681 |
| 504. | 1.845 | 7038. | 0.659 |
| 536. | 1.837 | 7098. | 0.653 |
| 570. | 1.819 | 7158. | 0.66 |
| 606. | 1.801 | 7218. | 0.65 |
| 642. | 1.788 | 7278. | 0.658 |
| 684. | 1.779 | 7338. | 0.652 |
| 726. | 1.76 | 7398. | 0.628 |
| 768. | 1.751 | 7458. | 0.628 |
| 816. | 1.733 | 7518. | 0.635 |
| 870. | 1.723 | 7578. | 0.625 |
| 918. | 1.701 | 7638. | 0.622 |
| 978. | 1.685 | 7698. | 0.609 |
| 1038. | 1.67 | 7758. | 0.594 |
| 1098. | 1.65 | 7818. | 0.594 |
| 1158. | 1.633 | 7878. | 0.592 |
| 1218. | 1.601 | 7938. | 0.594 |
| 1278. | 1.589 | 7998. | 0.584 |
| 1338. | 1.576 | 8058. | 0.578 |
| 1398. | 1.564 | 8118. | 0.578 |
| 1458. | 1.552 | 8178. | 0.572 |
| 1518. | 1.537 | 8238. | 0.577 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 1578. | 1.518 | 8298. | 0.556 |
| 1638. | 1.501 | 8358. | 0.556 |
| 1698. | 1.484 | 8418. | 0.558 |
| 1758. | 1.462 | 8478. | 0.536 |
| 1818. | 1.455 | 8538. | 0.548 |
| 1878. | 1.441 | 8598. | 0.535 |
| 1938. | 1.452 | 8658. | 0.525 |
| 1998. | 1.416 | 8718. | 0.531 |
| 2058. | 1.4 | 8778. | 0.528 |
| 2118. | 1.393 | 8838. | 0.528 |
| 2178. | 1.379 | 8898. | 0.518 |
| 2238. | 1.38 | 8958. | 0.51 |
| 2298. | 1.349 | 9018. | 0.51 |
| 2358. | 1.334 | 9078. | 0.511 |
| 2418. | 1.324 | 9138. | 0.495 |
| 2478. | 1.316 | 9198. | 0.488 |
| 2538. | 1.296 | 9258. | 0.486 |
| 2598. | 1.284 | 9318. | 0.488 |
| 2658. | 1.289 | 9378. | 0.48 |
| 2718. | 1.256 | 9438. | 0.474 |
| 2778. | 1.247 | 9498. | 0.466 |
| 2838. | 1.232 | 9558. | 0.471 |
| 2898. | 1.221 | 9618. | 0.462 |
| 2958. | 1.217 | 9678. | 0.462 |
| 3018. | 1.211 | 9738. | 0.462 |
| 3078. | 1.194 | 9798. | 0.458 |
| 3138. | 1.193 | 9858. | 0.457 |
| 3198. | 1.172 | 9918. | 0.436 |
| 3258. | 1.148 | 9978. | 0.438 |
| 3318. | 1.155 | 1.004E+4 | 0.445 |
| 3378. | 1.147 | 1.01E+4 | 0.429 |
| 3438. | 1.127 | 1.016E+4 | 0.438 |
| 3498. | 1.129 | 1.022E+4 | 0.433 |
| 3558. | 1.123 | 1.028E+4 | 0.43 |
| 3618. | 1.11 | 1.034E+4 | 0.426 |
| 3678. | 1.11 | 1.04E+4 | 0.417 |
| 3738. | 1.102 | 1.046E+4 | 0.412 |
| 3798. | 1.076 | 1.052E+4 | 0.398 |
| 3858. | 1.071 | 1.058E+4 | 0.417 |
| 3918. | 1.064 | 1.064E+4 | 0.392 |
| 3978. | 1.061 | 1.07E+4 | 0.399 |
| 4038. | 1.025 | 1.076E+4 | 0.409 |

## SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 2.306

## VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 7.662E-7 | cm/sec |
| y0 | 2.06 | ft |

T = K*b = 0.0003078 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 7.65E-7 | 6.288E-9 | +/- 1.239E-8 | 121.7 | cm/sec |
| y0 | 2.06 | 0.007372 | +/- 0.01453 | 279.5 | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.0003073 cm²/sec

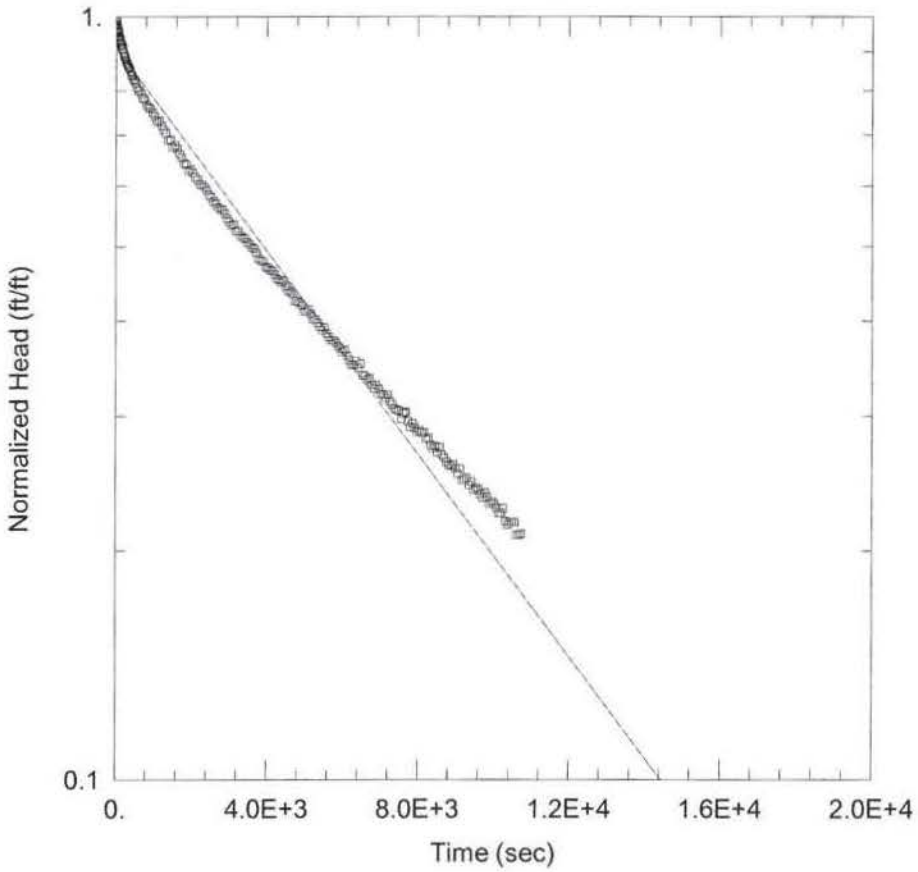
Parameter Correlations

| | K | y0 |
|---|---|---|
| K | 1.00 | 0.58 |
| y0 | 0.58 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 0.733 $ft^2$
Variance . . . . . 0.003302 $ft^2$
Std. Deviation . . . . . 0.05746 ft
Mean . . . . . 0.003858 ft
No. of Residuals . . . . . 224
No. of Estimates . . . . . 2




RISING HEAD

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 969.aqt
Date: 02/02/15 Time: 12:23:27

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-969
Test Date: 10/30/2014

AQUIFER DATA

Saturated Thickness: 12.99 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GW969)

Initial Displacement: 2.266 ft
Total Well Penetration Depth: 12.99 ft
Casing Radius: 0.167 ft
Static Water Column Height: 12.99 ft
Screen Length: 5. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
K = 7.115E-7 cm/sec
Solution Method: Bouwer-Rice
y0 = 2.062 ft

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 969.aqt
Title: Rising Head
Date: 02/02/15
Time: 12:23:42

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/30/2014
Test Well: GW-969

AQUIFER DATA

Saturated Thickness: 12.99 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GW969

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.266 ft
Static Water Column Height: 12.99 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 5. ft
Total Well Penetration Depth: 12.99 ft

No. of Observations: 216

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 5. | 2.242 | 4323. | 1.026 |
| 8. | 2.266 | 4383. | 1.018 |
| 11. | 2.246 | 4443. | 1.023 |
| 15. | 2.234 | 4503. | 1.007 |
| 18. | 2.225 | 4563. | 0.993 |
| 22. | 2.211 | 4623. | 0.988 |
| 26. | 2.206 | 4683. | 0.983 |
| 30. | 2.188 | 4743. | 0.962 |
| 34. | 2.202 | 4803. | 0.961 |
| 39. | 2.184 | 4863. | 0.957 |
| 45. | 2.166 | 4923. | 0.95 |
| 49. | 2.172 | 4983. | 0.932 |
| 56. | 2.16 | 5043. | 0.932 |
| 61. | 2.164 | 5103. | 0.938 |
| 67. | 2.161 | 5163. | 0.925 |
| 74. | 2.144 | 5223. | 0.91 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 81. | 2.141 | 5283. | 0.91 |
| 89. | 2.131 | 5343. | 0.901 |
| 97. | 2.106 | 5403. | 0.891 |
| 105. | 2.113 | 5463. | 0.882 |
| 114. | 2.106 | 5523. | 0.889 |
| 124. | 2.09 | 5583. | 0.873 |
| 133. | 2.087 | 5643. | 0.863 |
| 144. | 2.075 | 5703. | 0.855 |
| 156. | 2.075 | 5763. | 0.855 |
| 168. | 2.055 | 5823. | 0.849 |
| 180. | 2.058 | 5883. | 0.84 |
| 193. | 2.032 | 5943. | 0.835 |
| 208. | 2.014 | 6003. | 0.825 |
| 223. | 2.016 | 6063. | 0.83 |
| 238. | 2.001 | 6123. | 0.816 |
| 255. | 1.983 | 6183. | 0.806 |
| 273. | 1.981 | 6243. | 0.795 |
| 292. | 1.964 | 6303. | 0.793 |
| 312. | 1.955 | 6363. | 0.803 |
| 333. | 1.947 | 6423. | 0.786 |
| 355. | 1.94 | 6483. | 0.797 |
| 379. | 1.925 | 6543. | 0.769 |
| 405. | 1.902 | 6603. | 0.768 |
| 431. | 1.895 | 6663. | 0.759 |
| 459. | 1.876 | 6723. | 0.762 |
| 489. | 1.871 | 6783. | 0.747 |
| 521. | 1.857 | 6843. | 0.74 |
| 555. | 1.828 | 6903. | 0.747 |
| 591. | 1.813 | 6963. | 0.738 |
| 627. | 1.813 | 7023. | 0.727 |
| 669. | 1.796 | 7083. | 0.726 |
| 711. | 1.771 | 7143. | 0.719 |
| 753. | 1.768 | 7203. | 0.725 |
| 801. | 1.738 | 7263. | 0.711 |
| 855. | 1.724 | 7323. | 0.704 |
| 903. | 1.718 | 7383. | 0.696 |
| 963. | 1.696 | 7443. | 0.693 |
| 1023. | 1.677 | 7503. | 0.691 |
| 1083. | 1.65 | 7563. | 0.674 |
| 1143. | 1.656 | 7623. | 0.686 |
| 1203. | 1.632 | 7683. | 0.688 |
| 1263. | 1.611 | 7743. | 0.669 |
| 1323. | 1.596 | 7803. | 0.658 |
| 1383. | 1.56 | 7863. | 0.665 |
| 1443. | 1.565 | 7923. | 0.656 |
| 1503. | 1.528 | 7983. | 0.648 |
| 1563. | 1.536 | 8043. | 0.651 |
| 1623. | 1.522 | 8103. | 0.647 |
| 1683. | 1.498 | 8163. | 0.647 |
| 1743. | 1.481 | 8223. | 0.634 |
| 1803. | 1.456 | 8283. | 0.637 |
| 1863. | 1.453 | 8343. | 0.623 |
| 1923. | 1.424 | 8403. | 0.617 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 1983. | 1.431 | 8463. | 0.621 |
| 2043. | 1.416 | 8523. | 0.609 |
| 2103. | 1.397 | 8583. | 0.619 |
| 2163. | 1.385 | 8643. | 0.605 |
| 2223. | 1.367 | 8703. | 0.6 |
| 2283. | 1.366 | 8763. | 0.592 |
| 2343. | 1.357 | 8823. | 0.586 |
| 2403. | 1.343 | 8883. | 0.585 |
| 2463. | 1.324 | 8943. | 0.588 |
| 2523. | 1.315 | 9003. | 0.58 |
| 2583. | 1.299 | 9063. | 0.571 |
| 2643. | 1.29 | 9123. | 0.58 |
| 2703. | 1.276 | 9183. | 0.561 |
| 2763. | 1.27 | 9243. | 0.561 |
| 2823. | 1.264 | 9303. | 0.564 |
| 2883. | 1.252 | 9363. | 0.552 |
| 2943. | 1.233 | 9423. | 0.558 |
| 3003. | 1.222 | 9483. | 0.544 |
| 3063. | 1.209 | 9543. | 0.548 |
| 3123. | 1.211 | 9603. | 0.545 |
| 3183. | 1.188 | 9663. | 0.537 |
| 3243. | 1.187 | 9723. | 0.532 |
| 3303. | 1.173 | 9783. | 0.539 |
| 3363. | 1.165 | 9843. | 0.533 |
| 3423. | 1.161 | 9903. | 0.522 |
| 3483. | 1.148 | 9963. | 0.525 |
| 3543. | 1.14 | 1.002E+4 | 0.522 |
| 3603. | 1.13 | 1.008E+4 | 0.516 |
| 3663. | 1.127 | 1.014E+4 | 0.508 |
| 3723. | 1.112 | 1.02E+4 | 0.508 |
| 3783. | 1.093 | 1.026E+4 | 0.515 |
| 3843. | 1.086 | 1.032E+4 | 0.495 |
| 3903. | 1.084 | 1.038E+4 | 0.49 |
| 3963. | 1.067 | 1.044E+4 | 0.494 |
| 4023. | 1.063 | 1.05E+4 | 0.494 |
| 4083. | 1.057 | 1.056E+4 | 0.494 |
| 4143. | 1.053 | 1.062E+4 | 0.475 |
| 4203. | 1.042 | 1.068E+4 | 0.475 |
| 4263. | 1.029 | 1.074E+4 | 0.477 |

## SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 2.299

## VISUAL ESTIMATION RESULTS

### Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 4.227E-7 | cm/sec |

| | | |
|---|---|---|
| y0 | 2.062 | ft |

T = K*b = 0.0001674 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 7.115E-7 | 7.451E-9 | +/- 1.469E-8 | 95.49 | cm/sec |
| y0 | 2.062 | 0.009631 | +/- 0.01898 | 214.1 | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.0002817 cm²/sec

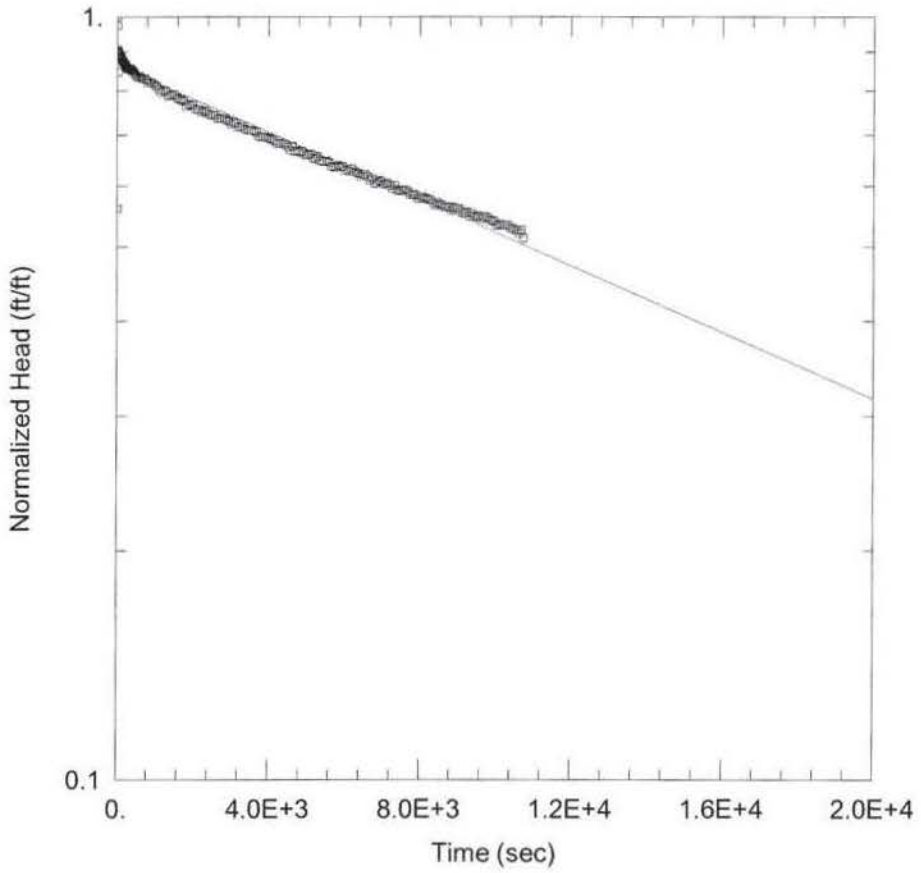
Parameter Correlations

| | K | y0 |
|---|---|---|
| K | 1.00 | 0.61 |
| y0 | 0.61 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 1.082 $ft^2$
Variance . . . . . 0.005058 $ft^2$
Std. Deviation . . . . . 0.07112 ft
Mean . . . . . 0.005475 ft
No. of Residuals . . . . . 216
No. of Estimates . . . . . 2




FALLING HEAD

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Falling Head GW 971.aqt
Date: 02/02/15 Time: 12:27:23

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-971
Test Date: 10/30/2014

AQUIFER DATA

Saturated Thickness: 10.44 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GW 971)

Initial Displacement: 2.308 ft
Total Well Penetration Depth: 10.44 ft
Casing Radius: 0.167 ft
Static Water Column Height: 10.44 ft
Screen Length: 10. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.221E-7 cm/sec
y0 = 1.992 ft

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Falling Head GW 971.aqt
Title: Falling Head
Date: 02/02/15
Time: 12:27:34

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/30/2014
Test Well: GW-971

AQUIFER DATA

Saturated Thickness: 10.44 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GW 971

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.308 ft
Static Water Column Height: 10.44 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 10. ft
Total Well Penetration Depth: 10.44 ft

No. of Observations: 220

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 7. | 2.308 | 4215. | 1.574 |
| 9. | 2.078 | 4275. | 1.573 |
| 12. | 1.295 | 4335. | 1.577 |
| 14. | 2.247 | 4395. | 1.576 |
| 17. | 2.089 | 4455. | 1.568 |
| 20. | 2.083 | 4515. | 1.557 |
| 23. | 1.954 | 4575. | 1.543 |
| 27. | 2.033 | 4635. | 1.562 |
| 30. | 2.078 | 4695. | 1.537 |
| 34. | 2.071 | 4755. | 1.542 |
| 38. | 2.072 | 4815. | 1.535 |
| 42. | 2.063 | 4875. | 1.539 |
| 46. | 2.062 | 4935. | 1.527 |
| 51. | 2.06 | 4995. | 1.519 |
| 57. | 2.044 | 5055. | 1.52 |
| 61. | 2.042 | 5115. | 1.527 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 67. | 2.045 | 5175. | 1.508 |
| 73. | 2.047 | 5235. | 1.503 |
| 79. | 2.042 | 5295. | 1.515 |
| 86. | 2.048 | 5355. | 1.494 |
| 93. | 2.042 | 5415. | 1.492 |
| 101. | 2.046 | 5475. | 1.491 |
| 109. | 2.027 | 5535. | 1.495 |
| 117. | 2.028 | 5595. | 1.488 |
| 126. | 2.024 | 5655. | 1.471 |
| 136. | 2.027 | 5715. | 1.467 |
| 145. | 2.018 | 5775. | 1.465 |
| 156. | 2.014 | 5835. | 1.475 |
| 168. | 2.01 | 5895. | 1.468 |
| 180. | 2.008 | 5955. | 1.471 |
| 192. | 2.003 | 6015. | 1.452 |
| 205. | 1.988 | 6075. | 1.458 |
| 220. | 1.996 | 6135. | 1.45 |
| 235. | 1.993 | 6195. | 1.46 |
| 250. | 1.973 | 6255. | 1.449 |
| 267. | 1.977 | 6315. | 1.443 |
| 285. | 1.973 | 6375. | 1.438 |
| 304. | 1.974 | 6435. | 1.427 |
| 324. | 1.967 | 6495. | 1.435 |
| 345. | 1.976 | 6555. | 1.435 |
| 367. | 1.971 | 6615. | 1.426 |
| 391. | 1.961 | 6675. | 1.411 |
| 417. | 1.961 | 6735. | 1.418 |
| 443. | 1.948 | 6795. | 1.395 |
| 471. | 1.943 | 6855. | 1.401 |
| 501. | 1.932 | 6915. | 1.409 |
| 533. | 1.926 | 6975. | 1.406 |
| 567. | 1.926 | 7035. | 1.393 |
| 603. | 1.929 | 7095. | 1.397 |
| 639. | 1.917 | 7155. | 1.396 |
| 681. | 1.916 | 7215. | 1.386 |
| 723. | 1.915 | 7275. | 1.375 |
| 765. | 1.909 | 7335. | 1.389 |
| 813. | 1.893 | 7395. | 1.369 |
| 867. | 1.894 | 7455. | 1.365 |
| 915. | 1.891 | 7515. | 1.368 |
| 975. | 1.881 | 7575. | 1.37 |
| 1035. | 1.872 | 7635. | 1.368 |
| 1095. | 1.855 | 7695. | 1.36 |
| 1155. | 1.838 | 7755. | 1.349 |
| 1215. | 1.849 | 7815. | 1.351 |
| 1275. | 1.843 | 7875. | 1.348 |
| 1335. | 1.819 | 7935. | 1.336 |
| 1395. | 1.822 | 7995. | 1.334 |
| 1455. | 1.827 | 8055. | 1.342 |
| 1515. | 1.822 | 8115. | 1.333 |
| 1575. | 1.808 | 8175. | 1.337 |
| 1635. | 1.802 | 8235. | 1.33 |
| 1695. | 1.796 | 8295. | 1.329 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 1755. | 1.79 | 8355. | 1.316 |
| 1815. | 1.762 | 8415. | 1.307 |
| 1875. | 1.774 | 8475. | 1.318 |
| 1935. | 1.766 | 8535. | 1.312 |
| 1995. | 1.77 | 8595. | 1.307 |
| 2055. | 1.748 | 8655. | 1.3 |
| 2115. | 1.746 | 8715. | 1.3 |
| 2175. | 1.744 | 8775. | 1.302 |
| 2235. | 1.731 | 8835. | 1.287 |
| 2295. | 1.74 | 8895. | 1.299 |
| 2355. | 1.733 | 8955. | 1.296 |
| 2415. | 1.72 | 9015. | 1.296 |
| 2475. | 1.718 | 9075. | 1.29 |
| 2535. | 1.715 | 9135. | 1.282 |
| 2595. | 1.714 | 9195. | 1.277 |
| 2655. | 1.697 | 9255. | 1.282 |
| 2715. | 1.7 | 9315. | 1.267 |
| 2775. | 1.697 | 9375. | 1.276 |
| 2835. | 1.699 | 9435. | 1.266 |
| 2895. | 1.69 | 9495. | 1.261 |
| 2955. | 1.684 | 9555. | 1.268 |
| 3015. | 1.668 | 9615. | 1.255 |
| 3075. | 1.678 | 9675. | 1.264 |
| 3135. | 1.675 | 9735. | 1.264 |
| 3195. | 1.654 | 9795. | 1.259 |
| 3255. | 1.659 | 9855. | 1.251 |
| 3315. | 1.658 | 9915. | 1.249 |
| 3375. | 1.646 | 9975. | 1.245 |
| 3435. | 1.64 | 1.004E+4 | 1.233 |
| 3495. | 1.639 | 1.01E+4 | 1.23 |
| 3555. | 1.639 | 1.016E+4 | 1.236 |
| 3615. | 1.635 | 1.022E+4 | 1.231 |
| 3675. | 1.63 | 1.028E+4 | 1.23 |
| 3735. | 1.61 | 1.034E+4 | 1.232 |
| 3795. | 1.606 | 1.04E+4 | 1.222 |
| 3855. | 1.607 | 1.046E+4 | 1.221 |
| 3915. | 1.607 | 1.052E+4 | 1.215 |
| 3975. | 1.602 | 1.058E+4 | 1.213 |
| 4035. | 1.598 | 1.064E+4 | 1.203 |
| 4095. | 1.594 | 1.07E+4 | 1.214 |
| 4155. | 1.586 | 1.076E+4 | 1.185 |

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 2.404

VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 1.87E-7 | cm/sec |
| y0 | 1.992 | ft |

T = K*b = 5.949E-5 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 1.221E-7 | 2.004E-9 | +/- 3.95E-9 | 60.95 | cm/sec |
| y0 | 1.992 | 0.007543 | +/- 0.01487 | 264.1 | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 3.887E-5 cm²/sec

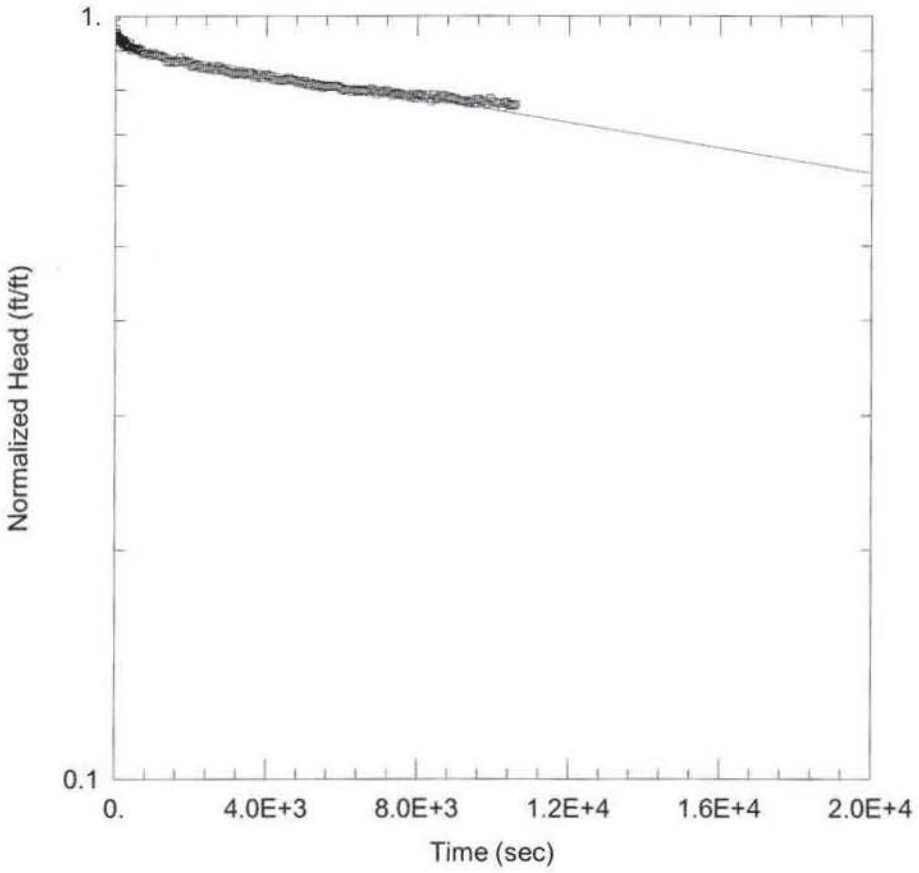
Parameter Correlations

| | K | y0 |
|---|---|---|
| K | 1.00 | 0.72 |
| y0 | 0.72 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 0.8968 $ft^2$
Variance . . . . . 0.004114 $ft^2$
Std. Deviation . . . . . 0.06414 ft
Mean . . . . . 0.0003135 ft
No. of Residuals . . . . . 220
No. of Estimates . . . . . 2




RISING HEAD

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 971.aqt
Date: 02/02/15 Time: 12:33:34

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-971
Test Date: 10/30/2014

AQUIFER DATA

Saturated Thickness: 11.67 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GW 971)

Initial Displacement: 1.926 ft
Total Well Penetration Depth: 11.67 ft
Casing Radius: 0.167 ft
Static Water Column Height: 11.67 ft
Screen Length: 10. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 4.78E-8 cm/sec
y0 = 1.757 ft

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 971.aqt
Title: Rising Head
Date: 02/02/15
Time: 12:33:45

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/30/2014
Test Well: GW-971

AQUIFER DATA

Saturated Thickness: 11.67 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GW 971

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 1.926 ft
Static Water Column Height: 11.67 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 10. ft
Total Well Penetration Depth: 11.67 ft

No. of Observations: 204

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 6. | 1.926 | 4524. | 1.588 |
| 10. | 1.853 | 4584. | 1.599 |
| 16. | 1.832 | 4644. | 1.592 |
| 22. | 1.819 | 4704. | 1.59 |
| 28. | 1.826 | 4764. | 1.582 |
| 35. | 1.817 | 4824. | 1.574 |
| 42. | 1.816 | 4884. | 1.583 |
| 50. | 1.811 | 4944. | 1.571 |
| 58. | 1.8 | 5004. | 1.582 |
| 66. | 1.803 | 5064. | 1.567 |
| 75. | 1.806 | 5124. | 1.566 |
| 85. | 1.797 | 5184. | 1.574 |
| 94. | 1.789 | 5244. | 1.559 |
| 105. | 1.802 | 5304. | 1.567 |
| 117. | 1.776 | 5364. | 1.559 |
| 129. | 1.788 | 5424. | 1.564 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 141. | 1.788 | 5484. | 1.552 |
| 154. | 1.783 | 5544. | 1.559 |
| 169. | 1.781 | 5604. | 1.556 |
| 184. | 1.792 | 5664. | 1.556 |
| 199. | 1.78 | 5724. | 1.561 |
| 216. | 1.789 | 5784. | 1.558 |
| 234. | 1.757 | 5844. | 1.555 |
| 253. | 1.772 | 5904. | 1.559 |
| 273. | 1.766 | 5964. | 1.548 |
| 294. | 1.762 | 6024. | 1.539 |
| 316. | 1.761 | 6084. | 1.544 |
| 340. | 1.754 | 6144. | 1.542 |
| 366. | 1.776 | 6204. | 1.544 |
| 392. | 1.754 | 6264. | 1.533 |
| 420. | 1.739 | 6324. | 1.544 |
| 450. | 1.739 | 6384. | 1.538 |
| 482. | 1.74 | 6444. | 1.533 |
| 516. | 1.749 | 6504. | 1.542 |
| 552. | 1.742 | 6564. | 1.537 |
| 588. | 1.748 | 6624. | 1.539 |
| 630. | 1.732 | 6684. | 1.532 |
| 672. | 1.738 | 6744. | 1.546 |
| 711. | 1.722 | 6804. | 1.543 |
| 762. | 1.72 | 6864. | 1.535 |
| 816. | 1.721 | 6924. | 1.524 |
| 864. | 1.723 | 6984. | 1.536 |
| 924. | 1.712 | 7044. | 1.533 |
| 984. | 1.722 | 7104. | 1.526 |
| 1044. | 1.714 | 7164. | 1.537 |
| 1104. | 1.712 | 7224. | 1.534 |
| 1164. | 1.71 | 7284. | 1.525 |
| 1224. | 1.704 | 7344. | 1.515 |
| 1284. | 1.698 | 7404. | 1.522 |
| 1344. | 1.683 | 7464. | 1.527 |
| 1404. | 1.677 | 7524. | 1.524 |
| 1464. | 1.682 | 7584. | 1.519 |
| 1524. | 1.675 | 7644. | 1.512 |
| 1584. | 1.677 | 7704. | 1.512 |
| 1644. | 1.678 | 7764. | 1.52 |
| 1704. | 1.7 | 7824. | 1.507 |
| 1764. | 1.679 | 7884. | 1.518 |
| 1824. | 1.684 | 7944. | 1.504 |
| 1884. | 1.67 | 8004. | 1.521 |
| 1944. | 1.68 | 8064. | 1.517 |
| 2004. | 1.655 | 8124. | 1.514 |
| 2064. | 1.658 | 8184. | 1.504 |
| 2124. | 1.662 | 8244. | 1.517 |
| 2184. | 1.661 | 8304. | 1.502 |
| 2244. | 1.649 | 8364. | 1.489 |
| 2304. | 1.646 | 8424. | 1.516 |
| 2364. | 1.647 | 8484. | 1.498 |
| 2424. | 1.648 | 8544. | 1.504 |
| 2484. | 1.641 | 8604. | 1.516 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 2544. | 1.652 | 8664. | 1.514 |
| 2604. | 1.638 | 8724. | 1.512 |
| 2664. | 1.64 | 8784. | 1.497 |
| 2724. | 1.654 | 8844. | 1.507 |
| 2784. | 1.636 | 8904. | 1.505 |
| 2844. | 1.642 | 8964. | 1.501 |
| 2904. | 1.635 | 9024. | 1.499 |
| 2964. | 1.628 | 9084. | 1.491 |
| 3024. | 1.624 | 9144. | 1.492 |
| 3084. | 1.623 | 9204. | 1.488 |
| 3144. | 1.616 | 9264. | 1.492 |
| 3204. | 1.62 | 9324. | 1.481 |
| 3264. | 1.627 | 9384. | 1.486 |
| 3324. | 1.619 | 9444. | 1.494 |
| 3384. | 1.616 | 9504. | 1.478 |
| 3444. | 1.615 | 9564. | 1.496 |
| 3504. | 1.622 | 9624. | 1.498 |
| 3564. | 1.625 | 9684. | 1.487 |
| 3624. | 1.614 | 9744. | 1.489 |
| 3684. | 1.6 | 9804. | 1.475 |
| 3744. | 1.609 | 9864. | 1.476 |
| 3804. | 1.609 | 9924. | 1.501 |
| 3864. | 1.599 | 9984. | 1.487 |
| 3924. | 1.599 | 1.004E+4 | 1.487 |
| 3984. | 1.613 | 1.01E+4 | 1.479 |
| 4044. | 1.609 | 1.016E+4 | 1.479 |
| 4104. | 1.606 | 1.022E+4 | 1.462 |
| 4164. | 1.591 | 1.028E+4 | 1.482 |
| 4224. | 1.59 | 1.034E+4 | 1.486 |
| 4284. | 1.586 | 1.04E+4 | 1.476 |
| 4344. | 1.588 | 1.046E+4 | 1.47 |
| 4404. | 1.585 | 1.052E+4 | 1.469 |
| 4464. | 1.589 | 1.058E+4 | 1.475 |

## SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 2.472

## VISUAL ESTIMATION RESULTS

### Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 7.553E-8 | cm/sec |
| y0 | 1.757 | ft |

$T = K*b = 2.687E\text{-}5\ cm^2/sec$

## AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 4.78E-8 | 9.683E-10 | +/- 1.909E-9 | 49.36 | cm/sec |
| y0 | 1.757 | 0.00363 | +/- 0.007158 | 484. | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 1.7E-5 $cm^2/sec$

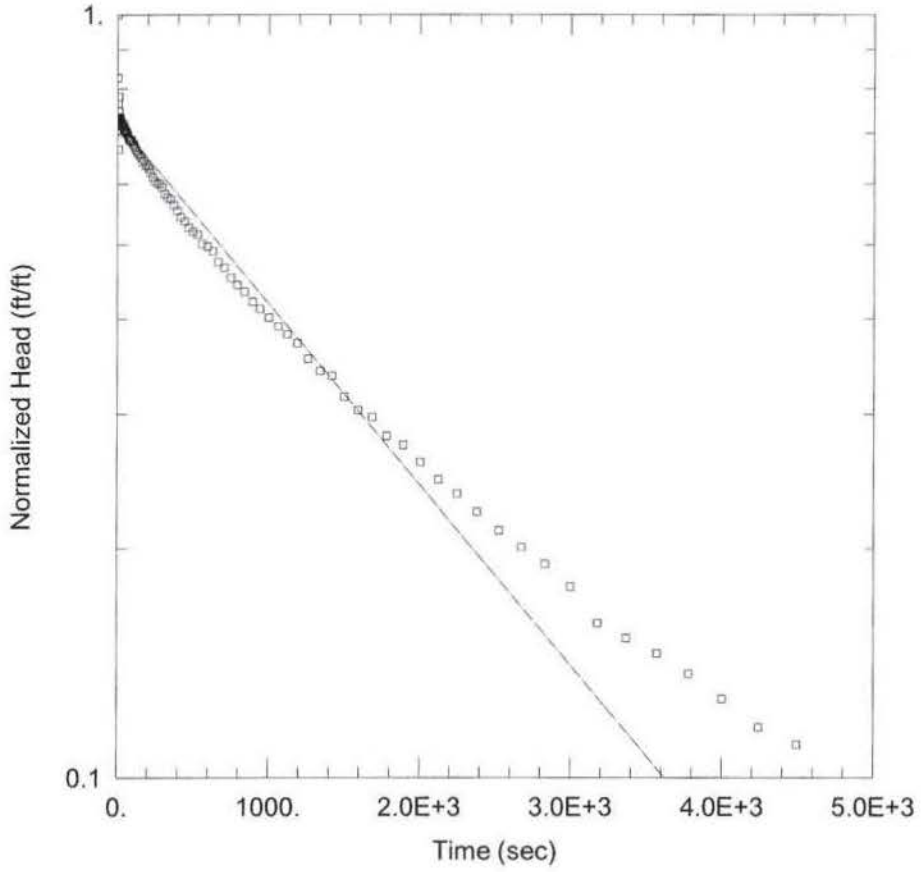
Parameter Correlations

| | K | y0 |
|---|---|---|
| K | 1.00 | 0.79 |
| y0 | 0.79 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 0.1742 $ft^2$
Variance . . . . . 0.0008623 $ft^2$
Std. Deviation . . . . . 0.02937 ft
Mean . . . . . 3.981E-5 ft
No. of Residuals . . . . . 204
No. of Estimates . . . . . 2




FALLING HEAD

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Falling Head GW 973.aqt
Date: 02/02/15 Time: 12:44:13

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-973
Test Date: 10/28/2014

AQUIFER DATA

Saturated Thickness: 15.35 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GW 973)

Initial Displacement: 2.885 ft
Total Well Penetration Depth: 15.35 ft
Casing Radius: 0.167 ft
Static Water Column Height: 15.35 ft
Screen Length: 10. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.458E-6 cm/sec
y0 = 2.088 ft

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Falling Head GW 973.aqt
Title: Falling Head
Date: 02/02/15
Time: 12:44:24

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/28/2014
Test Well: GW-973

AQUIFER DATA

Saturated Thickness: 15.35 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GW 973

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.885 ft
Static Water Column Height: 15.35 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 10. ft
Total Well Penetration Depth: 15.35 ft

No. of Observations: 108

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 2. | 2.885 | 208. | 1.813 |
| 3. | 2.386 | 220. | 1.794 |
| 4. | 2.205 | 234. | 1.768 |
| 5. | 2.111 | 248. | 1.746 |
| 6. | 2.024 | 263. | 1.737 |
| 7. | 2.035 | 279. | 1.731 |
| 8. | 1.924 | 295. | 1.715 |
| 9. | 2.253 | 313. | 1.681 |
| 10. | 2.159 | 332. | 1.663 |
| 11. | 2.081 | 352. | 1.654 |
| 12. | 2.105 | 373. | 1.626 |
| 13. | 2.12 | 396. | 1.599 |
| 14. | 2.116 | 420. | 1.569 |
| 15. | 2.104 | 445. | 1.549 |
| 16. | 2.112 | 471. | 1.52 |
| 17. | 2.112 | 499. | 1.501 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 19. | 2.098 | 529. | 1.489 |
| 20. | 2.095 | 561. | 1.447 |
| 22. | 2.093 | 595. | 1.436 |
| 23. | 2.085 | 631. | 1.415 |
| 25. | 2.087 | 667. | 1.37 |
| 27. | 2.083 | 709. | 1.346 |
| 28. | 2.079 | 751. | 1.306 |
| 30. | 2.065 | 793. | 1.278 |
| 32. | 2.071 | 841. | 1.252 |
| 35. | 2.069 | 895. | 1.216 |
| 37. | 2.059 | 943. | 1.19 |
| 40. | 2.049 | 1003. | 1.159 |
| 42. | 2.046 | 1063. | 1.129 |
| 45. | 2.07 | 1123. | 1.102 |
| 48. | 2.044 | 1189. | 1.072 |
| 51. | 2.036 | 1261. | 1.023 |
| 55. | 2.033 | 1339. | 0.986 |
| 58. | 2.028 | 1417. | 0.972 |
| 62. | 2.016 | 1501. | 0.913 |
| 66. | 2.015 | 1591. | 0.876 |
| 70. | 1.999 | 1687. | 0.858 |
| 75. | 1.979 | 1783. | 0.811 |
| 79. | 1.984 | 1891. | 0.789 |
| 85. | 1.978 | 2005. | 0.749 |
| 89. | 1.969 | 2125. | 0.711 |
| 96. | 1.976 | 2251. | 0.681 |
| 102. | 1.954 | 2383. | 0.645 |
| 108. | 1.952 | 2527. | 0.61 |
| 114. | 1.937 | 2677. | 0.58 |
| 121. | 1.924 | 2833. | 0.551 |
| 129. | 1.912 | 3001. | 0.514 |
| 137. | 1.898 | 3181. | 0.46 |
| 145. | 1.892 | 3367. | 0.44 |
| 154. | 1.878 | 3572. | 0.42 |
| 164. | 1.851 | 3781. | 0.395 |
| 174. | 1.86 | 4003. | 0.366 |
| 184. | 1.839 | 4243. | 0.336 |
| 196. | 1.828 | 4495. | 0.319 |

## SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 2.636

## VISUAL ESTIMATION RESULTS

### Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 2.417E-6 | cm/sec |
| y0 | 2.088 | ft |

T = K*b = 0.001131 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 1.458E-6 | 4.158E-8 | +/- 8.244E-8 | 35.07 | cm/sec |
| y0 | 2.088 | 0.0144 | +/- 0.02855 | 145. | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.0006821 cm²/sec

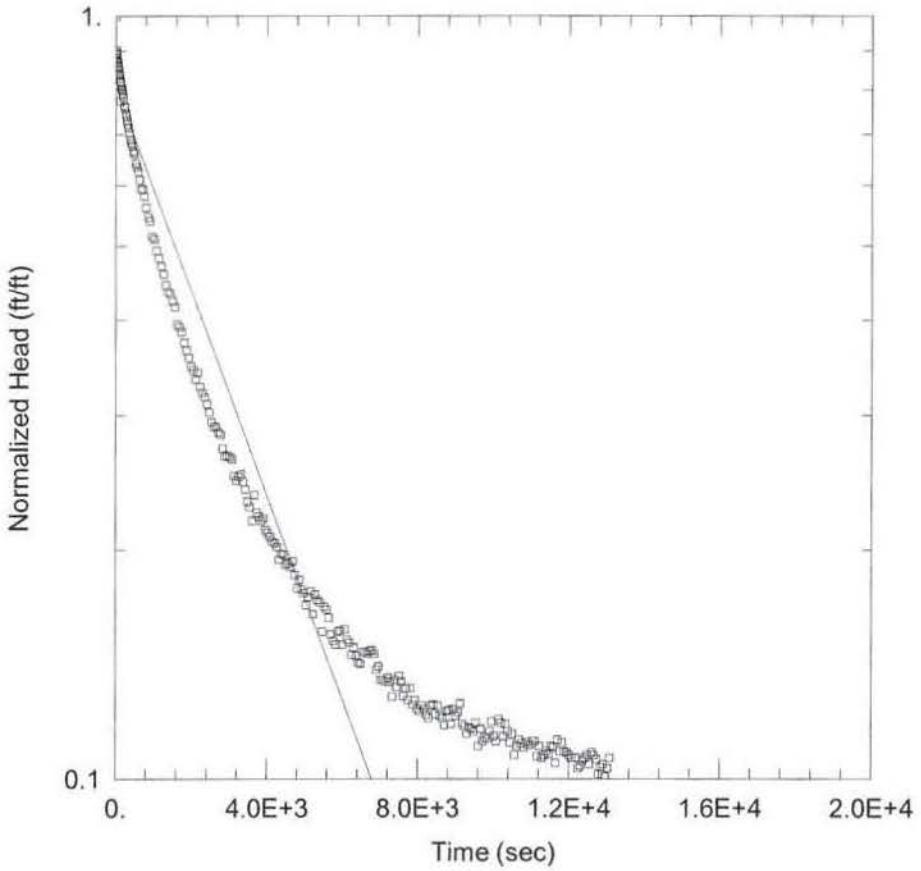
Parameter Correlations

| | K | y0 |
|---|---|---|
| K | 1.00 | 0.49 |
| y0 | 0.49 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 1.172 $ft^2$
Variance . . . . . 0.01106 $ft^2$
Std. Deviation . . . . . 0.1052 ft
Mean . . . . . 0.006793 ft
No. of Residuals . . . . . 108
No. of Estimates . . . . . 2




RISING HEAD

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 973.aqt
Date: 02/02/15 Time: 12:48:18

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-973
Test Date: 10/28/2014

AQUIFER DATA

Saturated Thickness: 15.55 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GW 973)

Initial Displacement: 2.364 ft
Total Well Penetration Depth: 15.55 ft
Casing Radius: 0.167 ft
Static Water Column Height: 15.55 ft
Screen Length: 10. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
K = 8.238E-7 cm/sec
Solution Method: Bouwer-Rice
y0 = 1.911 ft

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 973.aqt
Title: Rising Head
Date: 02/02/15
Time: 12:48:31

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/28/2014
Test Well: GW-973

AQUIFER DATA

Saturated Thickness: 15.55 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GW 973

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.364 ft
Static Water Column Height: 15.55 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 10. ft
Total Well Penetration Depth: 15.55 ft

No. of Observations: 257

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 5. | 2.364 | 5468. | 0.369 |
| 7. | 2.114 | 5528. | 0.398 |
| 10. | 2.129 | 5588. | 0.395 |
| 13. | 2.116 | 5648. | 0.385 |
| 16. | 2.132 | 5708. | 0.366 |
| 20. | 2.106 | 5768. | 0.359 |
| 23. | 2.104 | 5828. | 0.355 |
| 27. | 2.106 | 5888. | 0.369 |
| 31. | 2.089 | 5948. | 0.37 |
| 35. | 2.082 | 6008. | 0.355 |
| 39. | 2.072 | 6068. | 0.372 |
| 44. | 2.063 | 6128. | 0.36 |
| 50. | 2.057 | 6188. | 0.357 |
| 54. | 2.053 | 6248. | 0.344 |
| 60. | 2.038 | 6308. | 0.352 |
| 67. | 2.036 | 6368. | 0.343 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 73. | 2.028 | 6428. | 0.336 |
| 79. | 2.011 | 6488. | 0.335 |
| 86. | 1.993 | 6548. | 0.347 |
| 94. | 1.983 | 6608. | 0.347 |
| 102. | 1.975 | 6668. | 0.345 |
| 110. | 1.959 | 6728. | 0.348 |
| 113. | 1.829 | 6788. | 0.349 |
| 119. | 1.942 | 6848. | 0.345 |
| 129. | 1.938 | 6908. | 0.329 |
| 138. | 1.917 | 6968. | 0.332 |
| 149. | 1.893 | 7028. | 0.319 |
| 161. | 1.9 | 7088. | 0.319 |
| 173. | 1.885 | 7148. | 0.317 |
| 185. | 1.869 | 7208. | 0.321 |
| 199. | 1.851 | 7268. | 0.317 |
| 228. | 1.801 | 7328. | 0.303 |
| 244. | 1.794 | 7388. | 0.319 |
| 260. | 1.764 | 7448. | 0.312 |
| 278. | 1.748 | 7508. | 0.323 |
| 297. | 1.723 | 7568. | 0.317 |
| 317. | 1.707 | 7628. | 0.304 |
| 338. | 1.689 | 7688. | 0.311 |
| 360. | 1.661 | 7748. | 0.3 |
| 384. | 1.628 | 7808. | 0.311 |
| 410. | 1.613 | 7868. | 0.296 |
| 436. | 1.599 | 7928. | 0.3 |
| 464. | 1.572 | 7988. | 0.292 |
| 494. | 1.561 | 8048. | 0.29 |
| 526. | 1.517 | 8108. | 0.295 |
| 560. | 1.5 | 8168. | 0.292 |
| 596. | 1.478 | 8228. | 0.287 |
| 632. | 1.442 | 8288. | 0.284 |
| 674. | 1.404 | 8348. | 0.295 |
| 716. | 1.401 | 8408. | 0.296 |
| 758. | 1.372 | 8468. | 0.287 |
| 806. | 1.327 | 8528. | 0.295 |
| 860. | 1.29 | 8588. | 0.286 |
| 908. | 1.276 | 8648. | 0.284 |
| 968. | 1.215 | 8708. | 0.278 |
| 1028. | 1.207 | 8768. | 0.29 |
| 1088. | 1.166 | 8828. | 0.291 |
| 1148. | 1.14 | 8888. | 0.279 |
| 1208. | 1.112 | 8948. | 0.292 |
| 1268. | 1.086 | 9008. | 0.286 |
| 1328. | 1.051 | 9068. | 0.289 |
| 1388. | 1.029 | 9128. | 0.297 |
| 1448. | 1.024 | 9188. | 0.279 |
| 1508. | 1.001 | 9248. | 0.277 |
| 1568. | 0.984 | 9308. | 0.271 |
| 1628. | 0.934 | 9368. | 0.276 |
| 1688. | 0.926 | 9428. | 0.275 |
| 1748. | 0.913 | 9488. | 0.273 |
| 1808. | 0.884 | 9548. | 0.28 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 1868. | 0.863 | 9608. | 0.261 |
| 1928. | 0.845 | 9668. | 0.275 |
| 1988. | 0.823 | 9728. | 0.265 |
| 2048. | 0.814 | 9788. | 0.268 |
| 2108. | 0.791 | 9848. | 0.267 |
| 2168. | 0.807 | 9908. | 0.273 |
| 2228. | 0.773 | 9968. | 0.281 |
| 2288. | 0.76 | 1.003E+4 | 0.269 |
| 2348. | 0.75 | 1.009E+4 | 0.265 |
| 2408. | 0.734 | 1.015E+4 | 0.283 |
| 2468. | 0.716 | 1.021E+4 | 0.28 |
| 2528. | 0.695 | 1.027E+4 | 0.269 |
| 2588. | 0.685 | 1.033E+4 | 0.279 |
| 2648. | 0.686 | 1.039E+4 | 0.273 |
| 2708. | 0.674 | 1.045E+4 | 0.264 |
| 2768. | 0.67 | 1.051E+4 | 0.271 |
| 2828. | 0.642 | 1.057E+4 | 0.254 |
| 2888. | 0.627 | 1.063E+4 | 0.261 |
| 2948. | 0.629 | 1.069E+4 | 0.266 |
| 3008. | 0.626 | 1.075E+4 | 0.263 |
| 3068. | 0.622 | 1.081E+4 | 0.26 |
| 3128. | 0.591 | 1.087E+4 | 0.264 |
| 3188. | 0.583 | 1.093E+4 | 0.262 |
| 3248. | 0.59 | 1.099E+4 | 0.262 |
| 3308. | 0.594 | 1.105E+4 | 0.265 |
| 3368. | 0.581 | 1.111E+4 | 0.265 |
| 3428. | 0.568 | 1.117E+4 | 0.253 |
| 3488. | 0.547 | 1.123E+4 | 0.261 |
| 3548. | 0.538 | 1.129E+4 | 0.252 |
| 3608. | 0.516 | 1.135E+4 | 0.254 |
| 3668. | 0.558 | 1.141E+4 | 0.257 |
| 3728. | 0.529 | 1.147E+4 | 0.255 |
| 3788. | 0.523 | 1.153E+4 | 0.261 |
| 3848. | 0.516 | 1.159E+4 | 0.26 |
| 3908. | 0.52 | 1.165E+4 | 0.248 |
| 3968. | 0.502 | 1.171E+4 | 0.266 |
| 4028. | 0.498 | 1.177E+4 | 0.257 |
| 4088. | 0.492 | 1.183E+4 | 0.264 |
| 4148. | 0.485 | 1.189E+4 | 0.257 |
| 4208. | 0.483 | 1.195E+4 | 0.256 |
| 4268. | 0.477 | 1.201E+4 | 0.254 |
| 4328. | 0.459 | 1.207E+4 | 0.252 |
| 4388. | 0.467 | 1.213E+4 | 0.236 |
| 4448. | 0.466 | 1.219E+4 | 0.252 |
| 4508. | 0.452 | 1.225E+4 | 0.244 |
| 4568. | 0.454 | 1.231E+4 | 0.246 |
| 4628. | 0.449 | 1.237E+4 | 0.25 |
| 4688. | 0.457 | 1.243E+4 | 0.252 |
| 4748. | 0.438 | 1.249E+4 | 0.254 |
| 4808. | 0.421 | 1.255E+4 | 0.247 |
| 4868. | 0.432 | 1.261E+4 | 0.256 |
| 4928. | 0.419 | 1.267E+4 | 0.254 |
| 4988. | 0.415 | 1.273E+4 | 0.251 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 5048. | 0.4 | 1.279E+4 | 0.24 |
| 5108. | 0.41 | 1.285E+4 | 0.245 |
| 5168. | 0.417 | 1.291E+4 | 0.247 |
| 5228. | 0.389 | 1.297E+4 | 0.238 |
| 5288. | 0.413 | 1.303E+4 | 0.244 |
| 5348. | 0.406 | 1.309E+4 | 0.252 |
| 5408. | 0.403 | | |

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 2.643

VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 1.366E-6 | cm/sec |
| y0 | 1.91 | ft |

T = K*b = 0.0006474 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 8.238E-7 | 2.127E-8 | +/- 4.187E-8 | 38.74 | cm/sec |
| y0 | 1.911 | 0.02292 | +/- 0.04512 | 83.38 | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.0003905 cm²/sec

Parameter Correlations

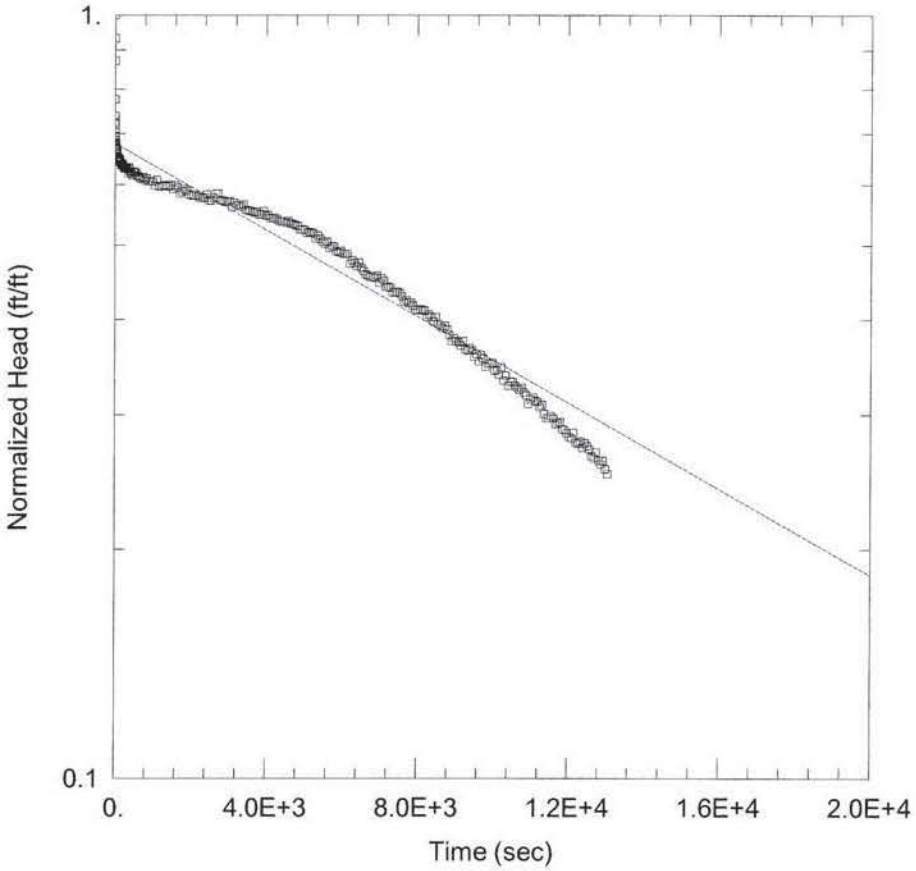
| | K | y0 |
|---|---|---|
| K | 1.00 | 0.52 |
| y0 | 0.52 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 5.991 $ft^2$
Variance . . . . . 0.02349 $ft^2$
Std. Deviation . . . . . 0.1533 ft
Mean . . . . . 0.05567 ft

No. of Residuals . . . . . 257
No. of Estimates . . . . . 2




RISING HEAD

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 975.aqt
Date: 02/02/15 Time: 13:20:31

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Well: GW-975
Test Date: 10/29/2014

AQUIFER DATA

Saturated Thickness: 3.97 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GW 975)

Initial Displacement: 2.131 ft
Total Well Penetration Depth: 3.971 ft
Casing Radius: 0.167 ft
Static Water Column Height: 3.97 ft
Screen Length: 3. ft
Well Radius: 0.417 ft

SOLUTION

Aquifer Model: Unconfined
K = 3.431E-7 cm/sec
Solution Method: Bouwer-Rice
y0 = 1.448 ft

Data Set: C:\Users\belindaprice\Documents\Files\DOE SLUG TESTS\Rising Head GW 975.aqt
Title: Rising Head
Date: 02/02/15
Time: 13:20:48

PROJECT INFORMATION

Company: Alliant
Client: DOE
Project: 4301-007
Location: EMDF
Test Date: 10/29/2014
Test Well: GW-975

AQUIFER DATA

Saturated Thickness: 3.97 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GW 975

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.131 ft
Static Water Column Height: 3.97 ft
Casing Radius: 0.167 ft
Well Radius: 0.417 ft
Well Skin Radius: 0.417 ft
Screen Length: 3. ft
Total Well Penetration Depth: 3.971 ft

No. of Observations: 275

Observation Data

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 1. | 2.131 | 4895. | 1.118 |
| 2. | 1.986 | 4955. | 1.118 |
| 3. | 1.857 | 5015. | 1.116 |
| 4. | 1.653 | 5075. | 1.106 |
| 6. | 1.572 | 5135. | 1.109 |
| 7. | 1.544 | 5195. | 1.107 |
| 8. | 1.535 | 5255. | 1.105 |
| 9. | 1.495 | 5315. | 1.088 |
| 10. | 1.481 | 5375. | 1.097 |
| 12. | 1.48 | 5435. | 1.086 |
| 13. | 1.474 | 5495. | 1.078 |
| 15. | 1.464 | 5555. | 1.071 |
| 17. | 1.461 | 5615. | 1.077 |
| 18. | 1.451 | 5675. | 1.057 |
| 20. | 1.454 | 5735. | 1.063 |
| 22. | 1.444 | 5795. | 1.061 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 24. | 1.439 | 5855. | 1.047 |
| 27. | 1.446 | 5915. | 1.043 |
| 29. | 1.445 | 5975. | 1.048 |
| 32. | 1.438 | 6035. | 1.04 |
| 34. | 1.427 | 6095. | 1.038 |
| 37. | 1.433 | 6155. | 1.038 |
| 40. | 1.412 | 6215. | 1.008 |
| 43. | 1.419 | 6275. | 1.019 |
| 47. | 1.407 | 6335. | 1.011 |
| 50. | 1.424 | 6395. | 1.001 |
| 54. | 1.413 | 6455. | 1.012 |
| 58. | 1.422 | 6515. | 0.996 |
| 62. | 1.403 | 6575. | 0.986 |
| 66. | 1.405 | 6635. | 0.976 |
| 71. | 1.385 | 6695. | 0.973 |
| 77. | 1.388 | 6755. | 0.969 |
| 81. | 1.385 | 6815. | 0.968 |
| 87. | 1.382 | 6875. | 0.966 |
| 93. | 1.387 | 6935. | 0.973 |
| 99. | 1.386 | 6995. | 0.952 |
| 106. | 1.371 | 7055. | 0.965 |
| 113. | 1.367 | 7115. | 0.958 |
| 121. | 1.371 | 7175. | 0.94 |
| 129. | 1.379 | 7235. | 0.94 |
| 137. | 1.37 | 7295. | 0.938 |
| 146. | 1.367 | 7355. | 0.924 |
| 156. | 1.354 | 7415. | 0.927 |
| 165. | 1.358 | 7475. | 0.927 |
| 176. | 1.361 | 7535. | 0.923 |
| 188. | 1.354 | 7595. | 0.914 |
| 200. | 1.354 | 7655. | 0.899 |
| 212. | 1.363 | 7715. | 0.903 |
| 225. | 1.343 | 7775. | 0.896 |
| 240. | 1.348 | 7835. | 0.897 |
| 255. | 1.344 | 7895. | 0.889 |
| 270. | 1.342 | 7955. | 0.877 |
| 287. | 1.344 | 8015. | 0.876 |
| 305. | 1.348 | 8075. | 0.879 |
| 324. | 1.34 | 8135. | 0.877 |
| 344. | 1.323 | 8195. | 0.875 |
| 365. | 1.345 | 8255. | 0.859 |
| 387. | 1.329 | 8315. | 0.865 |
| 411. | 1.331 | 8375. | 0.859 |
| 437. | 1.32 | 8435. | 0.847 |
| 463. | 1.315 | 8495. | 0.858 |
| 491. | 1.329 | 8555. | 0.841 |
| 521. | 1.326 | 8615. | 0.835 |
| 553. | 1.326 | 8675. | 0.83 |
| 587. | 1.314 | 8735. | 0.836 |
| 623. | 1.31 | 8795. | 0.827 |
| 659. | 1.303 | 8855. | 0.813 |
| 701. | 1.301 | 8915. | 0.799 |
| 743. | 1.308 | 8975. | 0.806 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 785. | 1.294 | 9035. | 0.799 |
| 833. | 1.302 | 9095. | 0.796 |
| 887. | 1.292 | 9155. | 0.788 |
| 935. | 1.292 | 9215. | 0.799 |
| 995. | 1.291 | 9275. | 0.779 |
| 1055. | 1.275 | 9335. | 0.777 |
| 1115. | 1.298 | 9395. | 0.782 |
| 1175. | 1.271 | 9455. | 0.777 |
| 1235. | 1.273 | 9515. | 0.762 |
| 1295. | 1.277 | 9575. | 0.769 |
| 1355. | 1.275 | 9635. | 0.752 |
| 1415. | 1.271 | 9695. | 0.766 |
| 1475. | 1.277 | 9755. | 0.758 |
| 1535. | 1.262 | 9815. | 0.739 |
| 1595. | 1.276 | 9875. | 0.746 |
| 1655. | 1.267 | 9935. | 0.746 |
| 1715. | 1.246 | 9995. | 0.748 |
| 1775. | 1.253 | 1.006E+4 | 0.73 |
| 1835. | 1.262 | 1.012E+4 | 0.732 |
| 1895. | 1.255 | 1.018E+4 | 0.722 |
| 1955. | 1.243 | 1.024E+4 | 0.738 |
| 2015. | 1.237 | 1.03E+4 | 0.709 |
| 2075. | 1.238 | 1.036E+4 | 0.72 |
| 2135. | 1.237 | 1.042E+4 | 0.698 |
| 2195. | 1.235 | 1.048E+4 | 0.707 |
| 2255. | 1.229 | 1.054E+4 | 0.706 |
| 2315. | 1.228 | 1.06E+4 | 0.698 |
| 2375. | 1.23 | 1.066E+4 | 0.694 |
| 2435. | 1.242 | 1.072E+4 | 0.69 |
| 2495. | 1.218 | 1.078E+4 | 0.694 |
| 2555. | 1.22 | 1.084E+4 | 0.684 |
| 2615. | 1.228 | 1.09E+4 | 0.678 |
| 2675. | 1.245 | 1.096E+4 | 0.661 |
| 2735. | 1.245 | 1.102E+4 | 0.67 |
| 2795. | 1.221 | 1.108E+4 | 0.674 |
| 2855. | 1.218 | 1.114E+4 | 0.667 |
| 2915. | 1.214 | 1.12E+4 | 0.665 |
| 2975. | 1.216 | 1.126E+4 | 0.655 |
| 3035. | 1.216 | 1.132E+4 | 0.659 |
| 3095. | 1.195 | 1.138E+4 | 0.641 |
| 3155. | 1.211 | 1.144E+4 | 0.633 |
| 3215. | 1.203 | 1.15E+4 | 0.633 |
| 3275. | 1.202 | 1.156E+4 | 0.637 |
| 3335. | 1.196 | 1.162E+4 | 0.633 |
| 3395. | 1.204 | 1.168E+4 | 0.621 |
| 3455. | 1.186 | 1.174E+4 | 0.624 |
| 3515. | 1.184 | 1.18E+4 | 0.626 |
| 3575. | 1.182 | 1.186E+4 | 0.612 |
| 3635. | 1.18 | 1.192E+4 | 0.611 |
| 3695. | 1.176 | 1.198E+4 | 0.605 |
| 3755. | 1.178 | 1.204E+4 | 0.599 |
| 3815. | 1.169 | 1.21E+4 | 0.596 |
| 3875. | 1.171 | 1.216E+4 | 0.606 |

| Time (sec) | Displacement (ft) | Time (sec) | Displacement (ft) |
|---|---|---|---|
| 3935. | 1.181 | 1.222E+4 | 0.588 |
| 3995. | 1.165 | 1.228E+4 | 0.586 |
| 4055. | 1.168 | 1.234E+4 | 0.59 |
| 4115. | 1.156 | 1.24E+4 | 0.579 |
| 4175. | 1.158 | 1.246E+4 | 0.587 |
| 4235. | 1.158 | 1.252E+4 | 0.582 |
| 4295. | 1.152 | 1.258E+4 | 0.576 |
| 4355. | 1.146 | 1.264E+4 | 0.565 |
| 4415. | 1.145 | 1.27E+4 | 0.561 |
| 4475. | 1.146 | 1.276E+4 | 0.571 |
| 4535. | 1.14 | 1.282E+4 | 0.557 |
| 4595. | 1.145 | 1.288E+4 | 0.551 |
| 4655. | 1.137 | 1.294E+4 | 0.557 |
| 4715. | 1.136 | 1.3E+4 | 0.543 |
| 4775. | 1.132 | 1.306E+4 | 0.535 |
| 4835. | 1.129 | | |

## SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 1.563

## VISUAL ESTIMATION RESULTS

### Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| K | 3.439E-7 | cm/sec |
| y0 | 1.448 | ft |

T = K*b = 4.162E-5 cm²/sec

## AUTOMATIC ESTIMATION RESULTS

### Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| K | 3.431E-7 | 6.225E-9 | +/- 1.226E-8 | 55.11 | cm/sec |
| y0 | 1.448 | 0.008168 | +/- 0.01608 | 177.3 | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 4.151E-5 cm²/sec

### Parameter Correlations

| | K | y0 |
|---|---|---|
| K | 1.00 | 0.66 |
| y0 | 0.66 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 1.653 $ft^2$
Variance . . . . . 0.006055 $ft^2$
Std. Deviation . . . . . 0.07781 ft
Mean . . . . . -0.0008758 ft
No. of Residuals . . . . . 275
No. of Estimates . . . . . 2

# EMDP Phase I Site Characterization
## Compilation of Slug Tests Input Parameters and Results

| Overburden Monitoring Well | | | | | | | |
|---|---|---|---|---|---|---|---|
| Input Parameters (ft) | GW-969 | | GW-971 | | GW-973 | | GW-975 |
| | Falling Head | Rising Head | Falling Head | Rising Head | Falling Head | Rising Head | Rising Head |
| rw, rp, rsk | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| rc | 0.167 | 0.167 | 0.167 | 0.167 | 0.167 | 0.167 | 0.167 |
| req | 0.165 | 0.165 | 0.165 | 0.165 | 0.165 | 0.165 | 0.165 |
| d | 8.18 | 7.99 | 0.44 | 1.67 | 5.35 | 5.55 | 0.971 |
| L | 5 | 5 | 10 | 10 | 10 | 10 | 3 |
| H (= d+L) | 13.18 | 12.99 | 10.44 | 11.67 | 15.35 | 15.55 | 3.97 |
| DTW | 2.75 | 2.94 | 15.18 | 13.95 | 10.05 | 9.85 | 8.57 |
| Ho | 2.523 | 2.266 | 2.308 | 1.926 | 2.885 | 2.364 | 2.131 |
| b | 13.18 | 12.99 | 10.44 | 11.67 | 15.35 | 15.55 | 3.97 |
| Test Date | 10/29/2014 | 10/30/2014 | 10/30/2014 | 10/30/2014 | 10/28/2014 | 10/28/2014 | 10/29/2014 |
| Result K (cm/s) | 7.650E-07 | 7.115E-07 | 1.221E-07 | 4.780E-08 | 1.458E-06 | 8.238E-07 | 3.431E-07 |

Average
6.102E-07

Notes: Caution - Slug Tests give an order of magnitude estimate
Only rising head test performed at GW-975 as top of water was below top of screen. Because AQTESOLV does not accept negative numbers, d and L were adjusted in the program to equal the actual water column height.
Well GW-977 is dry.
Terms:
DTW - depth to water (measured from TOC at start of test)
rw - well radius (in.)
rc - casing radius (in.)
d - depth to top of screen (ft.)
L - screen length (ft.)
d+L - static water column height (ft.)
$H_0$ - initial displacement in well (ft.)
b - aquifer thickness (ft.)
req - assummed req is 0.165 (has to be less than rc)
rsk = rw

## Slug Test Data at the former LLWWDD site in West Bear Creek valley along strike with the EMDF

Hydraulic conductivity data from shallow open hole bedrock monitoring wells located at the former LLWWDD site in WBCV are presented in Table 1. The site was located along strike with the EMDF and therefore provide data for comparison with the EMDF. The table was compiled from data presented in the Performance Assessment for the Class L-II Disposal Facility (ORNL 1997 – Table E.1), based on data from Golder Associates (1988) from rising head slug tests. Table 1 was restricted to only the 14 tested wells completed in the outcrop belts of the Rutledge/Pumpkin Valley (1), Rogersville (3), and Maryville (10) which occur below the EMDF site [the remainder of the 39 tests were conducted in wells completed in the Nolichucky or Maynardville]. As shown in Table 1, the tests were conducted from open hole intervals apparently from the upper portion of the bedrock. The open hole intervals are mostly on the order of 10 to 13 ft, except for two wells with intervals about 5 and 8 ft. The K values for these tests span three orders of magnitude, from a low K of $4.24 \times 10^{-6}$ cm/sec to a high of $3.35 \times 10^{-4}$ cm/sec. The three K values from the Rogersville Shale also span this three orders of magnitude range, while the single K value from the Rutledge/Pumpkin Valley well is intermediate at $2.47 \times 10^{-5}$ cm/sec.

**Table 1. Slug test results from upper bedrock intervals at the former LLWWDD site**

| Well ID | Top (TOC ft) | Bottom (TOC ft) | Open Hole Length (ft) | Geologic Formations Tested | Hydraulic Conductivity K (cm/s) |
|---|---|---|---|---|---|
| GW-405 | 25.5 | 36.7 | 11.2 | Cm | 1.77E-4 |
| GW-407 | 33.5 | 42.7 | 9.2 | Crg | 8.12E-6 |
| GW-409 | 48.3 | 60.5 | 12.2 | Cm | 4.24E-6 |
| GW-412 | 29.2 | 42.1 | 12.9 | Crt/Cpv | 2.47E-5 |
| GW-414 | 45.5 | 57.6 | 12.1 | Cm | 1.57E-5 |
| GW-415 | 26.6 | 30.0 | 3.4 | Cm | 3.35E-4 |
| GW-416 | 49.9 | 63.2 | 13.3 | Cm | 5.42E-5 |
| GW-432 | 34.3 | 46.1 | 11.8 | Cm | 5.94E-5 |
| GW-433 | 7.1 | 15.5 | 8.4 | Cm / Cm –Cm saprolite | 8.54E-5 |
| GW-434 | 30.2 | 42.2 | 12 | Crg | 2.70E-04 |
| GW-436 | 34.9 | 47.3 | 12.4 | Cm | 4.53E-06 |
| GW-437 | 53.3 | 65.1 | 11.8 | Cm | 1.52E-04 |
| GW-448 | 32.6 | 46.1 | 13.5 | Cm | 6.49E-05 |
| GW-450 | 45.8 | 57.6 | 11.8 | Crg | 2.37E-05 |

Source: From ORNL 1997 – original data from Golder Associates (1988)

**Table Abbreviations:**

TOC – top of casing; Cpv - Pumpkin Valley Shale; Crt - Rutledge Limestone (Friendship Formation); Crg - Rogersville Shale Cm – Maryville Limestone (Dismal Gap Formation);

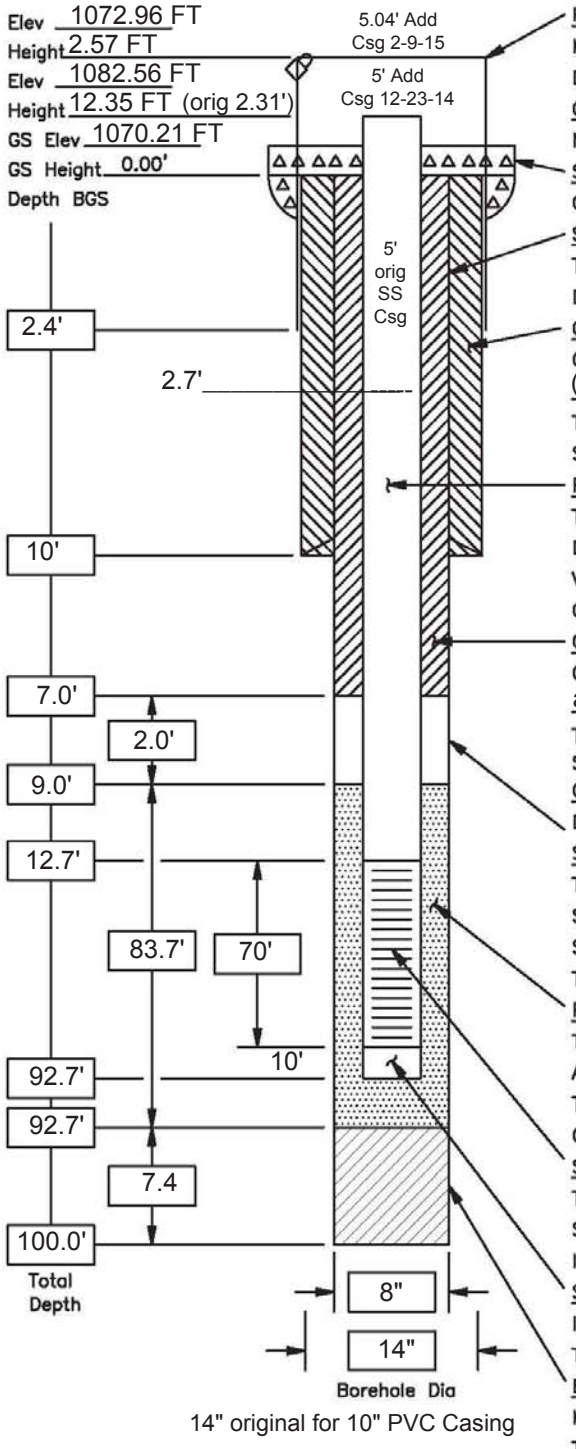
The Phase I slug test results are relatively low compared with the K values from the LLWWDD site, but the Phase I results were determined from wells completed with filter packs and screens in regolith soils and not from open hole wells completed within the upper portion of bedrock. Hydraulic conductivities typically range over several orders of magnitude on the ORR as a result of natural variations in subsurface conditions. Heterogeneities, anisotropy, and preferential pathways for ground water are associated with variations in regolith materials (residuum/alluvium/saprolite), bedrock lithologies, stratigraphic changes, and structural features (fracture density/spacing, joints, bedding planes, folds, faults, shear fractures, etc.). The Phase I slug test data is quite limited. Additional hydraulic conductivity testing is recommended for a Phase II investigation both from regolith and bedrock boreholes/wells.

# EXHIBIT A.11:
# MONITORING WELL CONSTRUCTION DIAGRAMS AND WELL MATERIAL SPECIFICATION CUT SHEETS

This page intentionally left blank.

# MONITORING WELL CONSTRUCTION LOG — Double Cased

| | | |
|---|---|---|
| WELL NO.: GW-968 | INSTALLATION: Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry/ EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START – DATE: 11/ 03 / 2014 TIME: 10 : 45 | END – DATE: 12 / 23 / 2014 TIME: 10 : 20 | |
| BUILT BY: George Akins | WELL COORDINATES: N 31535.57 E 48979.13 | |




PROTECTIVE CSG
Material / Type Steel
Diameter 6" Square Weep Hole ☒ Yes ☐ No
GUARD POSTS ☐ Yes ☒ No
No. ____ Type ____

SURFACE PAD
Composition & Size Concrete 4' x 4' x 0.5 '

SURFACE CSG
Type Sch 40 PVC; Added 5' 12/23 & 5.04' 2/9 (total 10.04')
Diameter 10" Total Length 10 ft

GROUT
Composition & Amount 3 Bags Portland Cement (Type I/II), 1/4 bag Quik-Gel (bentonite powder)
Tremied ☒ Yes ☐ No Pressure Grouted ☒ Yes ☐ No
Setup/Hydration Time 2 days

RISER PIPE
Type Sch 40 PVC (10 FT); stainless-steel (15 FT)
Diameter 4" Total Length (TOC to TOS) 25.1 FT
Ventilated Cap ☒ Yes ☐ No
O–Rings For Threads ☐ Yes ☒ No

GROUT
Composition & Amount 2 Bags Portland Cement, QuikGel and 12-14 gallons of water
Tremied ☒ Yes ☐ No Interval BGS 0' to 7'
Setup/Hydration Time 17.5 hours

CENTRALIZERS ☒ Yes ☐ No
Depth(s) 87.5', 57.5' and 27.5'

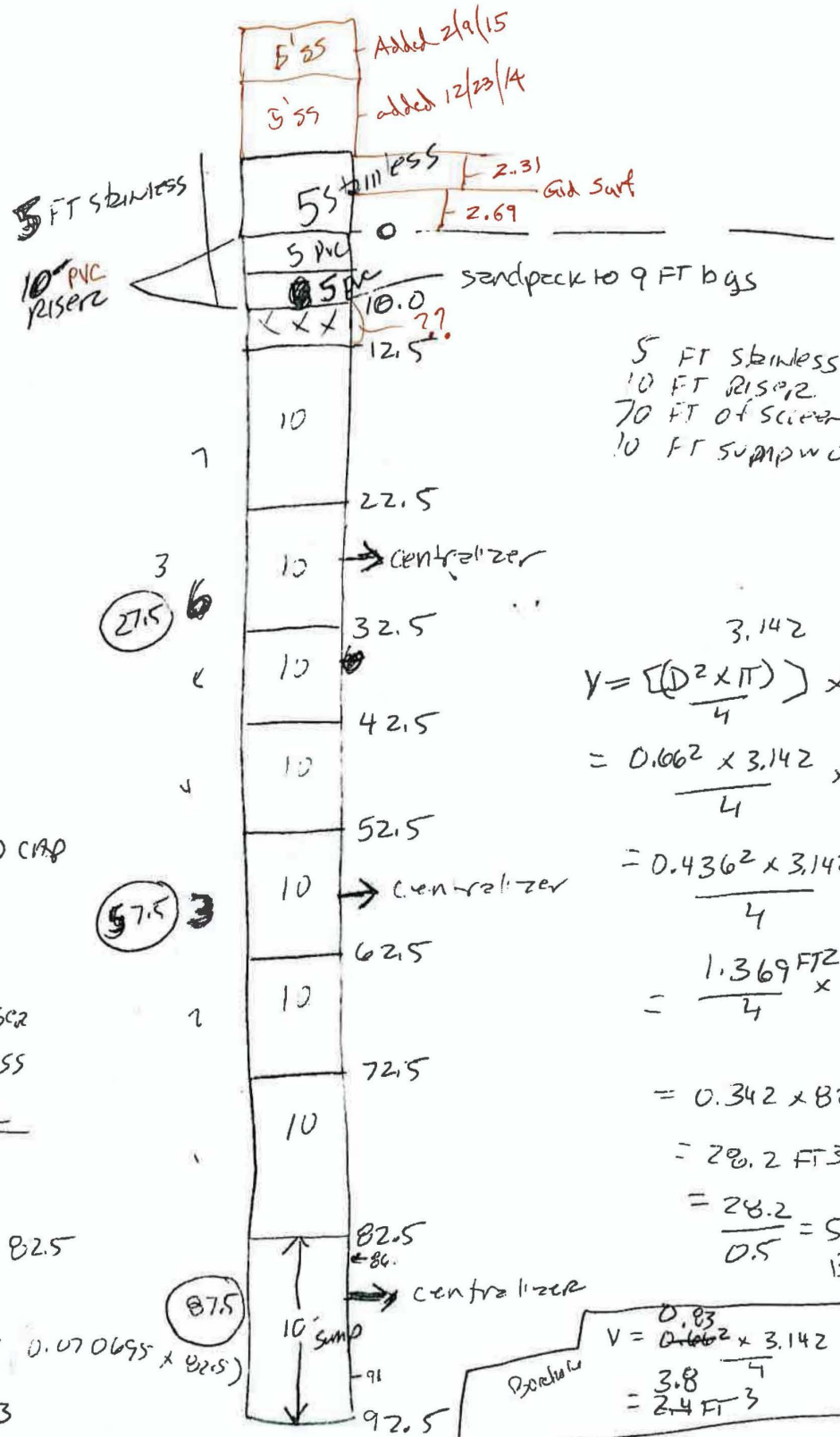
SEAL
Type Enviroplug 3/8" bentonite pellets
Source Wyoming Bentonite
Setup/Hydration Time 7 Hours
Tremied ☐ Yes ☒ No Volume Fluid Added None*
None* = No water added since hole already filled with water.

FILTER PACK
Type Filter Media GP #2
Amount Used 39.5 bags
Tremied ☐ Yes ☒ No Source Southern Prod. & Silica
Gr Size Dist 0.8 - 120 mm

SCREEN
Type Sch 40 PVC Diameter 4"
Slot Size 0.01"
Interval BGS 12.7' to 82.7'

SUMP
Interval BGS 82.7' to 92.7' (10')
Type of Bottom Cap 0.1' PVC

~~BACKFILL PLUG~~ Open Borehole Collapse
Material ____
Tremied ☐ Yes ☐ No Setup/Hydration Time ____




SAND
10 bags
10 bags
10 bags
9.5 bags
40 bags
39.5

5 FT stainless
10 FT Riser
70 FT of screen
10 FT sump w 0.1' end cap

$$V = \left[\frac{(D^2 \times \pi)}{4}\right] \times L \text{ (FT)}$$

3.142

$$= \frac{0.66^2 \times 3.142}{4} \times 82.5$$

$$= \frac{0.436^2 \times 3.142}{4} \times 82.5$$

$$= \frac{1.369 \text{ FT}^2}{4} \times 82.5$$

$$= 0.342 \times 82.5$$

$$= 28.2 \text{ FT}^3$$

$$= \frac{28.2}{0.5} = 56 \text{ Bags}$$

10 FT sump
W/0.1 FT END CAP
4" PVC

(7) screens
(1) 10 FT PVC Riser
(1) 5 FT stainless

casing volume

$$\frac{D^2 \times \pi}{4}$$

$$\frac{(0.3)^2 \times \pi}{4} \times 82.5$$

$$\frac{0.09 \times 3.142}{4} \quad (0.070695 \times 82.5)$$

$$5.8 \text{ FT}^3$$

$$28.2 - 5.8 = 22.4$$

45 bags

Borehole

$$V = \frac{0.83^2 \times 3.142}{4} \times 7 \text{ FT}$$

$$= 3.8 \text{ FT}^3$$

casing vol

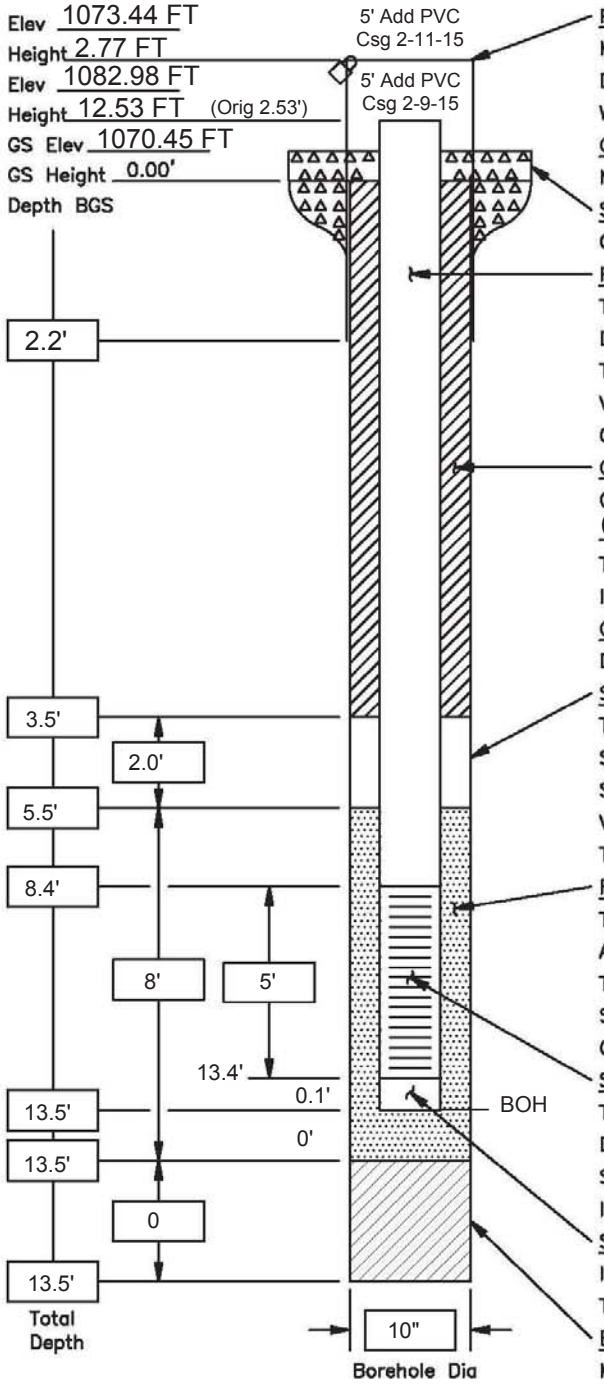
$$\frac{(0.3)^2 \times \pi}{4} = 1.97 \text{ FT}^3$$

1.8 FT³ Grout

Need no bags

# MONITORING WELL CONSTRUCTION LOG — Standard

| | | |
|---|---|---|
| WELL NO.: GW-969 | INSTALLATION: Y-12 EMDF | SITE: EMDF Y-12 |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry / EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START – DATE: 9/25/2014 TIME: 12:30 | END – DATE: 10/1/2014 TIME: 14:30 | |
| BUILT BY: George Akins | WELL COORDINATES: N 31539.77 E 48698.13 | |




**PROTECTIVE CSG**
Material / Type: Steel
Diameter: 6" Square
Weep Hole: ☒ Yes ☐ No
GUARD POSTS: ☐ Yes ☒ No
No. ____ Type ____

**SURFACE PAD**
Composition & Size: Concrete 4' x 4' x 0.5'

**RISER PIPE**
Type: Sch 40 PVC; Added 5' on 2/9 & 2/11 (10 ft total)
Diameter: 4"
Total Length (TOC to TOS): 10.9 FT
Ventilated Cap: ☒ Yes ☐ No
O–Rings For Threads: ☒ Yes ☐ No

**GROUT**
Composition & Amount: 2 Bags Portland Cement (Type I/II), Quik-Gel (bentonite powder), & water see calcs on attached
Tremied: ☐ Yes ☒ No
Interval BGS: 1 - 3.5 bgs

**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s): N/A

**SEAL**
Type: EnviroPlug 3/8" Bentonite Pellets
Source: Wyoming Bentonite
Setup/Hydration Time: 15 min / 6" Lift
Volume Fluid Added: ~5 gallons
Tremied: ☐ Yes ☒ No

**FILTER PACK**
Type: Filter Media GP # 2
Amount Used: 6 (0.5 cubic FT bags)
Tremied: ☐ Yes ☒ No
Source: Southern Products & Silica
Gr Size Dist: 0.8 - 1.20 mm

**SCREEN**
Type: Sch 40 PVC
Diameter: 4"
Slot Size: 0.01"
Interval BGS: 8.4' to 13.4'

**SUMP**
Interval BGS: 13.4' to 13.5'
Type of Bottom Cap: 0.1' PVC

**BACKFILL PLUG**
Material: N/A
Setup/Hydration Time: ____
Tremied: ☐ Yes ☐ No

GW 969

Grout volume

Borehole — $V = [(D^2 * \pi)/4] \times L$

$V = (0.8\ FT^2 \times 3.142)/4 \times 3.5\ FT$

$V = 0.5\ FT^2 \times 3.5\ FT$ RS 9-29-14

$V = 1.8\ FT^3$

$1.8\ FT \times 7.48\ gal/FT^3 = 13.2\ gal$

~~$1.6\ FT^3 \times 7.48\ gal/FT^3 = 12.3\ gal$~~ RS 9-29-14

~~$12.8\ gal / 7.5\ gal/bag = 1.75\ bags$~~ RS 9-29-14

well casing

$V = [(D^2) * \pi]/4 \times L$

$= [(0.33)^2 \times 3.142]/4 \times 3.5\ FT$

$= 0.29\ FT^3$

$= 0.3\ FT^3 \times 7.48\ gal/FT =$

$= 2.2\ gal$

$13.2\ gal - 2.2\ gal = 11\ gal$

$11\ gal / 7\ gal/bag = 1.6\ bag$ cement

SAND volume

Borehole $V = [(D^2 \times 3.142)/4] \times 8\ FT$

$= [(0.8)^2 \times 3.142)/4] \times 8\ FT$

$= 0.5\ FT^2 \times 8\ FT$

$= 4\ FT^3$

Casing volume

$V = [(D^2 \times \pi)/4] \times L$

$= [(0.33)^2 \times 3.142/4] \times 8$

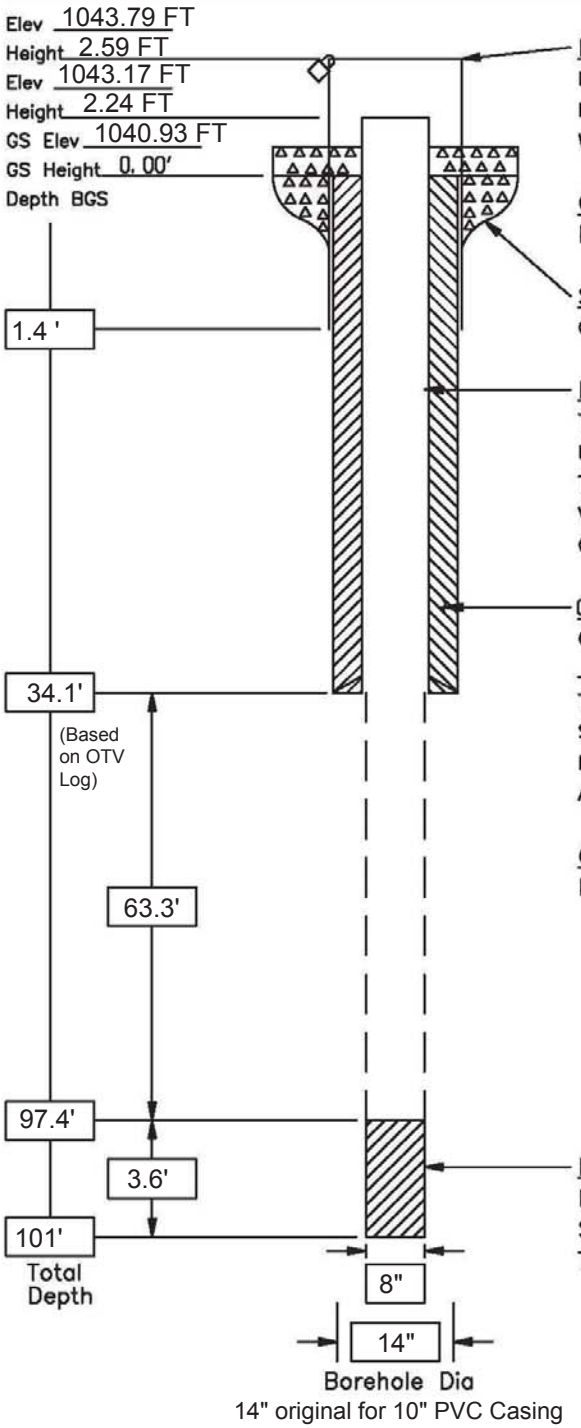
$= 0.68\ FT^3$

$4\ FT^3 - 0.7\ FT^3 = 3.3\ FT^3$

$3.3\ FT^3 / 0.5\ FT^3/bag = 6.6$ bags SAND

# MONITORING WELL CONSTRUCTION LOG — Open Hole

| | | |
|---|---|---|
| WELL NO.: GW-970 | INSTALLATION: EMDF / Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | CLIENT/PROJECT: DOE/EMDF Site Characterization | |
| CONTRACTOR: Alliant | DRILLING CONTRACTOR: M&W Drilling | |
| START — DATE: 9 / 2 /14 TIME: 09:40 | END — DATE: 11/6/14 / /TIME: 1153 | |
| BUILT BY: George Akins | WELL COORDINATES: N31392.90 E 49568.45 | |




14" original for 10" PVC Casing

**PROTECTIVE CSG**
Material / Type: Steel/Round
Diameter: 14"
Weep Hole: ☒ Yes ☐ No

**GUARD POSTS** ☐ Yes ☒ No
No. _____ Type _____

**SURFACE PAD**
Composition & Size: 4 FT x 4 FT x 0.5 FT

**ISOLATION CASING**
Type: PVC
Diameter: 10"
Total Length (TOC to Top of Open Hole): 34.6
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

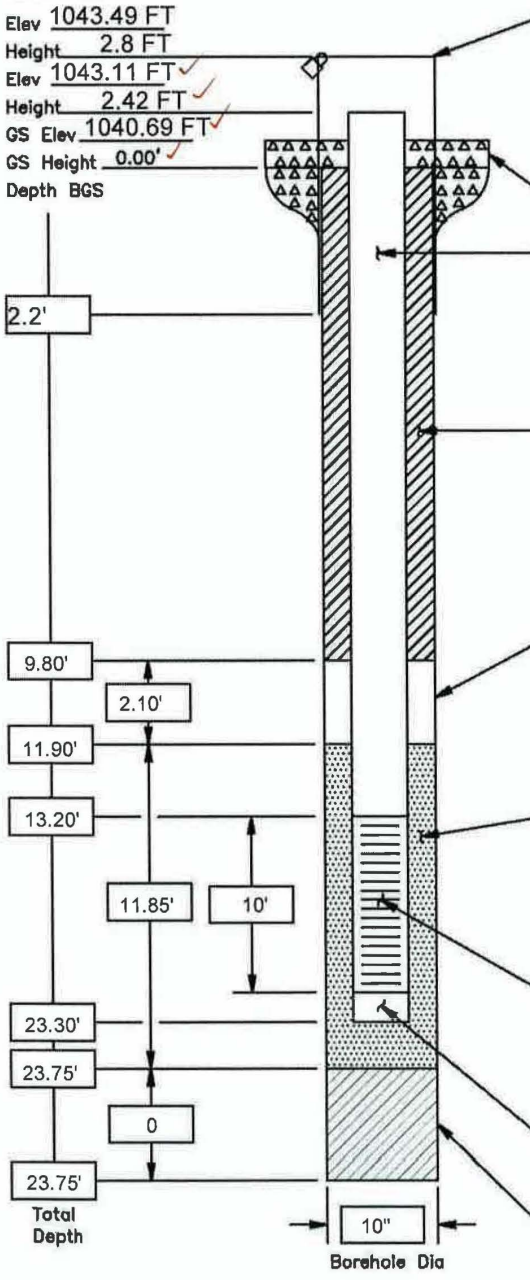
**GROUT**
Composition & Amount: 14.1 lbs/gal, 14 Bags Portland & 0.75 Bags Bentonite
Tremied: ☒ Yes ☐ No Pressure Grouted: ☒ Yes ☐ No
Setup/Hydration Time: >2 Months
Interval BGS: 0 to 34.6 FT
Additional Material to Bridge Foot of Casing: N/A

**CENTRALIZERS** ☐ Yes ☒ No
Depth(s) _____

**~~BACKFILL PLUG~~** Open Borehole Collapse
Material _____
Setup/Hydration Time _____
Tremied ☐ Yes ☐ No

# MONITORING WELL CONSTRUCTION LOG — Standard

| | | |
|---|---|---|
| WELL NO.: GW-971 | INSTALLATION: Y-12 | SITE: EMDF, Y-12 |
| PROJECT NO.: 4301 | | CLIENT/PROJECT: Brian Henry/EMDF Phase 1 |
| CONTRACTOR: Alliant Corp | | DRILLING CONTRACTOR: M&W Drilling |
| START – DATE: 9/17/2014 TIME: 07:56 | | END – DATE: 12/23/2014 TIME: 13:27 |
| BUILT BY: George Akins | | WELL COORDINATES: N 31392.01 E 49560.23 |




**PROTECTIVE CSG**
Material / Type: Steel
Diameter: 6" Square
Weep Hole: ☒ Yes ☐ No
GUARD POSTS: ☐ Yes ☒ No
No. ____ Type ____

**SURFACE PAD**
Composition & Size: Concrete 4' x 4' x 0.5'

**RISER PIPE**
Type: Sch 40 PVC
Diameter: 4"
Total Length (TOC to TOS): 15.6'
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

**GROUT**
Composition & Amount: 3 Bags Portland (94 lb) Cement (Type I/II), Quik-Gel (Bentonite) & water
Tremied: ☐ Yes ☒ No
Interval BGS: 0 - 9.8'

**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s): N/A

**SEAL**
Type: EnviroPlug 3/8 inch Bentonite Pellets
Source: Wyoming Bentonite
Setup/Hydration Time: 17 Hours
Volume Fluid Added: 5 gal
Tremied: ☐ Yes ☒ No

**FILTER PACK**
Type: Filter Media GP # 2
Amount Used: 11 Bags, 0.5 cu FT Each
Tremied: ☐ Yes ☒ No
Source: Southern Products & Silica
Gr Size Dist: 0.80 - 1.20 mm (8-30)

**SCREEN**
Type: Sch 40 PVC
Diameter: 4"
Slot Size: 0.01"
Interval BGS: 13.2' to 23.2'

**SUMP**
Interval BGS: 23.2' to 23.3'
Type of Bottom Cap: 0.1' PVC

**BACKFILL PLUG**
Material: N/A
Setup/Hydration Time: ____
Tremied: ☐ Yes ☐ No

GW 971

Grout volume

Casing volume

$V = \frac{[(D)^2 \times \pi)]}{4} \times L$

$= \frac{(0.33)^2 \times 3.142}{4} \times 9.8$

$= 0.8\ FT^3$

Borehole VOL $V = \frac{[(D^2) \times \pi)]}{4} \times L$

$= \frac{[(0.8)^2 \times 3.142)]}{4} \times 9.8$

$= 0.6\ FT^2 \times \frac{3.142}{4} \times 9.8\ FT$

$= 4.6\ FT^3$

$4.6\ FT^3 \times 7.48\ gal/FT^3 = 34.4\ gal$

$4.6\ FT^3 - 0.8\ FT^3 = 3.8\ FT^3$

$3.8\ FT^3 \times 7.48\ gal/FT^3 = 28.4\ gal$

~~$\frac{34.4\ gal}{7\ gal/bag} = 4.9\ bags$~~ RS 9-22-14

$\frac{28.4\ gal}{7\ gal/bag} =$ 4 bags cement

SAND volume

Casing volume

$V = \frac{[(D)^2 \times \pi]}{4} \times L$

$= \frac{(0.33)^2 \times 3.142}{4} \times 11.85\ FT$

$= 1\ FT^3$

Borehole volume

$V = \frac{[(D)^2 \times \pi]}{4} \times L$

$V = \frac{(0.8)^2 \times 3.142}{4} \times 11.85$

$= 5.95\ FT^3$

$6\ FT^3 - 1\ FT^3 = 5\ FT^3$

$\frac{5\ FT^3}{0.5\ FT^3/bag} =$ 10 bags SAND

# MONITORING WELL CONSTRUCTION LOG — Open Hole

| | | |
|---|---|---|
| WELL NO.: GW-972 | INSTALLATION: EMDF / Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry/EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START — DATE: 9 / 4 /14 TIME: 09:39 | END — DATE: 12 / 23 /14 TIME: 13:27 | |
| BUILT BY: George Akins | WELL COORDINATES: N31259.06 E49092.0 | |

Elev 1026.79 FT
Height 3.04 FT
Elev 1026.20 FT
Height 2.65 FT
GS Elev 1023.55 FT
GS Height 0.00'
Depth BGS

1.2 '

24.6'

(23.8' based on OTV Log)

74.9'

(75.9' based on OTV Log)

99.6'

1.4'

101'
Total Depth

8"

14"
Borehole Dia

14" original for 10" PVC Casing

**PROTECTIVE CSG**
Material / Type Steel
Diameter 14" Round
Weep Hole ☒ Yes ☐ No

**GUARD POSTS** ☐ Yes ☒ No
No. _____ Type _____

**SURFACE PAD**
Composition & Size Concrete 4' x 4' x 0.5'

**ISOLATION CASING**
Type Sch 40 PVC
Diameter 10"
Total Length (TOC to Top of Open Hole) 27.25'
Ventilated Cap ☒ Yes ☐ No
O-Rings For Threads ☒ Yes ☐ No

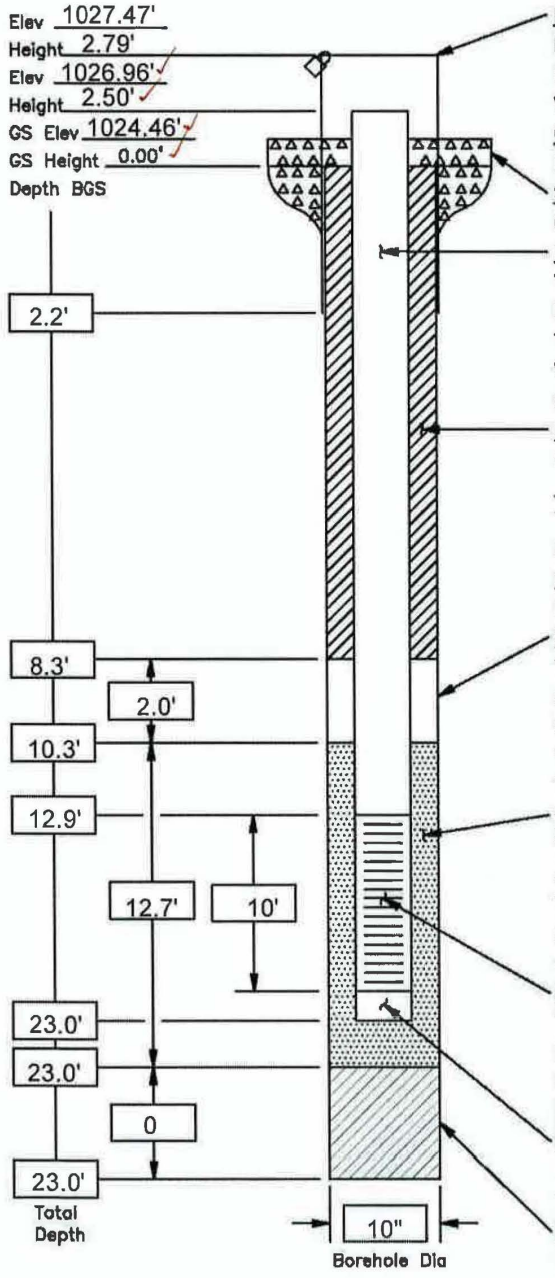
**GROUT**
Composition & Amount 9 Bags Portland Cement (Type I/II), Quik-Gel (25 lbs)
Tremied ☒ Yes ☐ No Pressure Grouted ☒ Yes ☐ No
Setup/Hydration Time 7 Days
Interval BGS 0' to 24.6'
Additional Material to Bridge Foot of Casing N/A

**CENTRALIZERS** ☐ Yes ☒ No
Depth(s) _____

**~~BACKFILL PLUG~~** Open Borehole Collapse
Material _____
Setup/Hydration Time _____
Tremied ☐ Yes ☐ No

# MONITORING WELL CONSTRUCTION LOG – Standard

| | | |
|---|---|---|
| WELL NO.: GW-973 | INSTALLATION: Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | | CLIENT/PROJECT: Brian Henry/EMDF Phase 1 |
| CONTRACTOR: Alliant Corp | | DRILLING CONTRACTOR: M&W Drilling |
| START – DATE: 9/25/2014 TIME: 07:45 | | END – DATE: 12/23/2014 TIME: 14:21 |
| BUILT BY: George Akins | | WELL COORDINATES: N 31268.37 E 49092.12 |




**PROTECTIVE CSG**
Material / Type: Steel
Diameter: 6" Square
Weep Hole: ☒ Yes ☐ No
GUARD POSTS: ☐ Yes ☒ No
No. ____ Type ____

**SURFACE PAD**
Composition & Size: Concrete (4' x 4' x 0.5')

**RISER PIPE**
Type: Sch 40 PVC
Diameter: 4"
Total Length (TOC to TOS): 15.2 FT
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

**GROUT**
Composition & Amount: 3 Bags Portland Cement (Type I/II), Quik-Gel, and water
Tremied: ☐ Yes ☒ No
Interval BGS: 0 - 8.3 FT

**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s): N/A

**SEAL**
Type: 3/8" EnviroPlug Bentonite Pellets
Source: Wyoming Bentonite
Setup/Hydration Time: 15 min/6" Lift
Volume Fluid Added: 5-gal
Tremied: ☐ Yes ☒ No

**FILTER PACK**
Type: Filter media GP # 2
Amount Used: 10.5 bags
Tremied: ☐ Yes ☒ No
Source: Southern Products & Silica
Gr Size Dist: 0.8 - 1.20 mm

**SCREEN**
Type: Sch 40 PVC
Diameter: 4"
Slot Size: 0.01"
Interval BGS: 12.90 to 22.90 FT

**SUMP**
Interval BGS: 22.90 to 23.0
Type of Bottom Cap: 0.1' PVC

**BACKFILL PLUG**
Material: N/A
Setup/Hydration Time ____
Tremied: ☐ Yes ☐ No

## Grout volume GW 573

**Borehole vol**

$V = \left[\frac{(D)^2 \times \pi}{4}\right] \times L$

$V = \left[\frac{(0.8\,FT)^2 \times 3.142}{4}\right] \times 8.3$ RS 9-29-14

$= 0.5\,FT^2 \times 8.3\,FT$

$= 4.1\,FT3$

**Casing vol**

$V = \left[\frac{(D)^2 \times \pi}{4}\right] \times L$

$= \frac{(0.33)^2 \times 3.142}{4} \times 8.3\,FT$

$= 0.71\,FT3$

$4.1\,FT3 - 0.71\,FT3 = 3.4\,FT3$

$3.4\,FT3 \times 7.48\,gal/FT3 = 25.3\,gallons$

$\frac{25.3\,gal}{7\,gal/bag} =$ **3.6 bags Cement**

## SAND volume

**Borehole vol**

$V = \left[\frac{(D)^2 \times \pi}{4}\right] \times L$

$= \left[\frac{(0.8\,FT)^2 \times 3.142}{4}\right] \times 12.7$

$= 0.5\,FT^2 \times 12.7\,FT$

$= 6.4\,FT3$

**Casing vol**

$V = \left[\frac{(D)^2 \times \pi}{4}\right] \times L$

$= \frac{(0.33)^2 \times 3.142}{4} \times 12.7$

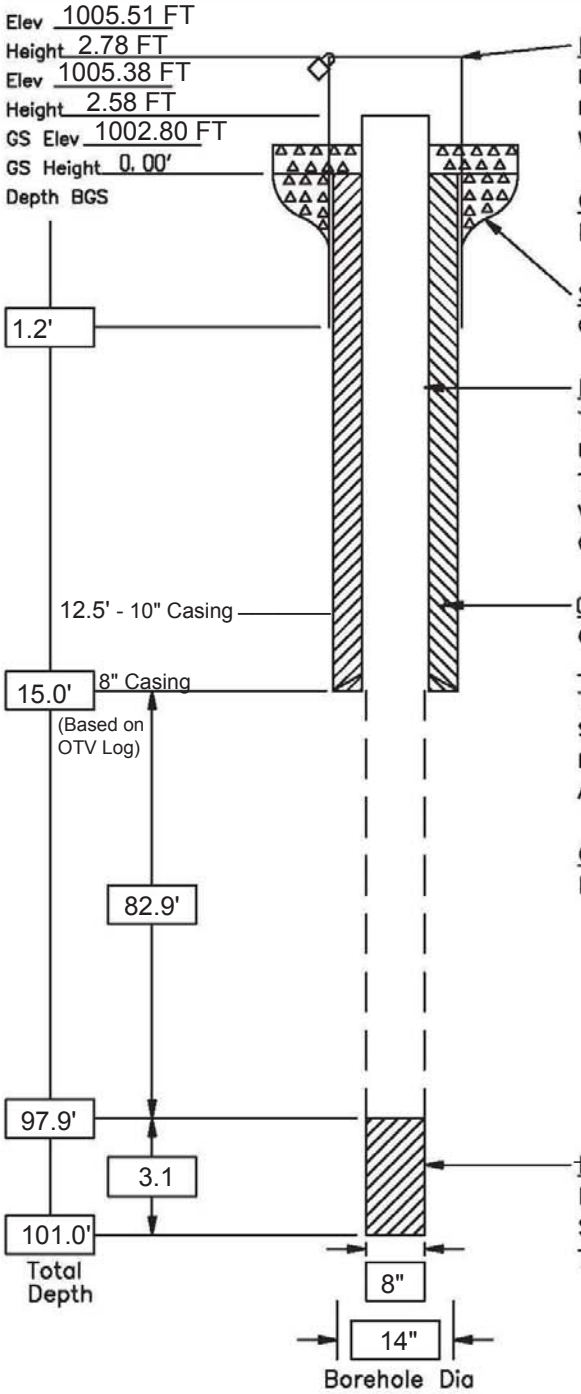
$= 1.1\,FT3$

$6.4\,FT3 - 1.1\,FT3 = 5.3\,FT3$

$5.3\,FT3 / 0.5\,FT3 =$ **10.6 Bags sand**

# MONITORING WELL CONSTRUCTION LOG — Open Hole

| | | |
|---|---|---|
| WELL NO.: GW-974 | INSTALLATION: EMDF / Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry/EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START — DATE: 9 / 18 /14 TIME: 08:10 | END — DATE: 12 / 23 /14 TIME: 13:27 | |
| BUILT BY: George Akins | WELL COORDINATES: N31105.66 E 48798.68 | |




**PROTECTIVE CSG**
Material / Type: Steel
Diameter: 14" Round
Weep Hole: ☒ Yes ☐ No

**GUARD POSTS**: ☐ Yes ☒ No
No. _____ Type _____

**SURFACE PAD**
Composition & Size: Concrete 4' x 4' x 0.5'

**ISOLATION CASING**
Type: Sch 40 PVC
Diameter: Initial = 10"; After Repair = 8"
Total Length (TOC to Top of Open Hole): 12.5' (10"); 18.1' (8")
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

**GROUT**
Composition & Amount: Initial = 6 bags Portland Cement, 12.5 lbs Quik-Gel (bentonite powder)
After repair: 1.5 bags Portland, 3 lbs Quik-Gel
Tremied ☒ Yes ☐ No Pressure Grouted ☒ Yes ☐ No
Setup/Hydration Time: 4 Days
Interval BGS: 0' to 15.5'
Additional Material to Bridge Foot of Casing _____

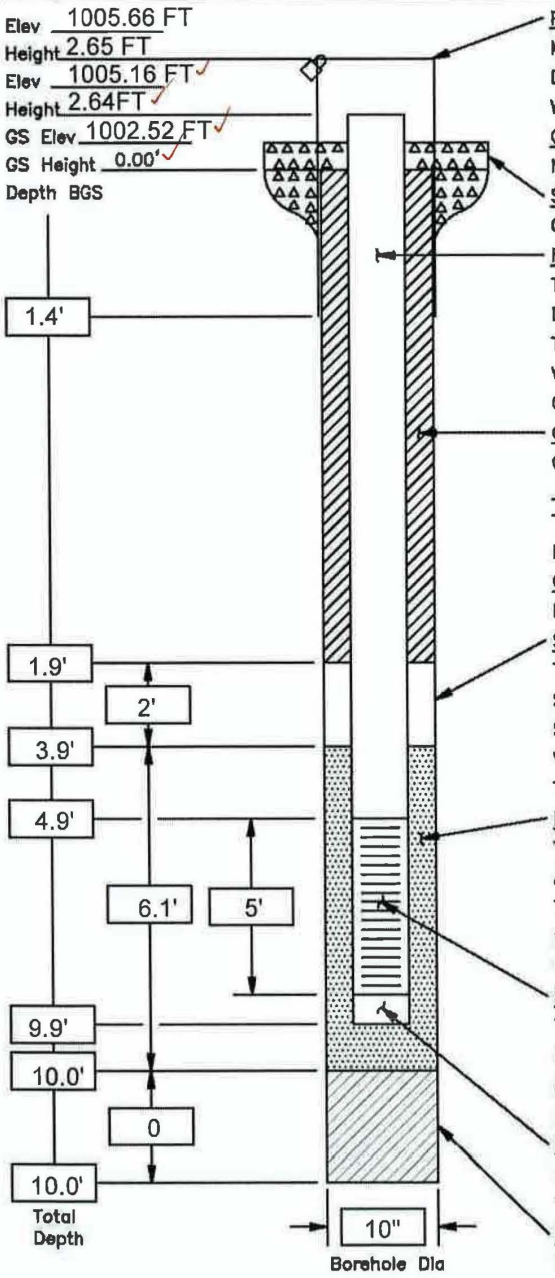
**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s) _____

**BACKFILL PLUG**
Material: Open Borehole Collapse
Setup/Hydration Time _____
Tremied: ☐ Yes ☐ No

14" original for 10" PVC Casing

# MONITORING WELL CONSTRUCTION LOG – Standard

| | | |
|---|---|---|
| WELL NO.: GW-975 | INSTALLATION: Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry/EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START – DATE: 9/29/2014 TIME: 08:26 | END – DATE: 12/23/2014 TIME: 13:27 | |
| BUILT BY: George Akins | WELL COORDINATES: N 31112.08 E 48789.94 | |




**PROTECTIVE CSG**
Material / Type: Steel (Cut 1 FT off the bottom)
Diameter: 6" Square
Weep Hole: ☒ Yes ☐ No
GUARD POSTS: ☐ Yes ☒ No
No. ____ Type ____

**SURFACE PAD**
Composition & Size: Concrete 4' x 4' x 0.5'

**RISER PIPE**
Type: Sch 40 PVC
Diameter: 4"
Total Length (TOC to TOS): 7.54 FT
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

**GROUT**
Composition & Amount: None. Cement from pad construction placed in last 1.9 FT of borehole.
Tremied: ☐ Yes ☒ No
Interval BGS: 0 - 1.9 FT

**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s) ____

**SEAL**
Type: EnviroPlug 3/8" Bentonite Pellets
Source: Wyoming Bentonite
Setup/Hydration Time: 15 min per 6" Lift
Volume Fluid Added: ~2.5 gal
Tremied: ☐ Yes ☒ No

**FILTER PACK**
Type: Filter Media GP #2
Amount Used: 4 Bags
Tremied: ☐ Yes ☒ No
Source: Southern Products & Silica
Gr Size Dist: 0.8 to 1.2 mm

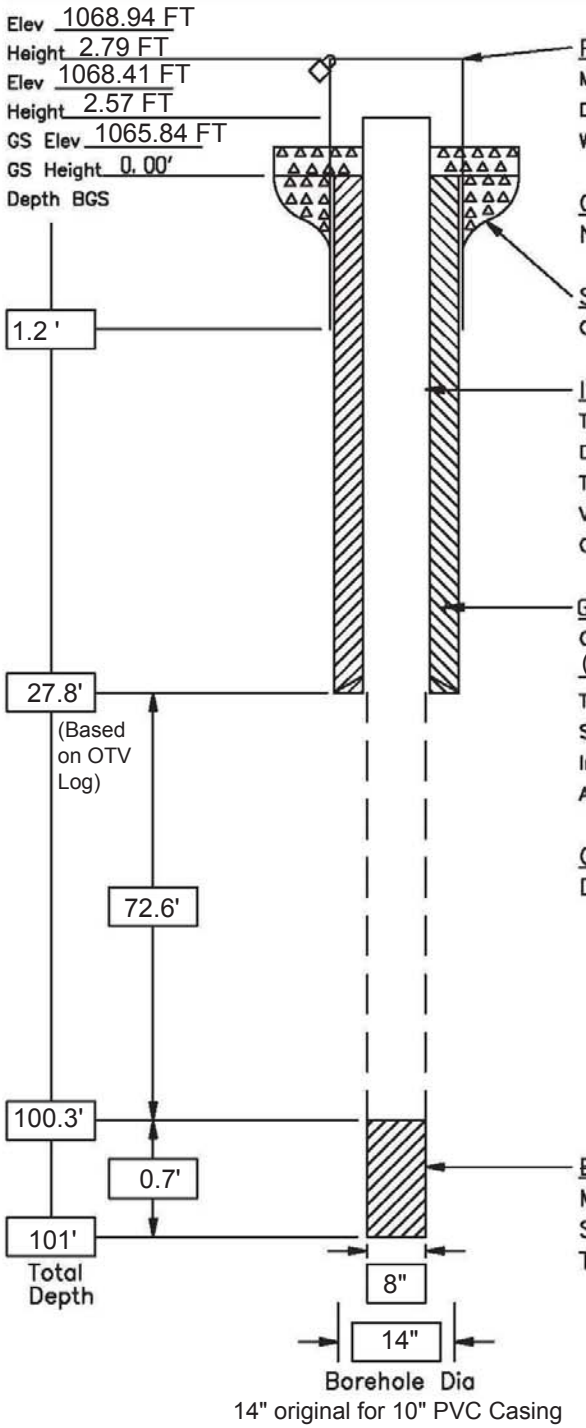
**SCREEN**
Type: Sch 40 PVC
Diameter: 4"
Slot Size: 0.01"
Interval BGS: 4.9 - 9.9 FT

**SUMP**
Interval BGS: 9.9 to 10.0 FT
Type of Bottom Cap: 0.1' PVC

**BACKFILL PLUG**
Material: N/A
Setup/Hydration Time ____
Tremied: ☐ Yes ☐ No

# MONITORING WELL CONSTRUCTION LOG — Open Hole

| | | |
|---|---|---|
| WELL NO.: GW-976 | INSTALLATION: EMDF / Y-12 | SITE: EMDF, Y-12 |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry/EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START — DATE: 9 / 9 /14 TIME: 08 :40 | END — DATE: 12 / 23 /14 /TIME: 13:27 | |
| BUILT BY: George Akins | WELL COORDINATES: N30838.21 E49394.31 | |




14" original for 10" PVC Casing

**PROTECTIVE CSG**
Material / Type: Steel
Diameter: 14" Round
Weep Hole: ☒ Yes ☐ No

**GUARD POSTS**: ☐ Yes ☒ No
No. _____ Type _____

**SURFACE PAD**
Composition & Size: Concrete 4' x 4' x 0.5'

**ISOLATION CASING**
Type: Sch 40 PVC
Diameter: 10"
Total Length (TOC to Top of Open Hole): 30.6'
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

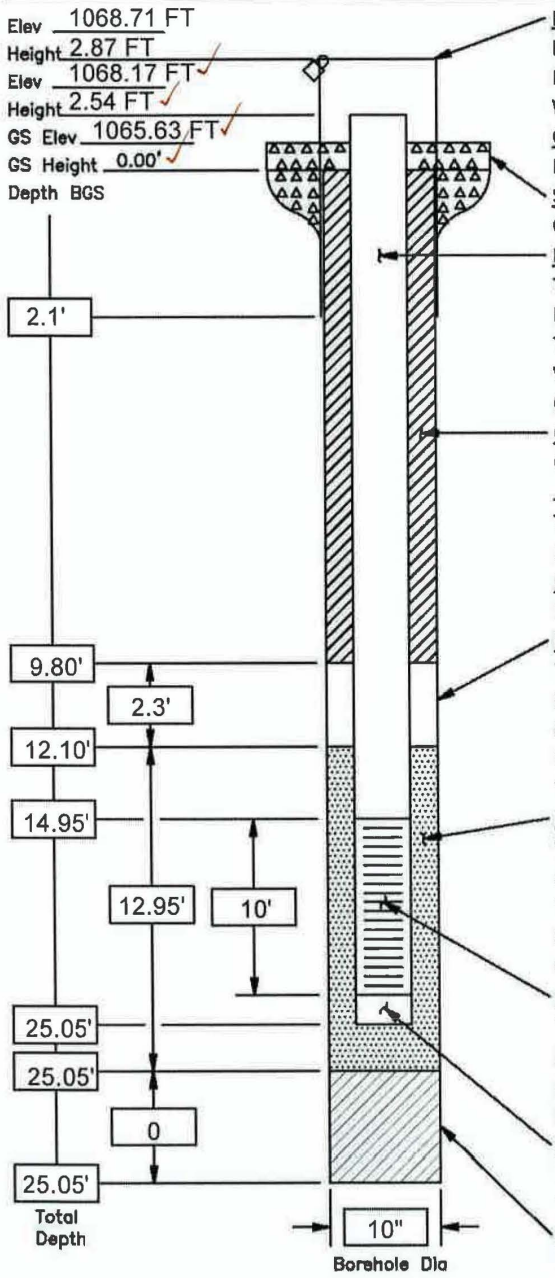
**GROUT**
Composition & Amount: 10 Bags Portland Cement (Type I/II), 25 lbs Quik-Gel (bentonite powder)
Tremied ☒ Yes ☐ No Pressure Grouted ☒ Yes ☐ No
Setup/Hydration Time: > 2 Months
Interval BGS: 0' to 28'
Additional Material to Bridge Foot of Casing

**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s)

**BACKFILL PLUG**
Material: Open Borehole Collapse (?)
Setup/Hydration Time
Tremied: ☐ Yes ☐ No

# MONITORING WELL CONSTRUCTION LOG — Standard

| | | |
|---|---|---|
| WELL NO.: GW-977 | INSTALLATION: Y-12 | SITE: EMDF |
| PROJECT NO.: 4301 | CLIENT/PROJECT: Brian Henry/ EMDF Phase 1 | |
| CONTRACTOR: Alliant Corp | DRILLING CONTRACTOR: M&W Drilling | |
| START – DATE: 9/ 24 / 2014 TIME: 08:00 | END – DATE: 12/ 23/ 2014 TIME: 13:27 | |
| BUILT BY: | WELL COORDINATES: N 30831.10 E 49397.4 | |




**PROTECTIVE CSG**
Material / Type: Steel
Diameter: 6" Square
Weep Hole: ☒ Yes ☐ No
**GUARD POSTS**: ☐ Yes ☒ No
No. ____ Type ____

**SURFACE PAD**
Composition & Size: Concrete 4' x 4' x 0.5'

**RISER PIPE**
Type: Sch 40 PVC
Diameter: 4"
Total Length (TOC to TOS): 17.49 FT
Ventilated Cap: ☒ Yes ☐ No
O-Rings For Threads: ☒ Yes ☐ No

**GROUT**
Composition & Amount: 4.5 Bags Portland Cement (Type I/II), Quik-Gel and water
Tremied: ☐ Yes ☒ No (see calcs on attached)
Interval BGS ____
**CENTRALIZERS**: ☐ Yes ☒ No
Depth(s) ____

**SEAL**
Type: EnviroPlug 3/8" Bentonite Pellets
Source: Wyoming Bentonite
Setup/Hydration Time: 15 min / 6" Lift
Volume Fluid Added: 5-gal
Tremied: ☐ Yes ☒ No

**FILTER PACK**
Type: Filter media GP # 2
Amount Used: 9.5 (0.5 cu ft bags)
Tremied: ☐ Yes ☒ No
Source: Southern Products & Silica
Gr Size Dist: 0.80 - 1.20 mm

**SCREEN**
Type: Sch 40 PVC
Diameter: 4"
Slot Size: 0.01"
Interval BGS: 14.95' to 24.95'

**SUMP**
Interval BGS: 24.95' to 25.05'
Type of Bottom Cap: 0.1 ' PVC

**BACKFILL PLUG**
Material: N/A
Setup/Hydration Time ____
Tremied: ☐ Yes ☐ No

GROUT Volume

**Bore hole volume**

$V = [(D^2 \times \pi)/4] \times L$

$= [(0.8)^2 \times 3.142)/4] \times 9.8$

$= 4.6 \text{ FT}^3$

$4.6 \text{ FT}^3 \times 7.48 \text{ gal}/\text{FT}^3 = 34.4 \text{ gal}$

**well casing volume**

$V = [(D^2 \times \pi)/4] \times 9.8$

$= 0.84 \text{ FT}^3$

$0.84 \text{ FT}^3 \times 7.48 \text{ gal}/\text{FT}^3 = 6.3 \text{ gal}$

$34.4 \text{ gal} - 6.3 \text{ gal} = 28.1 \text{ gal}$

$\frac{28.1 \text{ gal}}{7 \text{ gal/bag}} =$ 4 bags cement

SAND volume

**Borehole volume**

$V = [(D^2 \times \pi)/4] \times L$

$= [(0.8)^2 \times 3.142/4] \times 13$

$= 6.5 \text{ FT}^3$

**well casing volume**

$V = [(D^2 \times \pi)/4] \times 13$

$= [(0.33^2) \times \pi/4] \times 13$

$= 1.1 \text{ FT}^3$

$6.5 \text{ FT}^3 - 1.1 \text{ FT}^3 = 5.4 \text{ FT}^3$

$\frac{5.4 \text{ FT}^3}{0.5 \text{ FT}^3/\text{bag}} =$ 11 bags SAND

# **ENVIROPLUG®** TABLETS and COATED **ENVIROPLUG®** TABLETS

Certified to NSF/ANSI 60

Product Information

## ENVIROPLUG® TABLETS

Description

**ENVIROPLUG®** TABLETS are manufactured for use in piezometer holes, monitor wells and other sealing and plugging applications and are available in 1/2", 3/8", and 1/4" sizes. **ENVIROPLUG®** TABLETS swell in water to more than 10 times their original volume.

Characteristics

- Clean, dust-free and easy to handle
- Non-toxic, non-polluting
- Permeability — 1 x 10 –8 to 1 x 10 –9 cm/sec
- Make-Up — Sodium Montmorillonite
- Bulk Density — 75 to 80 pounds per cubic foot
- Color — Gray to grayish tan

Application

**ENVIROPLUG®** TABLETS should be poured directly into the hole or may be placed by the tremie method. Since the result desired is actually a "bentonite pack", some care must be used in placing the tablets to prevent bridging, just as in gravel packing. The tablet seal or plug should be placed against a clay or other impervious formation. Tablets should be allowed to hydrate 1 to 2 hours before a bentonite grout medium is installed. If a cementitious grout is being used allow 2 to 4 hours for hydration as cement can restrict or prevent proper bentonite hydration.

## COATED ENVIROPLUG® TABLETS

Description

COATED **ENVIROPLUG®** TABLETS allow for deeper, more predictable placement of tablets. The coated exterior prevents the "sticky rind" from forming once water contacts the bentonite. Because hydration time is retarded, the COATED **ENVIROPLUG®** TABLETS can be placed through a tremie line assisting in predictable placement. They make a high density, low permeability buffer seal between sand packs and cement or bentonite grouts.

Application

Once in place, the COATED **ENVIROPLUG®** TABLETS should be allowed to hydrate for 4 to 6 hours before a bentonite grout medium is installed. If cementitious grout is used allow a minimum of 6 hours hydration time. They can be used in conjunction with steel or PVC casing and generate no heat while hydrating.

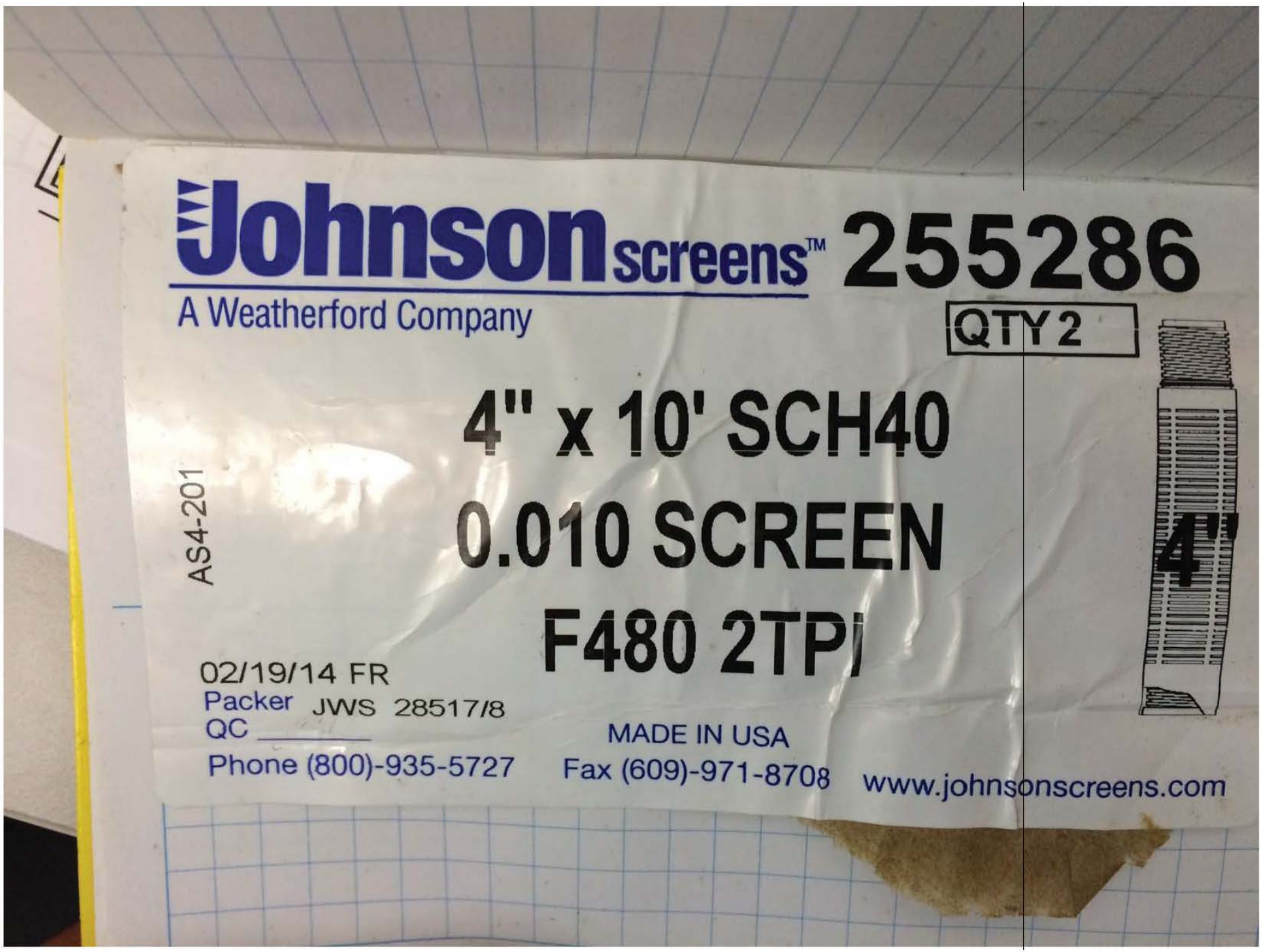
| | CASING SIZE | | |
|---|---|---|---|
| **Hole Diameter** | **2 Inch** | **4 Inch** | **6 Inch** |
| 4 inch | 0.4 gal/ft | NA | NA |
| 6 inch | 1.3 gal/ft | 0.7 gal/ft | NA |
| 8 inch | 2.3 gal/ft | 1.8 gal/ft | 0.8 gal/ft |
| 10 inch | 3.8 gal/ft | 3.2 gal/ft | 2.3 gal/ft |

Packaging

**ENVIROPLUG®** TABLETS are packaged in 50 pound plastic pails.

**WYO-BEN, INC.**, Billings, Montana 800.548.7055 406.652.6351 **www.wyoben.com**

The information and data made herein are believed to be accurate. As Wyo-Ben, Inc. has no control over use or application of this product, it is sold without warranty or guarantee of results.


Johnson screens™
A Weatherford Company
255286
QTY 2
4" x 10' SCH40
0.010 SCREEN
F480 2TPI
AS4-201
02/19/14 FR
Packer JWS 28517/8
QC _____
Phone (800)-935-5727
MADE IN USA
Fax (609)-971-8708
www.johnsonscreens.com
4"

Since 1933 Southern Products & Silica Co.

About Us Technical Data Filter Sand & Gravel Catalyst Suport
Well Gravel Packs Industrial Sand / Specialty Products
Transportation/Packaging/Pricing Contact Us/Ordering Info

P.O. Drawer 189 Hoffman, NC 28347 1.800.572.6348 910.281.3189 (fax)910.281.3815

# Material Safety Data Sheet

Back

**SOUTHERN PRODUCTS & SILICA COMPANY**
P.O. Drawer 189, Hoffman, N.C. 28347 phone 910-281-3189 fax 910-281-3815

MATERIAL SAFETY DATA SHEET
01/01/2010

PRODUCT NAMES/SYNONYMS: Washed, dried and screened sub-angular silica sands and gravel. High purity, quartzite, crystalline silica, silicon dioxide.

HAZARDOUS INGREDIENTS: High purity quartzite. Typical chemical analysis of silica content as $SiO_2$ is 99.72%.

PHYSICAL DATA:

| | |
|---|---|
| Melting Point - 2912 | Ph Effect - Not Applicable - Not Soluble |
| Boiling Point - Not Applicable - 4000F | Form - Free Flowing, Granular Solid |
| Specific Gravity - 2.60 | Color - Grayish White |
| Evaporation Rate - Not Volatile | Odor - Odorless |
| Vapor Density - Not Volatile | |
| Vapor Pressure - Not Volatile | |
| Water Solubility - Not Soluble | |

FIRE AND EXPLOSION HAZARD DATA: Contains "free silica". Prolonged, repeated, inhalation of restorable silica dust may cause silicosis or chronic fibrotic lung disease. Follow OSHA safety and health standards or as amended. AVOID BREATHING RESPIRABLE DUSTS FROM THESE PRODUCTS.

REACTIVITY DATA:
Stability - Stable Decomposition - Will not occur Incompatibility - Active fluorine compounds Polymerization - Will not occur

SPILL OR LEAK PROCEDURES:
AVOID BREATHING RESPIRABLE DUST OVER EXTENDED PERIOD. Sand and gravel may be disposed of in landfill operation or other areas where local regulations permit.

SPECIAL PROTECTION INFORMATION: Follow current OSHA safety and health standards or as amended, if exposure limits to respirable dust are likely to be exceeded. Use an OSHA approved respirator.

SPECIAL PRECAUTIONS: Avoid respiration of silica dust over an extended period of time. Use an OSHA approved respirator if exposure limits to respirable dust are likely to be exceeded. See OSHA safety and health standards to determine exposure limits.

CARCINOGENICITY: In February 1992, the National Toxicology Program (NTP), an agency of the U.S. Department of Health and Human Services, listed "respirable crystalline silica" in its 6th Annual Report on Carcinogen. In 1987, the International Agency for Research on Cancer (IARC) in its publication of Monograph 42 concluded that there is sufficient evidence of the carcinogenicity of crystalline silica to experimental animals, and there is limited evidence of the carcinogenicity of crystalline silica to humans.

Back

Since 1933 Southern Products & Silica Co.

About Us | Technical Data | Filter Sand & Gravel | Catalyst Suport
Well Gravel Packs | Industrial Sand / Specialty Products
Transportation/Packaging/Pricing | Contact Us/Ordering Info

P.O. Drawer 189 Hoffman, NC 28347 1.800.572.6348 910.281.3189 (fax)910.281.3815

**Technical Data:**

We offer hard, rounded quartzite sand and gravel, free of clay, silt, iron, mica and other foreign matter. All filtering material is washed, screen-sized, washed and sized again according to current American Water Works Association B100 Standards for Filtering Materials and is NSF listed.

View Material Safety Data Sheet

**Chemical Properties:**

| **Water Filter Sand and Gravel** | | **Typical Chemical Analysis (% By Weight)** | |
|---|---|---|---|
| **Filter Sand** | | Loss on Ignition | 0.16 |
| Effective Size | Uniformity Coefficient | Sulfur as $SO_3$ | 0.01 |
| .45mm-.55mm | U.C. 1.6 Max | Aluminum as $AI_2O_3$ | 0.04 |
| .80mm-1.20mm | U.C. 1.6 Max | Iron as $Fe_2O_3$ | 0.05 |
| 2mm-3mm | U.C. 1.6 Max | Calcium as CaO | 0.02 |
| **Filter Gravel** | | Manganese as $MnO_2$ | <0.01 |
| 2 1/2 x 1 1/2 | 3/4 x 1/2 | Magnesium as MgO | 0.01 |
| 1 1/2 x 1 | 1/2 x 1/4 | **Silica as $SiO_2$** | **99.72** |
| 1 1/2 x 3/4 | 3/8 x 3/16 | Titanium as $TiO_2$ | 0.01 |
| 1 x 5/8 | 1/4 x 1/8 | Total Carbon | 0.09 |
| 1 x 1/2 | 3/16 x #10 | Carbonate as $CaCO_3$ | <0.01 |
| 5/8 x 3/8 | #5 x #16 | | |

| **Quartz Pebbles for Catalyst Support** |
|---|
| 1 1/4 x 3/4 |

| **Well Gravel Packs** | |
|---|---|
| Product | Approximate Sieve Size |
| Gravel Pack #1 | 16 - 40 |
| | |

EMDF Monitoring Well Filter Pack Material is Gravel Pack #2 from Southern Products &

| | |
|---|---|
| Gravel Pack #1A | 12 - 40 |
| Gravel Pack #2 | 8 - 30 |
| Gravel Pack #3 | 5 - 16 |
| Gravel Pack #4 | 4 - 10 |

| Industrial Sand | |
|---|---|
| Grade | Approximate Sieve Size |
| Extra Fine | 25 - 70 |
| Fine | 12 - 40 |
| Medium | 8 - 30 |
| Coarse | 5 - 16 |

**Geothermal Sand**

Our silica sands have been used extensively in geothermal applications and are NSF listed.

**Epoxy Aggregates**

Available in various sizes.

**Assurance of Quality**

Full service laboratory testing continually monitors sand & gravel specifications for compliance with standards. All filtering materials meet current AWWA B100 standards and is NSF listed. Certified testing analysis is available on all filter sand and gravel shipments.

**Transportation**

All material can be shipped by truck, bagged or bulk.

**Packaging**

Products are bagged in .5 cu. ft. or 1.0 cu. ft., plastic bags, or 3000 lb. super sacks. All material is quoted with pallet and stretch wrap.

**Pricing**

Prices for all materials depend on selected packaging options. Prices are quoted F.O.B. Hoffman, NC.

**Ordering Information**

Our sales staff will be pleased to assist you between the hours of 7:30 a.m. and 4:30 p.m., Monday - Friday. Contact us here.

# EXHIBIT A.12:
# WELL DEVELOPMENT LOGS

This page intentionally left blank.

**ALLIANT CORPORATION**

## Well Development Log



| | | | |
|---|---|---|---|
| Project Number: | 4301 | | |
| Project Name: | EMDF - Limited Phase I Site Characterization | Site ID: | EMDF |
| Form Completed by: | R. Stout | Location ID: | GW-968 |
| Well Developed by/firm: | M&W Drilling/Alliant Corporation | Date Started: | 11/5/14 |

### Monitoring Well Information

| | | | | | |
|---|---|---|---|---|---|
| Development Method: | Surging, pumping | Screen Height (ft): | 12.9 (from GS) | Beginning Measurements (FTOC) | |
| Development Equipment: | 4" Surge blocks, | Filter pack length (ft): | 82.5 (Incl. 10' Sump) | Depth to Water (ft): | 1.35 |
| and Grundfos pump (Rediflo) | | Casing Diameter (in): | 4 | Total depth of Well (ft): | 95.20 |
| | | | | Water Column (ft): | 93.85 |

### Monitoring Well Purge Calculations

**Volume of Water in Casing:**

Gallons/foot = 0.041 x $d^2$, where casing diameter in inches = (0.041 x $(4)^2$) = 0.656 gal/ft — 2.624

Well Volume (gallons) = Water Column (ft) x Gal/ft = 93.85 ft x 0.656 gal/ft = 61.57 gallons — 139.07

**Volume of Water in Filter Pack:**

Gallons/foot = 0.041 x ($D^2$ - $d^2$), where D is total borehole diameter in inches & d is casing diameter in inches = 0.041 x ($(8)^2$- $(4)^2$) = 1.968 gal/ft

Filter Pack Volume (gal) = (the less of the filter pack length or water column) x gal/ft x porosity (0.3) = 82.5 ft x (3.444) gal/ft x 0.3 = 48.71 gal

Blue= automatically calculated
Yellow= you have to input

**Purge Well Volume:** Purge well volume = Filter pack volume + well volume = 48.71 gal + 61.57 gal = 110.27 gal

| 1 x Purge Well Volume | 2 x Purge Well Volume | 3 x Purge Well Volume | 4 x Purge Well Volume | 5 x Purge Well Volume |
|---|---|---|---|---|
| 110.3 gal | 220.5 gal | 330.8 gal | 441.1 gal | 551.4 gal |

### Development Record

| Date | Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/5/14 | 0753 | 0 | 1.35 | >800 | Gray,Cloudy | 13.84 | 6.47 | 0.237 | 7.29 | 138 | |
| 11/5/14 | 0755 | 5 | 15.51 | >800 | Gray,Cloudy | 14.21 | 6.77 | 0.22 | 1.6 | 132 | |
| 11/5/14 | 0757 | 10 | 15.6 | >800 | Gray,Cloudy | 14.36 | 6.76 | 0.219 | 1.52 | 134 | |
| 11/5/14 | 0759 | 20 | 17.35 | >800 | Gray,Cloudy | 14.47 | 6.74 | 0.217 | 4.6 | 129 | |
| 11/5/14 | 0803 | 30 | 21.56 | >800 | Gray,Cloudy | 14.48 | 6.77 | 0.214 | 6.6 | 119 | |
| 11/5/14 | 0805 | 35 | 24.28 | >800 | Gray,Cloudy | 14.48 | 6.75 | 0.209 | 6.19 | 107 | |
| 11/5/14 | 0808 | 45 | 29.09 | >800 | Gray,Cloudy | 14.49 | 6.71 | 0.206 | 3.89 | 103 | |
| 11/5/14 | 0812 | 55 | 32.67 | >800 | Gray,Cloudy | 14.58 | 6.78 | 0.203 | 2.11 | 101 | |
| 11/5/14 | 0825 | 70 | 42.61 | >800 | Gray,Cloudy | 15.24 | 6.68 | 0.206 | 2.73 | 112 | Stop pump |
| 11/5/14 | 0836 | 85 | 53.50 | >800 | Gray,Cloudy | 14.89 | 6.76 | 0.192 | 2.48 | 87 | |
| 11/5/14 | 0845 | 100 | 57.25 | >800 | Gray,Cloudy | 14.57 | 6.68 | 0.182 | 3.47 | 52 | |
| 11/5/14 | 0850 | 115 | 62.19 | >800 | Gray,Cloudy | 14.92 | 6.65 | 0.19 | 2.19 | 41 | |
| 11/5/14 | 0854 | 130 | 66.80 | >800 | Gray,Cloudy | 14.96 | 6.65 | 0.179 | 3.79 | 43 | |
| 11/5/14 | 0859 | 145 | 75.01 | >800 | Gray,Cloudy | 14.87 | 6.67 | 0.194 | 3.51 | 49 | |
| 11/5/14 | 0904 | 160 | 83.15 | >800 | Gray,Cloudy | 14.9 | 6.86 | 0.214 | 2.09 | 48 | |
| 11/5/14 | 0914 | 175 | 84.70 | >800 | Gray,Cloudy | 14.58 | 7.01 | 0.175 | 2.48 | 70 | Stop pump |
| 11/5/14 | 0922 | 190 | 86.10 | 177 | Clearing | 14.86 | 7.04 | 0.166 | 6.51 | 75 | Water clearing, Stop pump |
| 11/5/14 | 0937 | 205 | 85.20 | 91.3 | Clearing | 14.74 | 6.99 | 0.164 | 5.65 | 65 | Water clearing, Stop pump |
| 11/5/14 | 1010 | 220 | 70.70 | 60.5 | Clearing | 14.75 | 6.82 | 0.163 | 6.23 | 84 | Water clearing |
| 11/5/14 | 1017 | 235 | 83.81 | 125 | Clearing | 14.84 | 6.77 | 0.16 | 6.46 | 75 | Water clearing |
| | | | | | | | | | | | |
| | See Next Page | | | | | | | | | | |

ALLIANT CORPORATION

**Well Development Log (Continuation)** 

Site ID: EMDF
Location ID: GW-968
Date Started: 11/5/2014

**Development Record (continuation)**

| Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 1028 | 250 | 85.01 | 48.6 | Clear | 15.14 | 6.72 | 0.163 | 5.61 | 79 | Stop pump |
| 1047 | 265 | 81.64 | 22.2 | Clear | 14.83 | 6.73 | 0.162 | 7.38 | 80 | |
| 1053 | 280 | 85.12 | 57.5 | Clear | 15.00 | 6.68 | 0.161 | 5.43 | 87 | |
| 1103 | 295 | 84.80 | 46 | Clear | 15.14 | 6.59 | 0.162 | 6.15 | 86 | Surge pump in well. Stop at 1107 |
| 1109 | 310 | 84.85 | 404 | cloudy | 15.15 | 6.67 | 0.162 | 5.81 | 74 | Stop pump at 1119 |
| 1127 | 325 | 83.91 | 121 | Clearing | 14.85 | 6.62 | 0.162 | 6.08 | 87 | |
| 1134 | 340 | 85.01 | 57.7 | Clear | 15.08 | 6.58 | 0.163 | 6.23 | 86 | |
| 1144 | 355 | 84.70 | 57.7 | Clear | 15.21 | 6.61 | 0.162 | 8.44 | 87 | |
| 1154 | 370 | 84.70 | 46.7 | Clear | 15.04 | 6.46 | 0.075 | 6.08 | 30 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Water Added: type_____ None
Chemical Added: type_____ None
Range and Average Discharge Rate: 370 gal in 150 min or 2.5 gal/min
Maximum Drawdown during Development: 84.7' at 2.1 gpm.
Disposition of Development Water: Drums Tank Other (Discharged to the ground)
Number of Containers for Development Water: None

Comments: Maxium drawdown was 86.10' (FTOC) - 1.35' (Original Water Level) = 84.7' at 0922.

Final Measurements (BTOC)

Total depth of Well (ft): 95.2 ft (includes 10 ft Sump)

Date Completed: 11/5/2014

Hours Developed: 4 hours

n:\shared\common\damgroup\fld_forms\Alliant Well Development Form GW968_141105.xls/Final Page/12/5/2014

## ALLIANT CORPORATION

**Well Development Log** **Page 1 of 1**

| | | | |
|---|---|---|---|
| Project Number: | 4301 | | |
| Project Name: | EMDF - Limited Phase I Site Characterization | Site ID: | EMDF |
| Form Completed by: | R. Stout | Location ID: | GW-969 |
| Well Developed by/firm: | M&W Drilling/Alliant Corporation | Date Started: | 9/30/14 |

**Monitoring Well Information**

| | | | | | |
|---|---|---|---|---|---|
| Development Method: | Surging, pumping, bailing | Screen Height (ft): | 8.4 (from GS) | Beginning Measurements (FTOC) | |
| Development Equipment: | 4" Surge blocks, | Filter pack length (ft): | 7.9 | Depth to Water (ft): | 2.59 |
| Whaler Pump, 1-gal Teflon Bailer | | Casing Diameter (in): | 4 | Total depth of Well (ft): | 13.5 |
| | | | | Water Column (ft): | 10.91 |

**Monitoring Well Purge Calculations**

**Volume of Water in Casing:**

Gallons/foot = 0.041 x $d^2$, where casing diameter in inches = (0.041 x $(4)^2$) = 0.656 gal/ft 2.624

Well Volume (gallons) = Water Column (ft) x Gal/ft = 10.91 ft x 0.656 gal/ft = 7.16 gallons 139.072

**Volume of Water in Filter Pack:**

Gallons/foot = 0.041 x ($D^2$ - $d^2$), where D is total borehole diameter in inches & d is casing diameter in inches = 0.041 x ($(10)^2$- $(4)^2$) = 3.44 gal/ft.

Filter Pack Volume (gal) = (the less of the filter pack length or water column) x gal/ft x porosity (0.3) = (7.9) ft x (3.44) gal/ft x 0.3 = 8.15 gal

**Purge Well Volume:** Purge Well Volume = Filter pack volume + well volume = 8.15 + 7.16 = 15.31 gal

| 1 x Purge Well Volume | 2 x Purge Well Volume | 3 x Purge Well Volume | 4 x Purge Well Volume | 5 x Purge Well Volume |
|---|---|---|---|---|
| 15.3 | 30.6 | 45.9 | 61.2 | 76.5 |

**Development Record**

| Date | Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/30/14 | 1230 | 8 | -- | -- | -- | -- | -- | -- | -- | -- | Pumped dry |
| 10/1/14 | 1430 | 12 | -- | -- | -- | -- | -- | -- | -- | -- | Pumped dry |
| 10/7/14 | 910 | 0 | 2.59 | 51.7 | Cloudy | 17.54 | 5.90 | 0.210 | 5.52 | 144 | |
| 10/7/14 | 912 | 5 | 12.52 | 13.6 | Clearing | 18.70 | 5.80 | 0.164 | 4.43 | 109 | |
| 10/7/14 | 915 | 9 | 14.97 | 529 | Cloudy | 17.98 | 5.78 | 0.113 | 3.97 | 106 | Pumped dry |
| 10/7/14 | 924 | 14 | 15.24 | 800 | Cloudy | 17.71 | 5.76 | 0.169 | 4.36 | 109 | Pumped dry |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

-- No reading obtained.

**ALLIANT CORPORATION**

## Well Development Log



| | | | |
|---|---|---|---|
| Project Number: | 4301 | | |
| Project Name: | EMDF - Limited Phase I Site Characterization | Site ID: | EMDF |
| Form Completed by: | R. Stout | Location ID: | GW-971 |
| Well Developed by/firm: | M&W Drilling/Alliant Corporation | Date Started: | 9/22/14 |

### Monitoring Well Information

| | | | | | |
|---|---|---|---|---|---|
| Development Method: | Surging, pumping, bailing | Screen Height (ft): | 13.2 (from GS) | Beginning Measurements (FTOC) | |
| Development Equipment: | 4" Surge blocks, | Filter pack length (ft): | 11.85 | Depth to Water (ft): | 16.7 |
| Whaler Pump, 1-gal Teflon Bailer | | Casing Diameter (in): | 4 | Total depth of Well (ft): | 23.3 |
| | | | | Water Column (ft): | 6.6 |

### Monitoring Well Purge Calculations

**Volume of Water in Casing:**

Gallons/foot = 0.041 x $d^2$, where casing diameter in inches = (0.041 x $(4)^2$) = 0.656 gal/ft — 2.624

Well Volume (gallons) = Water Column (ft) x Gal/ft = 6.6 ft x 0.656 gal/ft = 4.33 gallons — 139.072

**Volume of Water in Filter Pack:**

Gallons/foot = 0.041 x ($D^2$ - $d^2$), where D is total borehole diameter in inches & d is casing diameter in inches = 0.041 x $((10)^2$- $(4)^2)$ = 3.444 gal/ft

Filter Pack Volume (gal) = (the less of the filter pack length or water column) x gal/ft x porosity (0.3) = 6.6 ft x (3.444) gal/ft x 0.3 = 6.82 gal

Blue= automatically calculated
Yellow= you have to input

**Purge Well Volume:** Purge well volume = Filter pack volume + well volume = 6.82 gal + 4.33 gal = 11.15 gal

| 1 x Purge Well Volume | 2 x Purge Well Volume | 3 x Purge Well Volume | 4 x Purge Well Volume | 5 x Purge Well Volume |
|---|---|---|---|---|
| 11.1 gal | 22.3 gal | 33.4 gal | 44.6 gal | 55.7 gal |

### Development Record

| Date | Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/22/14 | 1308 | 2.5 | 16.7 | -- | Brown | -- | -- | -- | -- | -- | Very turbid |
| 9/22/14 | 1313 | 5 | 19.98 | -- | Brown | -- | -- | -- | -- | -- | Very turbid |
| 9/22/14 | 1323 | 7.5 | 21.26 | -- | Light brown | -- | -- | -- | -- | -- | Less turbid |
| 9/22/14 | 1328 | 10 | 22.2 | -- | Light brown | -- | -- | -- | -- | -- | Less turbid |
| 9/22/14 | 1333 | 12.5 | 23.35 | -- | Light brown | -- | -- | -- | -- | -- | Less turbid |
| 9/22/14 | 1338 | 13.5 | 24.01 | -- | Light brown | -- | -- | -- | -- | -- | Less turbid |
| 9/22/14 | 1343 | 15 | 24.06 | -- | Light brown | -- | -- | -- | -- | -- | Less turbid |
| 9/22/14 | 1345 | 15.5 | 24.11 | -- | Light brown | -- | -- | -- | -- | -- | Well pumped dry |
| 9/29/14 | 1535 | 4 | 19.65 | 585 | cloudy | 22.90 | 4.86 | 0.158 | -- | -- | |
| 9/29/14 | 1543 | 6.5 | 21.76 | 399 | cloudy | 20.07 | 4.46 | 0.068 | -- | -- | |
| 9/29/14 | 1552 | 10 | -- | 800 | Very Cloudy | 17.41 | 4.54 | 0.076 | -- | -- | Well pumped dry |
| 9/30/14 | 1520 | 5 | 24.21 | 800+ | Very turbid | 15.74 | 4.75 | 0.096 | 6.21 | 175 | Initial depth to water 19.72' |
| 9/30/14 | 1528 | 8 | 24.34 | 432 | Turbid | 15.46 | 4.55 | 0.088 | 7.28 | 192 | |
| 9/30/14 | 1533 | 10 | 25.72 | 300 | | 15.43 | 4.66 | 0.103 | 4.66 | 153 | Well pumped dry |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

-- No reading obtained.

# ALLIANT CORPORATION

**Well Development Log** **Page 1 of 1**

| | | | |
|---|---|---|---|
| Project Number: | 4301 | | |
| Project Name: | EMDF - Limited Phase I Site Characterization | Site ID: | EMDF |
| Form Completed by: | R. Stout | Location ID: | GW-973 |
| Well Developed by/firm: | M&W Drilling/Alliant Corporation | Date Started: | 9/30/14 |

## Monitoring Well Information

| | | | | | |
|---|---|---|---|---|---|
| Development Method: | Surging, pumping, bailing | Screen Height (ft): | 12.9 (from GS) | Beginning Measurements (FTOC) | |
| Development Equipment: | 4" Surge blocks, | Filter pack length (ft): | 12.6 | Depth to Water (ft): | 12.36 |
| Whaler Pump, 1-gal Teflon Bailer | | Casing Diameter (in): | 4 | Total depth of Well (ft): | 23.00 |
| | | | | Water Column (ft): | 10.64 |

## Monitoring Well Purge Calculations

**Volume of Water in Casing:**

Gallons/foot = 0.041 x $d^2$, where casing diameter in inches = (0.041 x $(4)^2$) = 0.656 gal/ft — 2.624

Well Volume (gallons) = Water Column (ft) x Gal/ft = 10.64 ft x 0.656 gal/ft = 6.98 gallons — 139.072

**Volume of Water in Filter Pack:**

Gallons/foot = 0.041 x ($D^2$ - $d^2$), where D is total borehole diameter in inches & d is casing diameter in inches = 0.041 x ($(10)^2$- $(4)^2$) = 3.444 gal/ft

Filter Pack Volume (gal) = (the less of the filter pack length or water column) x gal/ft x porosity (0.3) = 10.64 ft x (3.444) gal/ft x 0.3 = 10.99 gal

Blue= automatically calculated
Yellow= you have to input

**Purge Well Volume:** Purge well volume = Filter pack volume + well volume = 10.99 gal + 6.98 gal = 17.97 gal

| 1 x Purge Well Volume | 2 x Purge Well Volume | 3 x Purge Well Volume | 4 x Purge Well Volume | 5 x Purge Well Volume |
|---|---|---|---|---|
| 18.0 gal | 35.9 gal | 53.9 gal | 71.9 gal | 89.9 gal |

## Development Record

| Date | Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/30/14 | 1420 | 2.5 | 12.36 | 13.9 | Slightly turbid | 16.24 | 5.07 | 0.218 | 3.48 | 148 | |
| 9/30/14 | 1440 | 10 | 20.2 | 11.2 | Clear | 16.6 | 4.75 | 0.196 | 4.75 | 153 | |
| 9/30/14 | 1450 | 15 | 21.77 | 29.8 | Slightly turbid | 15.88 | 4.65 | 0.177 | 8.7 | 135 | |
| 9/30/14 | 1454 | 20 | 22.79 | 148 | Turbid | 15.65 | 4.61 | 0.192 | 2.43 | 93 | |
| 9/30/14 | 1500 | 24 | 25.6 | -- | -- | -- | -- | -- | -- | -- | Well pumped dry |
| 10/1/14 | 1430 | 20 | -- | -- | -- | -- | -- | -- | -- | -- | Well pumped dry |
| 10/2/14 | 1042 | 0 | 12.92 | 145 | Cloudy | 18.93 | 6.55 | 0.128 | 6.11 | 87 | |
| 10/2/14 | 1045 | 5 | 18.81 | 26.9 | Clearing | 17.8 | 6.21 | 0.075 | 11.53 | 108 | |
| 10/2/14 | 1047 | 10 | 22.15 | 61 | Cloudy | 16.97 | 6.13 | 0.071 | 11.45 | 121 | |
| 10/2/14 | 1050 | 15 | 24.44 | 45 | Clearing | 16.41 | 6.07 | 0.102 | 5.96 | 126 | |
| 10/2/14 | 1052 | 19 | -- | -- | -- | -- | -- | -- | -- | -- | Well pumped dry |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

-- No reading obtained.

**ALLIANT CORPORATION**

## Well Development Log



| | | | |
|---|---|---|---|
| Project Number: | 4301 | | |
| Project Name: | EMDF - Limited Phase I Site Characterization | Site ID: | EMDF |
| Form Completed by: | R. Stout | Location ID: | GW-975 |
| Well Developed by/firm: | M&W Drilling/Alliant Corporation | Date Started: | 9/30/14 |

### Monitoring Well Information

| | | | | | |
|---|---|---|---|---|---|
| Development Method: | Surging, pumping, bailing | Screen Height (ft): | 4.9 (from GS) | Beginning Measurements (FTOC) | |
| Development Equipment: | 4" Surge blocks, | Filter pack length (ft): | 6.0 | Depth to Water (ft): | 9.68 |
| Whaler Pump, 1-gal Teflon Bailer | | Casing Diameter (in): | 4 | Total depth of Well (ft): | 12.32 |
| | | | | Water Column (ft): | 2.64 |

### Monitoring Well Purge Calculations

**Volume of Water in Casing:**

Gallons/foot = 0.041 x $d^2$, where casing diameter in inches = (0.041 x $(4)^2$) = 0.656 gal/ft 2.624

Well Volume (gallons) = Water Column (ft) x Gal/ft = 2.64 ft x 0.656 gal/ft = 1.73 gallons 139.072

**Volume of Water in Filter Pack:**

Gallons/foot = 0.041 x ($D^2$ - $d^2$), where D is total borehole diameter in inches & d is casing diameter in inches = 0.041 x $((10)^2$- $(4)^2)$ = 3.444 gal/ft

Filter Pack Volume (gal) = (the less of the filter pack length or water column) x gal/ft x porosity (0.3) = 2.64 ft x (3.444) gal/ft x 0.3 = 2.73 gal

Blue= automatically calculated
Yellow= you have to input

**Purge Well Volume:** Purge well volume = Filter pack volume + well volume = 2.73 gal + 1.73 gal = 4.46 gal

| 1 x Purge Well Volume | 2 x Purge Well Volume | 3 x Purge Well Volume | 4 x Purge Well Volume | 5 x Purge Well Volume |
|---|---|---|---|---|
| 4.5 gal | 8.9 gal | 13.4 gal | 17.8 gal | 22.3 gal |

### Development Record

| Date | Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/30/14 | 1205 | 2 | -- | -- | -- | -- | -- | -- | -- | -- | Well pumped dry |
| 10/1/14 | 1002 | 0.5 | 10.92 | 800 | Cloudy | 18.16 | 6.42 | 0.582 | 7.4 | 86 | |
| 10/1/14 | 1008 | 1.5 | -- | -- | -- | -- | -- | -- | -- | -- | Well bailed dry |
| 10/6/14 | 0930 | 0.8 | 10.42 | 0 | Clear | 16.78 | 6.56 | 0.599 | 6.22 | 136 | |
| 10/6/14 | 0933 | 1 | 12.01 | 800 | Cloudy | 16.74 | 6.71 | 0.545 | 6.61 | 129 | |
| 10/6/14 | 0936 | 2 | -- | -- | -- | -- | -- | -- | -- | -- | Well bailed dry |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

-- No reading obtained.

## ALLIANT CORPORATION

**Well Development Log** **Page 1 of 1**

| | | | |
|---|---|---|---|
| Project Number: | 4301 | | |
| Project Name: | EMDF - Limited Phase I Site Characterization | Site ID: | EMDF |
| Form Completed by: | R. Stout | Location ID: | GW-977 |
| Well Developed by/firm: | M&W Drilling/Alliant Corporation | Date Started: | 9/30/14 |

**Monitoring Well Information**

| | | | | | |
|---|---|---|---|---|---|
| Development Method: | Surging, pumping, bailing | Screen Height (ft): | 14.95 (from GS) | Beginning Measurements (FTOC) | |
| Development Equipment: | 4" Surge blocks, | Filter pack length (ft): | 12.95 | Depth to Water (ft): | 27.42 |
| Whaler Pump, 1-gal Teflon Bailer | | Casing Diameter (in): | 4 | Total depth of Well (ft): | 27.42 |
| | | | | Water Column (ft): | 0.00 |

**Monitoring Well Purge Calculations**

**Volume of Water in Casing:**

Gallons/foot = 0.041 x $d^2$, where casing diameter in inches = (0.041 x $(4)^2$) = 0.656 gal/ft 2.624

Well Volume (gallons) = Water Column (ft) x Gal/ft = 0 ft x 0.656 gal/ft = 0.00 gallons 139.072

**Volume of Water in Filter Pack:**

Gallons/foot = 0.041 x ($D^2$ - $d^2$), where D is total borehole diameter in inches & d is casing diameter in inches = 0.041 x ($(10)^2$- $(4)^2$) = 3.444 gal/ft

Filter Pack Volume (gal) = (the less of the filter pack length or water column) x gal/ft x porosity (0.3) = 0 ft x (3.444) gal/ft x 0.3 = 0.00 gal

Blue= automatically calculated
Yellow= you have to input

**Purge Well Volume:** Purge well volume = Filter pack volume + well volume = 0.00 gal + 0.00 gal = 0.00 gal

| 1 x Purge Well Volume | 2 x Purge Well Volume | 3 x Purge Well Volume | 4 x Purge Well Volume | 5 x Purge Well Volume |
|---|---|---|---|---|
| 0.0 gal | 0.0 gal | 0.0 gal | 0.0 gal | 0.0 gal |

**Development Record**

| Date | Time (24 hrs) | Volume Removed (gal) | Water Level (ft) (TOC) | Turbidity (NTU) | Clarity (color) | Temp. (C) | pH (Std Units) | Conductivity (mS/cm) | D.O. (mg/L) | Redox (mV) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/30/14 | 1510 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Well is dry |
| 10/2/14 | 0755 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Well is dry |
| 10/6/14 | 0836 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Well is dry |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

-- No reading obtained.

This page intentionally left blank.

# EXHIBIT A.13:
# CUTTHROAT FLUME DISCHARGE RATING TABLES AND LONG-TERM RUNOFF HYDROGRAPHS

This page intentionally left blank.

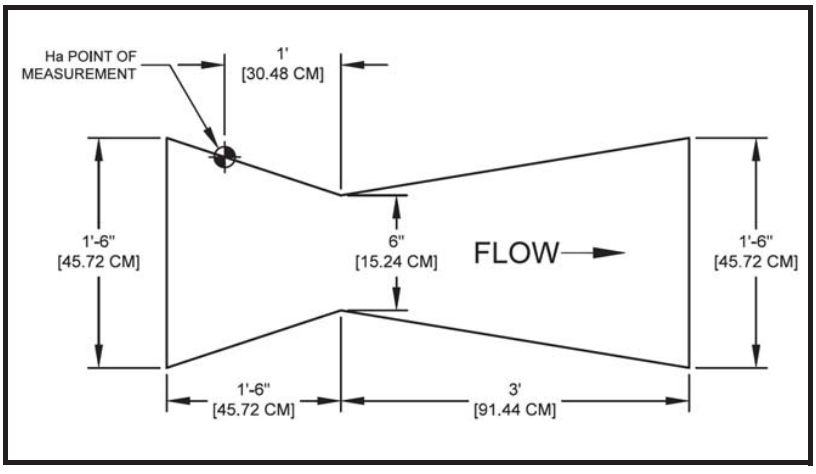
# 54-Inch L x 6-Inch W Cutthroat Flume Discharge Table

70% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 1.96 $H_{ft.}^{1.72}$ GPM = 879.6 $H_{ft.}^{1.72}$ MGD = 1.267 $H_{ft.}^{1.72}$

Formulas (H in meters): L/S = 428.2 $H_{m}^{1.72}$ M3/HR = 1541 $H_{m}^{1.72}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 0.01 | 0.12 | 0.0030 | Excessive error due to fluid-flow properties and boundary conditions | | | | |
| 0.02 | 0.24 | 0.0061 | | | | | |
| 0.03 | 0.36 | 0.0091 | | | | | |
| 0.04 | 0.48 | 0.0122 | | | | | |
| 0.05 | 0.60 | 0.0152 | | | | | |
| 0.06 | 0.72 | 0.0183 | | | | | |
| 0.07 | 0.84 | 0.0213 | | | | | |
| 0.08 | 0.96 | 0.0244 | | | | | |
| 0.09 | 1.08 | 0.0274 | | | | | |
| 0.10 | 1.20 | 0.0305 | 0.0373 | 16.76 | 0.0241 | 1.058 | 3.806 |
| 0.11 | 1.32 | 0.0335 | 0.0440 | 19.75 | 0.0284 | 1.246 | 4.484 |
| 0.12 | 1.44 | 0.0366 | 0.0511 | 22.94 | 0.0330 | 1.447 | 5.207 |
| 0.13 | 1.56 | 0.0396 | 0.0586 | 26.32 | 0.0379 | 1.661 | 5.976 |
| 0.14 | 1.68 | 0.0427 | 0.0666 | 29.90 | 0.0431 | 1.887 | 6.788 |
| 0.15 | 1.80 | 0.0457 | 0.0750 | 33.67 | 0.0485 | 2.124 | 7.644 |
| 0.16 | 1.92 | 0.0488 | 0.0838 | 37.62 | 0.0542 | 2.374 | 8.541 |
| 0.17 | 2.04 | 0.0518 | 0.0930 | 41.75 | 0.0601 | 2.635 | 9.480 |
| 0.18 | 2.16 | 0.0549 | 0.1026 | 46.07 | 0.0663 | 2.907 | 10.46 |
| 0.19 | 2.28 | 0.0579 | 0.1126 | 50.56 | 0.0728 | 3.190 | 11.48 |
| 0.20 | 2.40 | 0.0610 | 0.1230 | 55.22 | 0.0795 | 3.484 | 12.54 |
| 0.21 | 2.52 | 0.0640 | 0.1338 | 60.05 | 0.0865 | 3.789 | 13.63 |
| 0.22 | 2.64 | 0.0671 | 0.1450 | 65.05 | 0.0937 | 4.105 | 14.77 |
| 0.23 | 2.76 | 0.0701 | 0.1565 | 70.22 | 0.1011 | 4.431 | 15.94 |
| 0.24 | 2.88 | 0.0732 | 0.1684 | 75.56 | 0.1088 | 4.768 | 17.16 |
| 0.25 | 3.00 | 0.0762 | 0.1806 | 81.05 | 0.1167 | 5.115 | 18.40 |
| 0.26 | 3.12 | 0.0792 | 0.1932 | 86.71 | 0.1249 | 5.471 | 19.69 |
| 0.27 | 3.24 | 0.0823 | 0.2062 | 92.52 | 0.1332 | 5.838 | 21.01 |
| 0.28 | 3.36 | 0.0853 | 0.2195 | 98.50 | 0.1418 | 6.215 | 22.36 |
| 0.29 | 3.48 | 0.0884 | 0.2331 | 104.6 | 0.1507 | 6.602 | 23.75 |
| 0.30 | 3.60 | 0.0914 | 0.2471 | 110.9 | 0.1597 | 6.998 | 25.18 |




Note: Discharge is calculated to top of flume

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972
Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 54-Inch L x 6-Inch W Cutthroat Flume Discharge Table

70% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 1.96 $H_{ft.}^{1.72}$ GPM = 879.6 $H_{ft.}^{1.72}$ MGD = 1.267 $H_{ft.}^{1.72}$

Formulas (H in meters): L/S = 428.2 $H_{m}^{1.72}$ M3/HR = 1541 $H_{m}^{1.72}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 0.31 | 3.72 | 0.0945 | 0.2615 | 117.3 | 0.1690 | 7.404 | 26.64 |
| 0.32 | 3.84 | 0.0975 | 0.2761 | 123.9 | 0.1785 | 7.820 | 28.14 |
| 0.33 | 3.96 | 0.1006 | 0.2911 | 130.7 | 0.1882 | 8.245 | 29.67 |
| 0.34 | 4.08 | 0.1036 | 0.3065 | 137.5 | 0.1981 | 8.679 | 31.23 |
| 0.35 | 4.20 | 0.1067 | 0.3221 | 144.6 | 0.2082 | 9.123 | 32.83 |
| 0.36 | 4.32 | 0.1097 | 0.3381 | 151.8 | 0.2185 | 9.576 | 34.46 |
| 0.37 | 4.44 | 0.1128 | 0.3545 | 159.1 | 0.2291 | 10.04 | 36.12 |
| 0.38 | 4.56 | 0.1158 | 0.3711 | 166.5 | 0.2398 | 10.51 | 37.81 |
| 0.39 | 4.68 | 0.1189 | 0.3880 | 174.2 | 0.2508 | 10.99 | 39.54 |
| 0.40 | 4.80 | 0.1219 | 0.4053 | 181.9 | 0.2620 | 11.48 | 41.30 |
| 0.41 | 4.92 | 0.1250 | 0.4229 | 189.8 | 0.2733 | 11.98 | 43.09 |
| 0.42 | 5.04 | 0.1280 | 0.4408 | 197.8 | 0.2849 | 12.48 | 44.92 |
| 0.43 | 5.16 | 0.1311 | 0.4590 | 206.0 | 0.2967 | 13.00 | 46.77 |
| 0.44 | 5.28 | 0.1341 | 0.4775 | 214.3 | 0.3086 | 13.52 | 48.66 |
| 0.45 | 5.40 | 0.1372 | 0.4963 | 222.8 | 0.3208 | 14.06 | 50.58 |
| 0.46 | 5.52 | 0.1402 | 0.5155 | 231.3 | 0.3331 | 14.60 | 52.53 |
| 0.47 | 5.64 | 0.1433 | 0.5349 | 240.1 | 0.3457 | 15.15 | 54.51 |
| 0.48 | 5.76 | 0.1463 | 0.5546 | 248.9 | 0.3584 | 15.71 | 56.52 |
| 0.49 | 5.88 | 0.1494 | 0.5746 | 257.9 | 0.3714 | 16.27 | 58.56 |
| 0.50 | 6.00 | 0.1524 | 0.5950 | 267.0 | 0.3845 | 16.85 | 60.63 |
| 0.51 | 6.12 | 0.1554 | 0.6156 | 276.3 | 0.3978 | 17.43 | 62.73 |
| 0.52 | 6.24 | 0.1585 | 0.6365 | 285.7 | 0.4114 | 18.02 | 64.86 |
| 0.53 | 6.36 | 0.1615 | 0.6577 | 295.2 | 0.4251 | 18.63 | 67.02 |
| 0.54 | 6.48 | 0.1646 | 0.6792 | 304.8 | 0.4389 | 19.23 | 69.21 |
| 0.55 | 6.60 | 0.1676 | 0.7009 | 314.6 | 0.4530 | 19.85 | 71.43 |
| 0.56 | 6.72 | 0.1707 | 0.7230 | 324.5 | 0.4673 | 20.48 | 73.67 |
| 0.57 | 6.84 | 0.1737 | 0.7454 | 334.5 | 0.4817 | 21.11 | 75.95 |
| 0.58 | 6.96 | 0.1768 | 0.7680 | 344.7 | 0.4963 | 21.75 | 78.26 |
| 0.59 | 7.08 | 0.1798 | 0.7909 | 355.0 | 0.5112 | 22.40 | 80.59 |
| 0.60 | 7.20 | 0.1829 | 0.8141 | 365.4 | 0.5262 | 23.06 | 82.96 |
| 0.61 | 7.32 | 0.1859 | 0.8376 | 375.9 | 0.5413 | 23.72 | 85.35 |
| 0.62 | 7.44 | 0.1890 | 0.8613 | 386.6 | 0.5567 | 24.39 | 87.77 |
| 0.63 | 7.56 | 0.1920 | 0.8854 | 397.4 | 0.5722 | 25.07 | 90.22 |
| 0.64 | 7.68 | 0.1951 | 0.9097 | 408.3 | 0.5879 | 25.76 | 92.70 |
| 0.65 | 7.80 | 0.1981 | 0.9343 | 419.3 | 0.6038 | 26.46 | 95.20 |
| 0.66 | 7.92 | 0.2012 | 0.9591 | 430.5 | 0.6199 | 27.16 | 97.73 |
| 0.67 | 8.04 | 0.2042 | 0.9842 | 441.7 | 0.6361 | 27.87 | 100.3 |
| 0.68 | 8.16 | 0.2073 | 1.010 | 453.1 | 0.6525 | 28.59 | 102.9 |
| 0.69 | 8.28 | 0.2103 | 1.035 | 464.7 | 0.6691 | 29.32 | 105.5 |
| 0.70 | 8.40 | 0.2134 | 1.061 | 476.3 | 0.6859 | 30.06 | 108.1 |
| 0.71 | 8.52 | 0.2164 | 1.087 | 488.1 | 0.7028 | 30.80 | 110.8 |
| 0.72 | 8.64 | 0.2195 | 1.114 | 499.9 | 0.7199 | 31.55 | 113.5 |
| 0.73 | 8.76 | 0.2225 | 1.141 | 511.9 | 0.7372 | 32.30 | 116.2 |
| 0.74 | 8.88 | 0.2256 | 1.168 | 524.1 | 0.7547 | 33.07 | 119.0 |
| 0.75 | 9.00 | 0.2286 | 1.195 | 536.3 | 0.7723 | 33.84 | 121.8 |
| 0.76 | 9.12 | 0.2316 | 1.223 | 548.7 | 0.7901 | 34.62 | 124.6 |
| 0.77 | 9.24 | 0.2347 | 1.250 | 561.1 | 0.8081 | 35.41 | 127.4 |
| 0.78 | 9.36 | 0.2377 | 1.278 | 573.7 | 0.8262 | 36.20 | 130.3 |
| 0.79 | 9.48 | 0.2408 | 1.307 | 586.4 | 0.8445 | 37.01 | 133.2 |
| 0.80 | 9.60 | 0.2438 | 1.335 | 599.3 | 0.8630 | 37.81 | 136.1 |


Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972

Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 54-Inch L x 6-Inch W Cutthroat Flume Discharge Table

70% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 1.96 $H_{ft.}^{1.72}$ GPM = 879.6 $H_{ft.}^{1.72}$ MGD = 1.267 $H_{ft.}^{1.72}$

Formulas (H in meters): L/S = 428.2 $H_{m}^{1.72}$ M3/HR = 1541 $H_{m}^{1.72}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 0.81 | 9.72 | 0.2469 | 1.364 | 612.2 | 0.8816 | 38.63 | 139.0 |
| 0.82 | 9.84 | 0.2499 | 1.393 | 625.3 | 0.9004 | 39.46 | 142.0 |
| 0.83 | 9.96 | 0.2530 | 1.423 | 638.4 | 0.9194 | 40.29 | 145.0 |
| 0.84 | 10.08 | 0.2560 | 1.452 | 651.7 | 0.9385 | 41.13 | 148.0 |
| 0.85 | 10.20 | 0.2591 | 1.482 | 665.1 | 0.9578 | 41.97 | 151.0 |
| 0.86 | 10.32 | 0.2621 | 1.512 | 678.7 | 0.9773 | 42.82 | 154.1 |
| 0.87 | 10.44 | 0.2652 | 1.543 | 692.3 | 0.9969 | 43.68 | 157.2 |
| 0.88 | 10.56 | 0.2682 | 1.573 | 706.0 | 1.017 | 44.55 | 160.3 |
| 0.89 | 10.68 | 0.2713 | 1.604 | 719.9 | 1.037 | 45.43 | 163.4 |
| 0.90 | 10.80 | 0.2743 | 1.635 | 733.8 | 1.057 | 46.31 | 166.6 |
| 0.91 | 10.92 | 0.2774 | 1.667 | 747.9 | 1.077 | 47.20 | 169.8 |
| 0.92 | 11.04 | 0.2804 | 1.698 | 762.1 | 1.098 | 48.09 | 173.0 |
| 0.93 | 11.16 | 0.2835 | 1.730 | 776.4 | 1.118 | 48.99 | 176.3 |
| 0.94 | 11.28 | 0.2865 | 1.762 | 790.8 | 1.139 | 49.90 | 179.6 |
| 0.95 | 11.40 | 0.2896 | 1.794 | 805.4 | 1.160 | 50.82 | 182.9 |
| 0.96 | 11.52 | 0.2926 | 1.827 | 820.0 | 1.181 | 51.74 | 186.2 |
| 0.97 | 11.64 | 0.2957 | 1.860 | 834.7 | 1.202 | 52.67 | 189.5 |
| 0.98 | 11.76 | 0.2987 | 1.893 | 849.6 | 1.223 | 53.61 | 192.9 |
| 0.99 | 11.88 | 0.3018 | 1.926 | 864.6 | 1.245 | 54.56 | 196.3 |
| 1.00 | 12.00 | 0.3048 | 1.960 | 879.6 | 1.267 | 55.51 | 199.7 |
| 1.01 | 12.12 | 0.3078 | 1.994 | 894.8 | 1.289 | 56.47 | 203.2 |
| 1.02 | 12.24 | 0.3109 | 2.028 | 910.1 | 1.311 | 57.43 | 206.6 |
| 1.03 | 12.36 | 0.3139 | 2.062 | 925.5 | 1.333 | 58.40 | 210.1 |
| 1.04 | 12.48 | 0.3170 | 2.097 | 941.0 | 1.355 | 59.38 | 213.7 |
| 1.05 | 12.60 | 0.3200 | 2.132 | 956.7 | 1.378 | 60.37 | 217.2 |
| 1.06 | 12.72 | 0.3231 | 2.167 | 972.4 | 1.400 | 61.36 | 220.8 |
| 1.07 | 12.84 | 0.3261 | 2.202 | 988.2 | 1.423 | 62.36 | 224.4 |
| 1.08 | 12.96 | 0.3292 | 2.237 | 1004 | 1.446 | 63.36 | 228.0 |
| 1.09 | 13.08 | 0.3322 | 2.273 | 1020 | 1.469 | 64.38 | 231.6 |
| 1.10 | 13.20 | 0.3353 | 2.309 | 1036 | 1.492 | 65.40 | 235.3 |
| 1.11 | 13.32 | 0.3383 | 2.345 | 1053 | 1.516 | 66.42 | 239.0 |
| 1.12 | 13.44 | 0.3414 | 2.382 | 1069 | 1.539 | 67.45 | 242.7 |
| 1.13 | 13.56 | 0.3444 | 2.419 | 1085 | 1.563 | 68.49 | 246.4 |
| 1.14 | 13.68 | 0.3475 | 2.455 | 1102 | 1.587 | 69.54 | 250.2 |
| 1.15 | 13.80 | 0.3505 | 2.493 | 1119 | 1.611 | 70.59 | 254.0 |
| 1.16 | 13.92 | 0.3536 | 2.530 | 1135 | 1.635 | 71.65 | 257.8 |
| 1.17 | 14.04 | 0.3566 | 2.568 | 1152 | 1.659 | 72.72 | 261.6 |
| 1.18 | 14.16 | 0.3597 | 2.606 | 1169 | 1.684 | 73.79 | 265.5 |
| 1.19 | 14.28 | 0.3627 | 2.644 | 1186 | 1.709 | 74.87 | 269.4 |
| 1.20 | 14.40 | 0.3658 | 2.682 | 1204 | 1.733 | 75.95 | 273.3 |
| 1.21 | 14.52 | 0.3688 | 2.720 | 1221 | 1.758 | 77.04 | 277.2 |
| 1.22 | 14.64 | 0.3719 | 2.759 | 1238 | 1.783 | 78.14 | 281.2 |
| 1.23 | 14.76 | 0.3749 | 2.798 | 1256 | 1.809 | 79.25 | 285.1 |
| 1.24 | 14.88 | 0.3780 | 2.838 | 1273 | 1.834 | 80.36 | 289.1 |
| 1.25 | 15.00 | 0.3810 | 2.877 | 1291 | 1.859 | 81.48 | 293.2 |
| 1.26 | 15.12 | 0.3840 | 2.917 | 1309 | 1.885 | 82.60 | 297.2 |
| 1.27 | 15.24 | 0.3871 | 2.957 | 1327 | 1.911 | 83.73 | 301.3 |
| 1.28 | 15.36 | 0.3901 | 2.997 | 1345 | 1.937 | 84.87 | 305.4 |
| 1.29 | 15.48 | 0.3932 | 3.037 | 1363 | 1.963 | 86.01 | 309.5 |
| 1.30 | 15.60 | 0.3962 | 3.078 | 1381 | 1.989 | 87.16 | 313.6 |


Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972

Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 54-Inch L x 6-Inch W Cutthroat Flume Discharge Table

70% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 1.96 $H_{ft.}^{1.72}$ GPM = 879.6 $H_{ft.}^{1.72}$ MGD = 1.267 $H_{ft.}^{1.72}$

Formulas (H in meters): L/S = 428.2 $H_{m}^{1.72}$ M3/HR = 1541 $H_{m}^{1.72}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 1.31 | 15.72 | 0.3993 | 3.119 | 1400 | 2.016 | 88.32 | 317.8 |
| 1.32 | 15.84 | 0.4023 | 3.160 | 1418 | 2.042 | 89.48 | 322.0 |
| 1.33 | 15.96 | 0.4054 | 3.201 | 1437 | 2.069 | 90.65 | 326.2 |
| 1.34 | 16.08 | 0.4084 | 3.242 | 1455 | 2.096 | 91.83 | 330.4 |
| 1.35 | 16.20 | 0.4115 | 3.284 | 1474 | 2.123 | 93.01 | 334.7 |
| 1.36 | 16.32 | 0.4145 | 3.326 | 1493 | 2.150 | 94.20 | 338.9 |
| 1.37 | 16.44 | 0.4176 | 3.368 | 1512 | 2.177 | 95.39 | 343.2 |
| 1.38 | 16.56 | 0.4206 | 3.411 | 1531 | 2.204 | 96.59 | 347.6 |
| 1.39 | 16.68 | 0.4237 | 3.453 | 1550 | 2.232 | 97.80 | 351.9 |
| 1.40 | 16.80 | 0.4267 | 3.496 | 1569 | 2.260 | 99.01 | 356.3 |
| 1.41 | 16.92 | 0.4298 | 3.539 | 1588 | 2.287 | 100.2 | 360.7 |
| 1.42 | 17.04 | 0.4328 | 3.583 | 1608 | 2.315 | 101.5 | 365.1 |
| 1.43 | 17.16 | 0.4359 | 3.626 | 1627 | 2.344 | 102.7 | 369.5 |
| 1.44 | 17.28 | 0.4389 | 3.670 | 1647 | 2.372 | 103.9 | 374.0 |
| 1.45 | 17.40 | 0.4420 | 3.714 | 1667 | 2.400 | 105.2 | 378.4 |
| 1.46 | 17.52 | 0.4450 | 3.758 | 1687 | 2.429 | 106.4 | 382.9 |
| 1.47 | 17.64 | 0.4481 | 3.802 | 1706 | 2.457 | 107.7 | 387.5 |
| 1.48 | 17.76 | 0.4511 | 3.847 | 1726 | 2.486 | 108.9 | 392.0 |
| 1.49 | 17.88 | 0.4542 | 3.892 | 1747 | 2.515 | 110.2 | 396.6 |
| 1.50 | 18.00 | 0.4572 | 3.937 | 1767 | 2.544 | 111.5 | 401.2 |

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972
Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

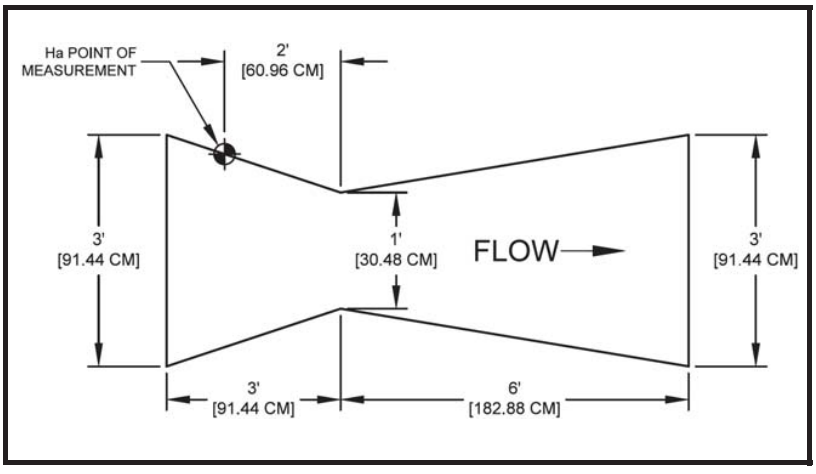
# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

80% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 0.01 | 0.12 | 0.0030 | Excessive error due to fluid-flow properties and boundary conditions | | | | |
| 0.02 | 0.24 | 0.0061 | | | | | |
| 0.03 | 0.36 | 0.0091 | | | | | |
| 0.04 | 0.48 | 0.0122 | | | | | |
| 0.05 | 0.60 | 0.0152 | | | | | |
| 0.06 | 0.72 | 0.0183 | | | | | |
| 0.07 | 0.84 | 0.0213 | | | | | |
| 0.08 | 0.96 | 0.0244 | | | | | |
| 0.09 | 1.08 | 0.0274 | | | | | |
| 0.10 | 1.20 | 0.0305 | 0.0964 | 43.26 | 0.0623 | 2.730 | 9.823 |
| 0.11 | 1.32 | 0.0335 | 0.1119 | 50.20 | 0.0723 | 3.168 | 11.40 |
| 0.12 | 1.44 | 0.0366 | 0.1281 | 57.50 | 0.0828 | 3.628 | 13.05 |
| 0.13 | 1.56 | 0.0396 | 0.1452 | 65.14 | 0.0938 | 4.111 | 14.79 |
| 0.14 | 1.68 | 0.0427 | 0.1629 | 73.13 | 0.1053 | 4.614 | 16.60 |
| 0.15 | 1.80 | 0.0457 | 0.1815 | 81.44 | 0.1173 | 5.139 | 18.49 |
| 0.16 | 1.92 | 0.0488 | 0.2007 | 90.06 | 0.1297 | 5.683 | 20.45 |
| 0.17 | 2.04 | 0.0518 | 0.2206 | 99.00 | 0.1426 | 6.247 | 22.48 |
| 0.18 | 2.16 | 0.0549 | 0.2412 | 108.2 | 0.1559 | 6.829 | 24.57 |
| 0.19 | 2.28 | 0.0579 | 0.2624 | 117.8 | 0.1696 | 7.430 | 26.74 |
| 0.20 | 2.40 | 0.0610 | 0.2842 | 127.6 | 0.1837 | 8.049 | 28.96 |
| 0.21 | 2.52 | 0.0640 | 0.3067 | 137.7 | 0.1982 | 8.686 | 31.25 |
| 0.22 | 2.64 | 0.0671 | 0.3298 | 148.0 | 0.2131 | 9.340 | 33.61 |
| 0.23 | 2.76 | 0.0701 | 0.3535 | 158.6 | 0.2285 | 10.01 | 36.02 |
| 0.24 | 2.88 | 0.0732 | 0.3777 | 169.5 | 0.2441 | 10.70 | 38.49 |
| 0.25 | 3.00 | 0.0762 | 0.4026 | 180.7 | 0.2602 | 11.40 | 41.02 |
| 0.26 | 3.12 | 0.0792 | 0.4280 | 192.1 | 0.2766 | 12.12 | 43.61 |
| 0.27 | 3.24 | 0.0823 | 0.4539 | 203.7 | 0.2934 | 12.86 | 46.26 |
| 0.28 | 3.36 | 0.0853 | 0.4804 | 215.6 | 0.3105 | 13.61 | 48.96 |
| 0.29 | 3.48 | 0.0884 | 0.5075 | 227.8 | 0.3280 | 14.37 | 51.71 |
| 0.30 | 3.60 | 0.0914 | 0.5350 | 240.1 | 0.3458 | 15.15 | 54.52 |




Note: Discharge is calculated to top of flume

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972
Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

80% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 0.31 | 3.72 | 0.0945 | 0.5631 | 252.7 | 0.3639 | 15.95 | 57.38 |
| 0.32 | 3.84 | 0.0975 | 0.5917 | 265.6 | 0.3824 | 16.76 | 60.29 |
| 0.33 | 3.96 | 0.1006 | 0.6208 | 278.6 | 0.4012 | 17.58 | 63.26 |
| 0.34 | 4.08 | 0.1036 | 0.6504 | 291.9 | 0.4203 | 18.42 | 66.27 |
| 0.35 | 4.20 | 0.1067 | 0.6805 | 305.4 | 0.4398 | 19.27 | 69.34 |
| 0.36 | 4.32 | 0.1097 | 0.7110 | 319.1 | 0.4596 | 20.14 | 72.46 |
| 0.37 | 4.44 | 0.1128 | 0.7421 | 333.1 | 0.4796 | 21.02 | 75.62 |
| 0.38 | 4.56 | 0.1158 | 0.7736 | 347.2 | 0.5000 | 21.91 | 78.83 |
| 0.39 | 4.68 | 0.1189 | 0.8056 | 361.6 | 0.5207 | 22.82 | 82.09 |
| 0.40 | 4.80 | 0.1219 | 0.8381 | 376.1 | 0.5416 | 23.73 | 85.40 |
| 0.41 | 4.92 | 0.1250 | 0.8710 | 390.9 | 0.5629 | 24.67 | 88.75 |
| 0.42 | 5.04 | 0.1280 | 0.9044 | 405.9 | 0.5845 | 25.61 | 92.15 |
| 0.43 | 5.16 | 0.1311 | 0.9382 | 421.0 | 0.6063 | 26.57 | 95.60 |
| 0.44 | 5.28 | 0.1341 | 0.9724 | 436.4 | 0.6285 | 27.54 | 99.09 |
| 0.45 | 5.40 | 0.1372 | 1.007 | 452.0 | 0.6509 | 28.52 | 102.6 |
| 0.46 | 5.52 | 0.1402 | 1.042 | 467.8 | 0.6736 | 29.52 | 106.2 |
| 0.47 | 5.64 | 0.1433 | 1.078 | 483.7 | 0.6966 | 30.52 | 109.8 |
| 0.48 | 5.76 | 0.1463 | 1.114 | 499.9 | 0.7198 | 31.54 | 113.5 |
| 0.49 | 5.88 | 0.1494 | 1.150 | 516.2 | 0.7434 | 32.57 | 117.2 |
| 0.50 | 6.00 | 0.1524 | 1.187 | 532.7 | 0.7672 | 33.62 | 121.0 |
| 0.51 | 6.12 | 0.1554 | 1.224 | 549.5 | 0.7912 | 34.67 | 124.8 |
| 0.52 | 6.24 | 0.1585 | 1.262 | 566.4 | 0.8156 | 35.74 | 128.6 |
| 0.53 | 6.36 | 0.1615 | 1.300 | 583.4 | 0.8402 | 36.82 | 132.5 |
| 0.54 | 6.48 | 0.1646 | 1.338 | 600.7 | 0.8650 | 37.90 | 136.4 |
| 0.55 | 6.60 | 0.1676 | 1.377 | 618.1 | 0.8902 | 39.01 | 140.3 |
| 0.56 | 6.72 | 0.1707 | 1.417 | 635.8 | 0.9155 | 40.12 | 144.3 |
| 0.57 | 6.84 | 0.1737 | 1.456 | 653.6 | 0.9412 | 41.24 | 148.4 |
| 0.58 | 6.96 | 0.1768 | 1.496 | 671.5 | 0.9671 | 42.37 | 152.5 |
| 0.59 | 7.08 | 0.1798 | 1.537 | 689.7 | 0.9932 | 43.52 | 156.6 |
| 0.60 | 7.20 | 0.1829 | 1.578 | 708.0 | 1.020 | 44.68 | 160.8 |
| 0.61 | 7.32 | 0.1859 | 1.619 | 726.5 | 1.046 | 45.84 | 165.0 |
| 0.62 | 7.44 | 0.1890 | 1.660 | 745.2 | 1.073 | 47.02 | 169.2 |
| 0.63 | 7.56 | 0.1920 | 1.702 | 764.0 | 1.100 | 48.21 | 173.5 |
| 0.64 | 7.68 | 0.1951 | 1.745 | 783.0 | 1.128 | 49.41 | 177.8 |
| 0.65 | 7.80 | 0.1981 | 1.787 | 802.2 | 1.155 | 50.62 | 182.1 |
| 0.66 | 7.92 | 0.2012 | 1.830 | 821.5 | 1.183 | 51.84 | 186.5 |
| 0.67 | 8.04 | 0.2042 | 1.874 | 841.0 | 1.211 | 53.07 | 190.9 |
| 0.68 | 8.16 | 0.2073 | 1.918 | 860.7 | 1.239 | 54.31 | 195.4 |
| 0.69 | 8.28 | 0.2103 | 1.962 | 880.5 | 1.268 | 55.56 | 199.9 |
| 0.70 | 8.40 | 0.2134 | 2.006 | 900.5 | 1.297 | 56.82 | 204.5 |
| 0.71 | 8.52 | 0.2164 | 2.051 | 920.6 | 1.326 | 58.09 | 209.0 |
| 0.72 | 8.64 | 0.2195 | 2.097 | 940.9 | 1.355 | 59.37 | 213.6 |
| 0.73 | 8.76 | 0.2225 | 2.142 | 961.4 | 1.384 | 60.67 | 218.3 |
| 0.74 | 8.88 | 0.2256 | 2.188 | 982.0 | 1.414 | 61.97 | 223.0 |
| 0.75 | 9.00 | 0.2286 | 2.234 | 1003 | 1.444 | 63.28 | 227.7 |
| 0.76 | 9.12 | 0.2316 | 2.281 | 1024 | 1.474 | 64.60 | 232.4 |
| 0.77 | 9.24 | 0.2347 | 2.328 | 1045 | 1.505 | 65.93 | 237.2 |
| 0.78 | 9.36 | 0.2377 | 2.375 | 1066 | 1.535 | 67.27 | 242.1 |
| 0.79 | 9.48 | 0.2408 | 2.423 | 1087 | 1.566 | 68.62 | 246.9 |
| 0.80 | 9.60 | 0.2438 | 2.471 | 1109 | 1.597 | 69.98 | 251.8 |


Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972

Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

80% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 0.81 | 9.72 | 0.2469 | 2.519 | 1131 | 1.628 | 71.35 | 256.7 |
| 0.82 | 9.84 | 0.2499 | 2.568 | 1153 | 1.660 | 72.73 | 261.7 |
| 0.83 | 9.96 | 0.2530 | 2.617 | 1175 | 1.691 | 74.12 | 266.7 |
| 0.84 | 10.08 | 0.2560 | 2.667 | 1197 | 1.723 | 75.52 | 271.7 |
| 0.85 | 10.20 | 0.2591 | 2.716 | 1219 | 1.755 | 76.92 | 276.8 |
| 0.86 | 10.32 | 0.2621 | 2.766 | 1241 | 1.788 | 78.34 | 281.9 |
| 0.87 | 10.44 | 0.2652 | 2.817 | 1264 | 1.820 | 79.76 | 287.0 |
| 0.88 | 10.56 | 0.2682 | 2.867 | 1287 | 1.853 | 81.20 | 292.2 |
| 0.89 | 10.68 | 0.2713 | 2.918 | 1310 | 1.886 | 82.64 | 297.4 |
| 0.90 | 10.80 | 0.2743 | 2.970 | 1333 | 1.919 | 84.10 | 302.6 |
| 0.91 | 10.92 | 0.2774 | 3.021 | 1356 | 1.953 | 85.56 | 307.9 |
| 0.92 | 11.04 | 0.2804 | 3.073 | 1379 | 1.986 | 87.03 | 313.1 |
| 0.93 | 11.16 | 0.2835 | 3.125 | 1403 | 2.020 | 88.51 | 318.5 |
| 0.94 | 11.28 | 0.2865 | 3.178 | 1426 | 2.054 | 90.00 | 323.8 |
| 0.95 | 11.40 | 0.2896 | 3.231 | 1450 | 2.088 | 91.50 | 329.2 |
| 0.96 | 11.52 | 0.2926 | 3.284 | 1474 | 2.122 | 93.00 | 334.6 |
| 0.97 | 11.64 | 0.2957 | 3.338 | 1498 | 2.157 | 94.52 | 340.1 |
| 0.98 | 11.76 | 0.2987 | 3.391 | 1522 | 2.192 | 96.04 | 345.6 |
| 0.99 | 11.88 | 0.3018 | 3.446 | 1546 | 2.227 | 97.58 | 351.1 |
| 1.00 | 12.00 | 0.3048 | 3.500 | 1571 | 2.262 | 99.12 | 356.7 |
| 1.01 | 12.12 | 0.3078 | 3.555 | 1595 | 2.297 | 100.7 | 362.2 |
| 1.02 | 12.24 | 0.3109 | 3.610 | 1620 | 2.333 | 102.2 | 367.8 |
| 1.03 | 12.36 | 0.3139 | 3.665 | 1645 | 2.369 | 103.8 | 373.5 |
| 1.04 | 12.48 | 0.3170 | 3.721 | 1670 | 2.405 | 105.4 | 379.2 |
| 1.05 | 12.60 | 0.3200 | 3.777 | 1695 | 2.441 | 107.0 | 384.9 |
| 1.06 | 12.72 | 0.3231 | 3.833 | 1720 | 2.477 | 108.6 | 390.6 |
| 1.07 | 12.84 | 0.3261 | 3.890 | 1746 | 2.514 | 110.2 | 396.4 |
| 1.08 | 12.96 | 0.3292 | 3.946 | 1771 | 2.551 | 111.8 | 402.1 |
| 1.09 | 13.08 | 0.3322 | 4.004 | 1797 | 2.588 | 113.4 | 408.0 |
| 1.10 | 13.20 | 0.3353 | 4.061 | 1823 | 2.625 | 115.0 | 413.8 |
| 1.11 | 13.32 | 0.3383 | 4.119 | 1849 | 2.662 | 116.6 | 419.7 |
| 1.12 | 13.44 | 0.3414 | 4.177 | 1875 | 2.699 | 118.3 | 425.6 |
| 1.13 | 13.56 | 0.3444 | 4.235 | 1901 | 2.737 | 119.9 | 431.6 |
| 1.14 | 13.68 | 0.3475 | 4.294 | 1927 | 2.775 | 121.6 | 437.5 |
| 1.15 | 13.80 | 0.3505 | 4.353 | 1953 | 2.813 | 123.3 | 443.5 |
| 1.16 | 13.92 | 0.3536 | 4.412 | 1980 | 2.851 | 124.9 | 449.6 |
| 1.17 | 14.04 | 0.3566 | 4.471 | 2007 | 2.890 | 126.6 | 455.6 |
| 1.18 | 14.16 | 0.3597 | 4.531 | 2034 | 2.928 | 128.3 | 461.7 |
| 1.19 | 14.28 | 0.3627 | 4.591 | 2061 | 2.967 | 130.0 | 467.8 |
| 1.20 | 14.40 | 0.3658 | 4.651 | 2088 | 3.006 | 131.7 | 474.0 |
| 1.21 | 14.52 | 0.3688 | 4.712 | 2115 | 3.045 | 133.4 | 480.2 |
| 1.22 | 14.64 | 0.3719 | 4.773 | 2142 | 3.085 | 135.2 | 486.4 |
| 1.23 | 14.76 | 0.3749 | 4.834 | 2170 | 3.124 | 136.9 | 492.6 |
| 1.24 | 14.88 | 0.3780 | 4.896 | 2197 | 3.164 | 138.6 | 498.9 |
| 1.25 | 15.00 | 0.3810 | 4.957 | 2225 | 3.204 | 140.4 | 505.2 |
| 1.26 | 15.12 | 0.3840 | 5.019 | 2253 | 3.244 | 142.1 | 511.5 |
| 1.27 | 15.24 | 0.3871 | 5.082 | 2281 | 3.284 | 143.9 | 517.8 |
| 1.28 | 15.36 | 0.3901 | 5.144 | 2309 | 3.325 | 145.7 | 524.2 |
| 1.29 | 15.48 | 0.3932 | 5.207 | 2337 | 3.365 | 147.5 | 530.6 |
| 1.30 | 15.60 | 0.3962 | 5.270 | 2365 | 3.406 | 149.2 | 537.0 |

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972

Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

80% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 1.31 | 15.72 | 0.3993 | 5.333 | 2394 | 3.447 | 151.0 | 543.5 |
| 1.32 | 15.84 | 0.4023 | 5.397 | 2422 | 3.488 | 152.8 | 550.0 |
| 1.33 | 15.96 | 0.4054 | 5.461 | 2451 | 3.529 | 154.7 | 556.5 |
| 1.34 | 16.08 | 0.4084 | 5.525 | 2480 | 3.571 | 156.5 | 563.0 |
| 1.35 | 16.20 | 0.4115 | 5.590 | 2509 | 3.613 | 158.3 | 569.6 |
| 1.36 | 16.32 | 0.4145 | 5.654 | 2538 | 3.654 | 160.1 | 576.2 |
| 1.37 | 16.44 | 0.4176 | 5.719 | 2567 | 3.696 | 162.0 | 582.8 |
| 1.38 | 16.56 | 0.4206 | 5.785 | 2596 | 3.739 | 163.8 | 589.5 |
| 1.39 | 16.68 | 0.4237 | 5.850 | 2626 | 3.781 | 165.7 | 596.1 |
| 1.40 | 16.80 | 0.4267 | 5.916 | 2655 | 3.824 | 167.5 | 602.8 |
| 1.41 | 16.92 | 0.4298 | 5.982 | 2685 | 3.866 | 169.4 | 609.6 |
| 1.42 | 17.04 | 0.4328 | 6.048 | 2715 | 3.909 | 171.3 | 616.3 |
| 1.43 | 17.16 | 0.4359 | 6.115 | 2744 | 3.952 | 173.2 | 623.1 |
| 1.44 | 17.28 | 0.4389 | 6.182 | 2774 | 3.995 | 175.1 | 629.9 |
| 1.45 | 17.40 | 0.4420 | 6.249 | 2804 | 4.039 | 177.0 | 636.8 |
| 1.46 | 17.52 | 0.4450 | 6.316 | 2835 | 4.082 | 178.9 | 643.6 |
| 1.47 | 17.64 | 0.4481 | 6.384 | 2865 | 4.126 | 180.8 | 650.5 |
| 1.48 | 17.76 | 0.4511 | 6.452 | 2896 | 4.170 | 182.7 | 657.4 |
| 1.49 | 17.88 | 0.4542 | 6.520 | 2926 | 4.214 | 184.6 | 664.4 |
| 1.50 | 18.00 | 0.4572 | 6.588 | 2957 | 4.258 | 186.6 | 671.3 |
| 1.51 | 18.12 | 0.4602 | 6.657 | 2988 | 4.302 | 188.5 | 678.3 |
| 1.52 | 18.24 | 0.4633 | 6.726 | 3019 | 4.347 | 190.5 | 685.4 |
| 1.53 | 18.36 | 0.4663 | 6.795 | 3050 | 4.392 | 192.4 | 692.4 |
| 1.54 | 18.48 | 0.4694 | 6.864 | 3081 | 4.436 | 194.4 | 699.5 |
| 1.55 | 18.60 | 0.4724 | 6.934 | 3112 | 4.481 | 196.4 | 706.6 |
| 1.56 | 18.72 | 0.4755 | 7.004 | 3143 | 4.527 | 198.4 | 713.7 |
| 1.57 | 18.84 | 0.4785 | 7.074 | 3175 | 4.572 | 200.3 | 720.9 |
| 1.58 | 18.96 | 0.4816 | 7.145 | 3206 | 4.618 | 202.3 | 728.0 |
| 1.59 | 19.08 | 0.4846 | 7.215 | 3238 | 4.663 | 204.3 | 735.2 |
| 1.60 | 19.20 | 0.4877 | 7.286 | 3270 | 4.709 | 206.3 | 742.5 |
| 1.61 | 19.32 | 0.4907 | 7.357 | 3302 | 4.755 | 208.4 | 749.7 |
| 1.62 | 19.44 | 0.4938 | 7.429 | 3334 | 4.801 | 210.4 | 757.0 |
| 1.63 | 19.56 | 0.4968 | 7.500 | 3366 | 4.847 | 212.4 | 764.3 |
| 1.64 | 19.68 | 0.4999 | 7.572 | 3398 | 4.894 | 214.4 | 771.6 |
| 1.65 | 19.80 | 0.5029 | 7.644 | 3431 | 4.941 | 216.5 | 779.0 |
| 1.66 | 19.92 | 0.5060 | 7.717 | 3463 | 4.987 | 218.5 | 786.3 |
| 1.67 | 20.04 | 0.5090 | 7.789 | 3496 | 5.034 | 220.6 | 793.7 |
| 1.68 | 20.16 | 0.5121 | 7.862 | 3529 | 5.081 | 222.7 | 801.2 |
| 1.69 | 20.28 | 0.5151 | 7.935 | 3561 | 5.129 | 224.7 | 808.6 |
| 1.70 | 20.40 | 0.5182 | 8.009 | 3594 | 5.176 | 226.8 | 816.1 |
| 1.71 | 20.52 | 0.5212 | 8.082 | 3627 | 5.224 | 228.9 | 823.6 |
| 1.72 | 20.64 | 0.5243 | 8.156 | 3661 | 5.271 | 231.0 | 831.1 |
| 1.73 | 20.76 | 0.5273 | 8.230 | 3694 | 5.319 | 233.1 | 838.7 |
| 1.74 | 20.88 | 0.5304 | 8.305 | 3727 | 5.367 | 235.2 | 846.3 |
| 1.75 | 21.00 | 0.5334 | 8.379 | 3761 | 5.416 | 237.3 | 853.9 |
| 1.76 | 21.12 | 0.5364 | 8.454 | 3794 | 5.464 | 239.4 | 861.5 |
| 1.77 | 21.24 | 0.5395 | 8.529 | 3828 | 5.512 | 241.5 | 869.1 |
| 1.78 | 21.36 | 0.5425 | 8.604 | 3862 | 5.561 | 243.7 | 876.8 |
| 1.79 | 21.48 | 0.5456 | 8.680 | 3896 | 5.610 | 245.8 | 884.5 |
| 1.80 | 21.60 | 0.5486 | 8.756 | 3930 | 5.659 | 248.0 | 892.2 |

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972
Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

80% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 1.81 | 21.72 | 0.5517 | 8.832 | 3964 | 5.708 | 250.1 | 900.0 |
| 1.82 | 21.84 | 0.5547 | 8.908 | 3998 | 5.757 | 252.3 | 907.7 |
| 1.83 | 21.96 | 0.5578 | 8.984 | 4032 | 5.807 | 254.4 | 915.5 |
| 1.84 | 22.08 | 0.5608 | 9.061 | 4067 | 5.856 | 256.6 | 923.3 |
| 1.85 | 22.20 | 0.5639 | 9.138 | 4101 | 5.906 | 258.8 | 931.2 |
| 1.86 | 22.32 | 0.5669 | 9.215 | 4136 | 5.956 | 261.0 | 939.0 |
| 1.87 | 22.44 | 0.5700 | 9.293 | 4171 | 6.006 | 263.2 | 946.9 |
| 1.88 | 22.56 | 0.5730 | 9.370 | 4205 | 6.056 | 265.4 | 954.8 |
| 1.89 | 22.68 | 0.5761 | 9.448 | 4240 | 6.106 | 267.6 | 962.8 |
| 1.90 | 22.80 | 0.5791 | 9.526 | 4275 | 6.157 | 269.8 | 970.7 |
| 1.91 | 22.92 | 0.5822 | 9.605 | 4311 | 6.207 | 272.0 | 978.7 |
| 1.92 | 23.04 | 0.5852 | 9.683 | 4346 | 6.258 | 274.2 | 986.7 |
| 1.93 | 23.16 | 0.5883 | 9.762 | 4381 | 6.309 | 276.5 | 994.7 |
| 1.94 | 23.28 | 0.5913 | 9.841 | 4417 | 6.360 | 278.7 | 1003 |
| 1.95 | 23.40 | 0.5944 | 9.920 | 4452 | 6.411 | 280.9 | 1011 |
| 1.96 | 23.52 | 0.5974 | 10.00 | 4488 | 6.463 | 283.2 | 1019 |
| 1.97 | 23.64 | 0.6005 | 10.08 | 4524 | 6.514 | 285.4 | 1027 |
| 1.98 | 23.76 | 0.6035 | 10.16 | 4560 | 6.566 | 287.7 | 1035 |
| 1.99 | 23.88 | 0.6066 | 10.24 | 4595 | 6.618 | 290.0 | 1043 |
| 2.00 | 24.00 | 0.6096 | 10.32 | 4632 | 6.670 | 292.3 | 1052 |
| 2.01 | 24.12 | 0.6126 | 10.40 | 4668 | 6.722 | 294.5 | 1060 |
| 2.02 | 24.24 | 0.6157 | 10.48 | 4704 | 6.774 | 296.8 | 1068 |
| 2.03 | 24.36 | 0.6187 | 10.56 | 4740 | 6.826 | 299.1 | 1076 |
| 2.04 | 24.48 | 0.6218 | 10.64 | 4777 | 6.879 | 301.4 | 1085 |
| 2.05 | 24.60 | 0.6248 | 10.73 | 4813 | 6.932 | 303.7 | 1093 |
| 2.06 | 24.72 | 0.6279 | 10.81 | 4850 | 6.984 | 306.1 | 1101 |
| 2.07 | 24.84 | 0.6309 | 10.89 | 4887 | 7.037 | 308.4 | 1110 |
| 2.08 | 24.96 | 0.6340 | 10.97 | 4924 | 7.091 | 310.7 | 1118 |
| 2.09 | 25.08 | 0.6370 | 11.05 | 4961 | 7.144 | 313.0 | 1126 |
| 2.10 | 25.20 | 0.6401 | 11.14 | 4998 | 7.197 | 315.4 | 1135 |
| 2.11 | 25.32 | 0.6431 | 11.22 | 5035 | 7.251 | 317.7 | 1143 |
| 2.12 | 25.44 | 0.6462 | 11.30 | 5072 | 7.304 | 320.1 | 1152 |
| 2.13 | 25.56 | 0.6492 | 11.39 | 5110 | 7.358 | 322.4 | 1160 |
| 2.14 | 25.68 | 0.6523 | 11.47 | 5147 | 7.412 | 324.8 | 1169 |
| 2.15 | 25.80 | 0.6553 | 11.55 | 5185 | 7.466 | 327.2 | 1177 |
| 2.16 | 25.92 | 0.6584 | 11.64 | 5222 | 7.521 | 329.5 | 1186 |
| 2.17 | 26.04 | 0.6614 | 11.72 | 5260 | 7.575 | 331.9 | 1194 |
| 2.18 | 26.16 | 0.6645 | 11.80 | 5298 | 7.629 | 334.3 | 1203 |
| 2.19 | 26.28 | 0.6675 | 11.89 | 5336 | 7.684 | 336.7 | 1212 |
| 2.20 | 26.40 | 0.6706 | 11.97 | 5374 | 7.739 | 339.1 | 1220 |
| 2.21 | 26.52 | 0.6736 | 12.06 | 5412 | 7.794 | 341.5 | 1229 |
| 2.22 | 26.64 | 0.6767 | 12.14 | 5450 | 7.849 | 343.9 | 1238 |
| 2.23 | 26.76 | 0.6797 | 12.23 | 5489 | 7.904 | 346.4 | 1246 |
| 2.24 | 26.88 | 0.6828 | 12.32 | 5527 | 7.960 | 348.8 | 1255 |
| 2.25 | 27.00 | 0.6858 | 12.40 | 5566 | 8.015 | 351.2 | 1264 |
| 2.26 | 27.12 | 0.6888 | 12.49 | 5604 | 8.071 | 353.6 | 1272 |
| 2.27 | 27.24 | 0.6919 | 12.57 | 5643 | 8.126 | 356.1 | 1281 |
| 2.28 | 27.36 | 0.6949 | 12.66 | 5682 | 8.182 | 358.5 | 1290 |
| 2.29 | 27.48 | 0.6980 | 12.75 | 5721 | 8.238 | 361.0 | 1299 |
| 2.30 | 27.60 | 0.7010 | 12.83 | 5760 | 8.295 | 363.5 | 1308 |

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972

Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

80% Submergence Transition ±3% Accuracy

Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 2.31 | 27.72 | 0.7041 | 12.92 | 5799 | 8.351 | 365.9 | 1317 |
| 2.32 | 27.84 | 0.7071 | 13.01 | 5838 | 8.407 | 368.4 | 1326 |
| 2.33 | 27.96 | 0.7102 | 13.10 | 5878 | 8.464 | 370.9 | 1334 |
| 2.34 | 28.08 | 0.7132 | 13.18 | 5917 | 8.521 | 373.4 | 1343 |
| 2.35 | 28.20 | 0.7163 | 13.27 | 5956 | 8.578 | 375.9 | 1352 |
| 2.36 | 28.32 | 0.7193 | 13.36 | 5996 | 8.635 | 378.4 | 1361 |
| 2.37 | 28.44 | 0.7224 | 13.45 | 6036 | 8.692 | 380.9 | 1370 |
| 2.38 | 28.56 | 0.7254 | 13.54 | 6075 | 8.749 | 383.4 | 1379 |
| 2.39 | 28.68 | 0.7285 | 13.63 | 6115 | 8.806 | 385.9 | 1388 |
| 2.40 | 28.80 | 0.7315 | 13.72 | 6155 | 8.864 | 388.4 | 1398 |
| 2.41 | 28.92 | 0.7346 | 13.80 | 6195 | 8.922 | 390.9 | 1407 |
| 2.42 | 29.04 | 0.7376 | 13.89 | 6236 | 8.980 | 393.5 | 1416 |
| 2.43 | 29.16 | 0.7407 | 13.98 | 6276 | 9.037 | 396.0 | 1425 |
| 2.44 | 29.28 | 0.7437 | 14.07 | 6316 | 9.096 | 398.6 | 1434 |
| 2.45 | 29.40 | 0.7468 | 14.16 | 6357 | 9.154 | 401.1 | 1443 |
| 2.46 | 29.52 | 0.7498 | 14.25 | 6397 | 9.212 | 403.7 | 1452 |
| 2.47 | 29.64 | 0.7529 | 14.34 | 6438 | 9.271 | 406.2 | 1462 |
| 2.48 | 29.76 | 0.7559 | 14.43 | 6478 | 9.329 | 408.8 | 1471 |
| 2.49 | 29.88 | 0.7590 | 14.53 | 6519 | 9.388 | 411.4 | 1480 |
| 2.50 | 30.00 | 0.7620 | 14.62 | 6560 | 9.447 | 413.9 | 1489 |
| 2.51 | 30.12 | 0.7650 | 14.71 | 6601 | 9.506 | 416.5 | 1499 |
| 2.52 | 30.24 | 0.7681 | 14.80 | 6642 | 9.565 | 419.1 | 1508 |
| 2.53 | 30.36 | 0.7711 | 14.89 | 6683 | 9.624 | 421.7 | 1517 |
| 2.54 | 30.48 | 0.7742 | 14.98 | 6725 | 9.684 | 424.3 | 1527 |
| 2.55 | 30.60 | 0.7772 | 15.08 | 6766 | 9.743 | 426.9 | 1536 |
| 2.56 | 30.72 | 0.7803 | 15.17 | 6807 | 9.803 | 429.6 | 1546 |
| 2.57 | 30.84 | 0.7833 | 15.26 | 6849 | 9.863 | 432.2 | 1555 |
| 2.58 | 30.96 | 0.7864 | 15.35 | 6890 | 9.923 | 434.8 | 1564 |
| 2.59 | 31.08 | 0.7894 | 15.45 | 6932 | 9.983 | 437.4 | 1574 |
| 2.60 | 31.20 | 0.7925 | 15.54 | 6974 | 10.04 | 440.1 | 1583 |
| 2.61 | 31.32 | 0.7955 | 15.63 | 7016 | 10.10 | 442.7 | 1593 |
| 2.62 | 31.44 | 0.7986 | 15.73 | 7058 | 10.16 | 445.4 | 1602 |
| 2.63 | 31.56 | 0.8016 | 15.82 | 7100 | 10.22 | 448.0 | 1612 |
| 2.64 | 31.68 | 0.8047 | 15.91 | 7142 | 10.29 | 450.7 | 1622 |
| 2.65 | 31.80 | 0.8077 | 16.01 | 7184 | 10.35 | 453.3 | 1631 |
| 2.66 | 31.92 | 0.8108 | 16.10 | 7227 | 10.41 | 456.0 | 1641 |
| 2.67 | 32.04 | 0.8138 | 16.20 | 7269 | 10.47 | 458.7 | 1650 |
| 2.68 | 32.16 | 0.8169 | 16.29 | 7312 | 10.53 | 461.4 | 1660 |
| 2.69 | 32.28 | 0.8199 | 16.39 | 7354 | 10.59 | 464.1 | 1670 |
| 2.70 | 32.40 | 0.8230 | 16.48 | 7397 | 10.65 | 466.8 | 1679 |
| 2.71 | 32.52 | 0.8260 | 16.58 | 7440 | 10.71 | 469.5 | 1689 |
| 2.72 | 32.64 | 0.8291 | 16.67 | 7483 | 10.78 | 472.2 | 1699 |
| 2.73 | 32.76 | 0.8321 | 16.77 | 7525 | 10.84 | 474.9 | 1709 |
| 2.74 | 32.88 | 0.8352 | 16.86 | 7569 | 10.90 | 477.6 | 1718 |
| 2.75 | 33.00 | 0.8382 | 16.96 | 7612 | 10.96 | 480.3 | 1728 |
| 2.76 | 33.12 | 0.8412 | 17.06 | 7655 | 11.02 | 483.0 | 1738 |
| 2.77 | 33.24 | 0.8443 | 17.15 | 7698 | 11.09 | 485.8 | 1748 |
| 2.78 | 33.36 | 0.8473 | 17.25 | 7742 | 11.15 | 488.5 | 1758 |
| 2.79 | 33.48 | 0.8504 | 17.35 | 7785 | 11.21 | 491.3 | 1768 |
| 2.80 | 33.60 | 0.8534 | 17.44 | 7829 | 11.27 | 494.0 | 1777 |

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972

Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974

# 108-Inch L x 12-Inch W Cutthroat Flume Discharge Table

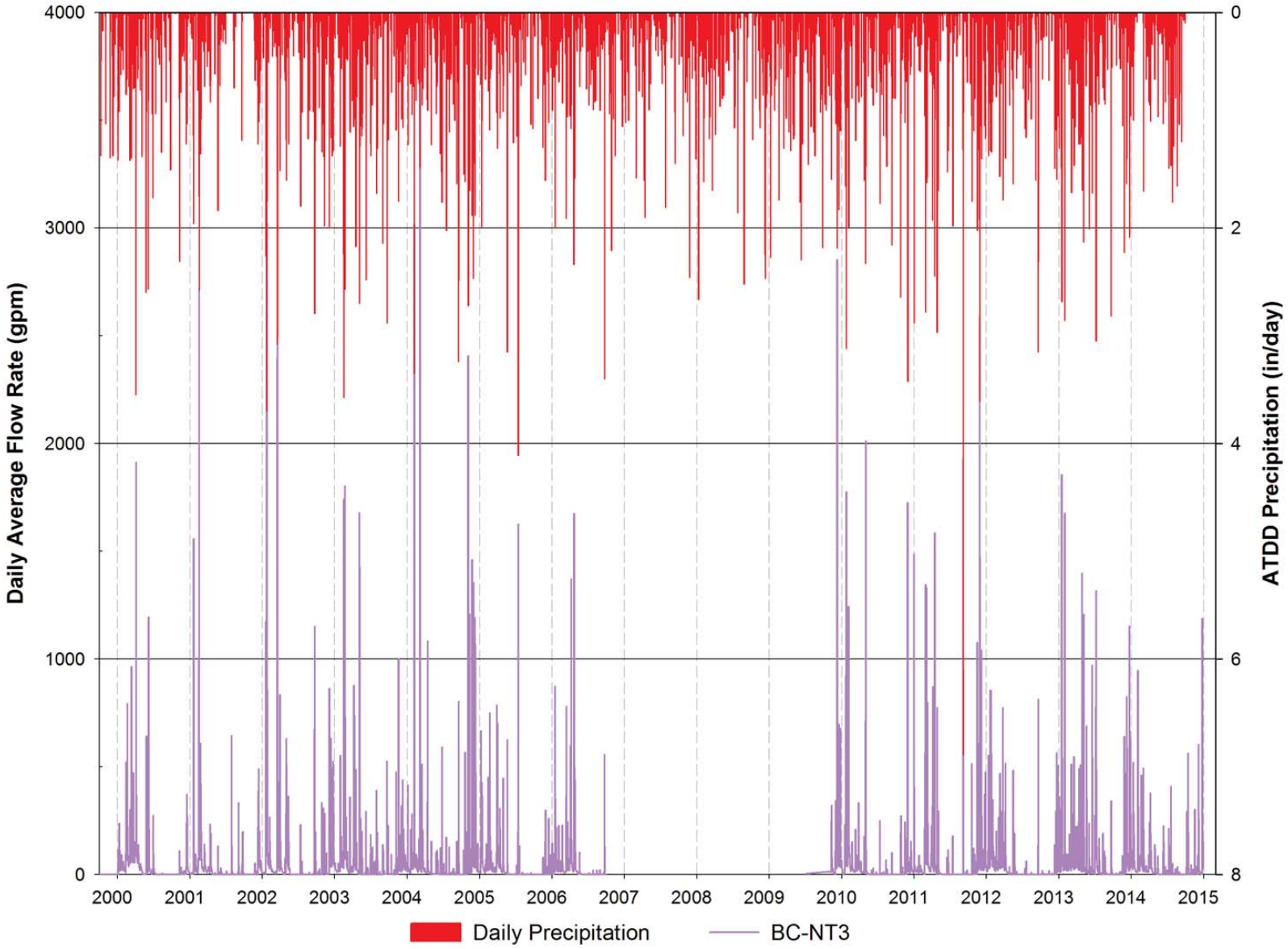
80% Submergence Transition ±3% Accuracy

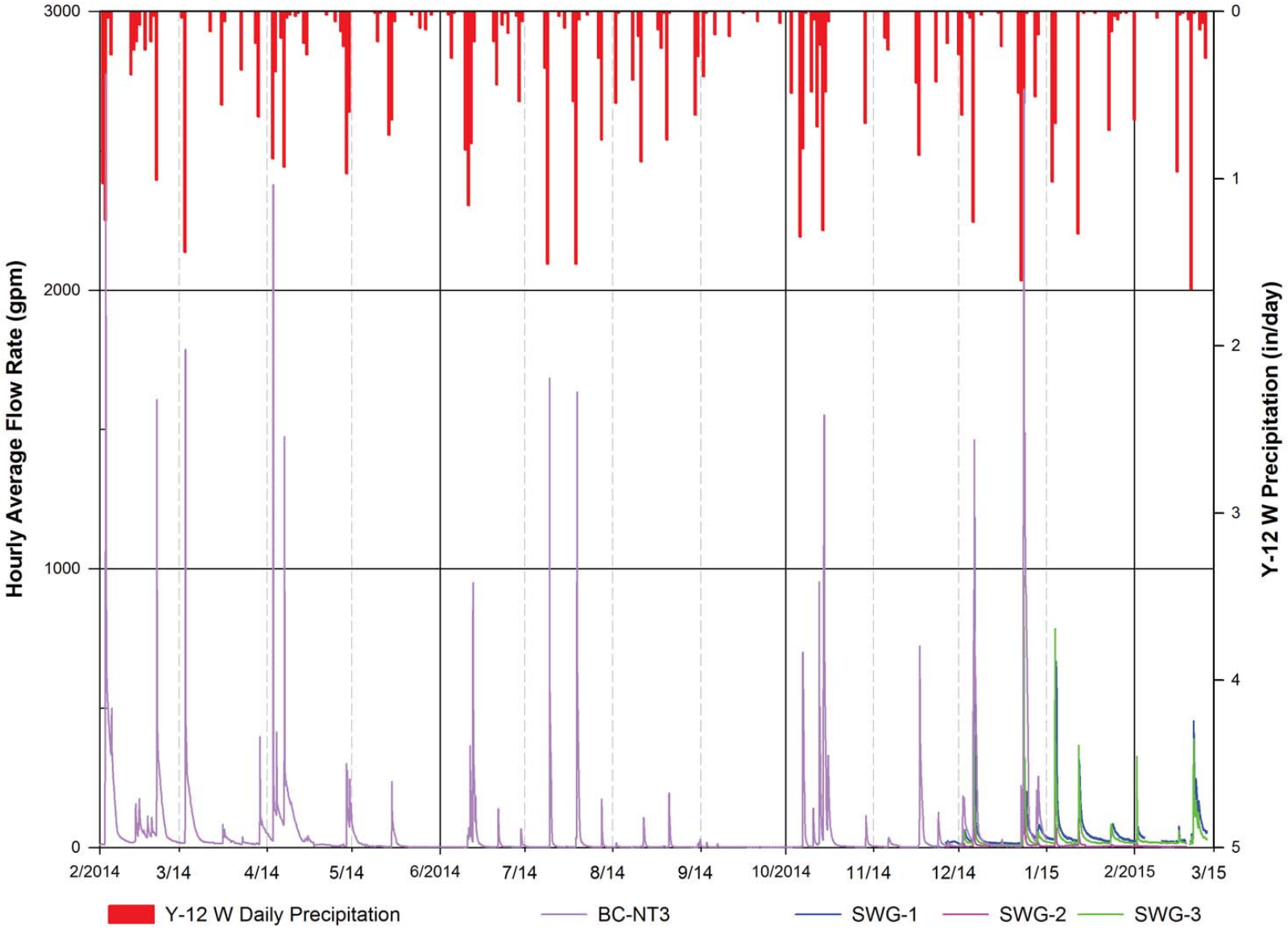
Formulas (H in feet): CFS = 3.50 $H_{ft.}^{1.56}$ GPM = 1571 $H_{ft.}^{1.56}$ MGD = 2.262 $H_{ft.}^{1.56}$

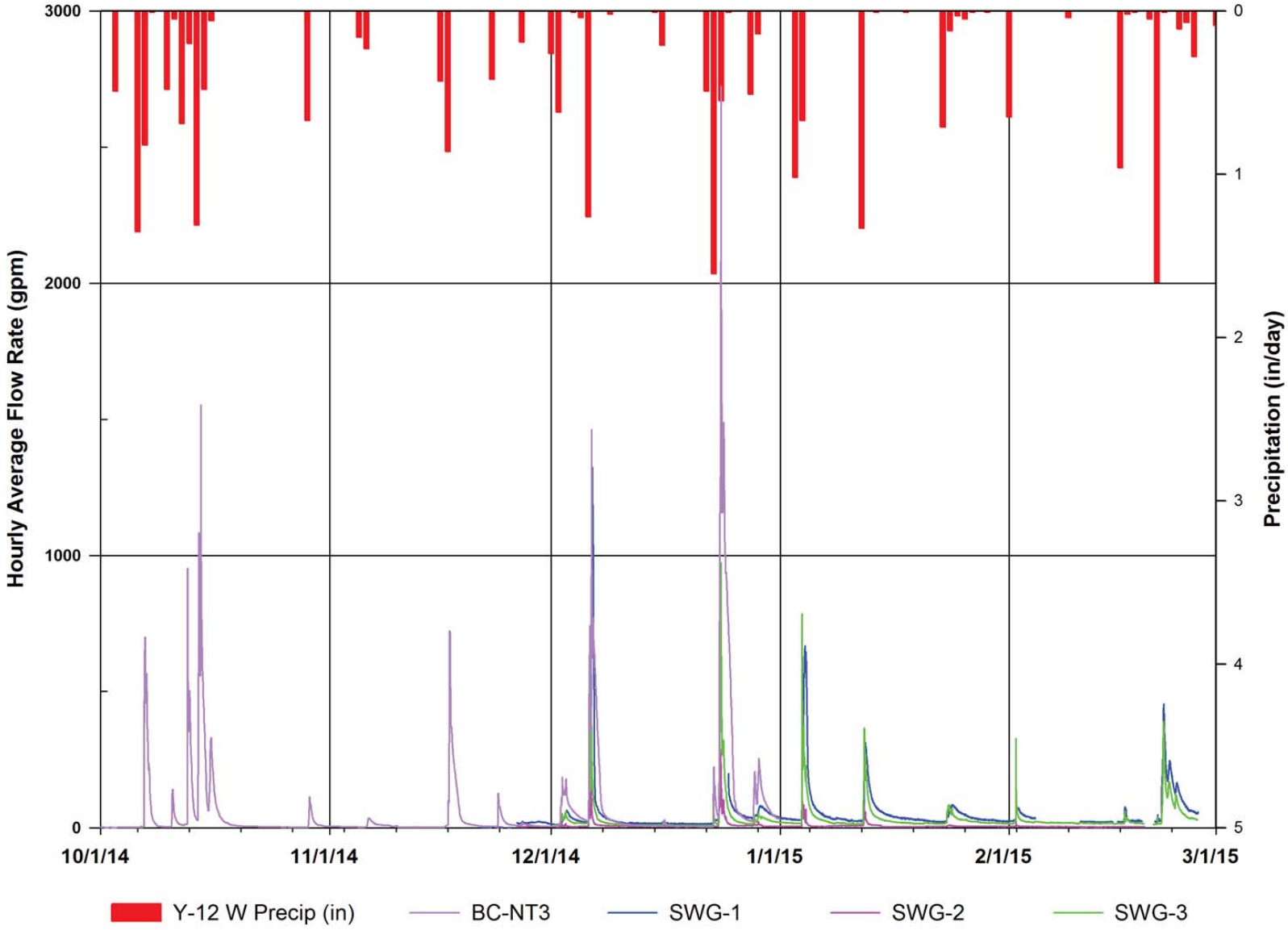
Formulas (H in meters): L/S = 632.3 $H_{m}^{1.56}$ M3/HR = 2276 $H_{m}^{1.56}$

| FEET | INCHES | METERS | CFS | GPM | MGD | L/S | M3/HR |
|---|---|---|---|---|---|---|---|
| 2.81 | 33.72 | 0.8565 | 17.54 | 7872 | 11.34 | 496.8 | 1787 |
| 2.82 | 33.84 | 0.8595 | 17.64 | 7916 | 11.40 | 499.5 | 1797 |
| 2.83 | 33.96 | 0.8626 | 17.74 | 7960 | 11.46 | 502.3 | 1807 |
| 2.84 | 34.08 | 0.8656 | 17.83 | 8004 | 11.53 | 505.1 | 1817 |
| 2.85 | 34.20 | 0.8687 | 17.93 | 8048 | 11.59 | 507.8 | 1827 |
| 2.86 | 34.32 | 0.8717 | 18.03 | 8092 | 11.65 | 510.6 | 1837 |
| 2.87 | 34.44 | 0.8748 | 18.13 | 8136 | 11.72 | 513.4 | 1847 |
| 2.88 | 34.56 | 0.8778 | 18.23 | 8180 | 11.78 | 516.2 | 1857 |
| 2.89 | 34.68 | 0.8809 | 18.33 | 8225 | 11.84 | 519.0 | 1867 |
| 2.90 | 34.80 | 0.8839 | 18.43 | 8269 | 11.91 | 521.8 | 1878 |
| 2.91 | 34.92 | 0.8870 | 18.52 | 8314 | 11.97 | 524.6 | 1888 |
| 2.92 | 35.04 | 0.8900 | 18.62 | 8358 | 12.04 | 527.4 | 1898 |
| 2.93 | 35.16 | 0.8931 | 18.72 | 8403 | 12.10 | 530.2 | 1908 |
| 2.94 | 35.28 | 0.8961 | 18.82 | 8448 | 12.17 | 533.1 | 1918 |
| 2.95 | 35.40 | 0.8992 | 18.92 | 8493 | 12.23 | 535.9 | 1928 |
| 2.96 | 35.52 | 0.9022 | 19.02 | 8538 | 12.29 | 538.7 | 1938 |
| 2.97 | 35.64 | 0.9053 | 19.12 | 8583 | 12.36 | 541.6 | 1949 |
| 2.98 | 35.76 | 0.9083 | 19.22 | 8628 | 12.42 | 544.4 | 1959 |
| 2.99 | 35.88 | 0.9114 | 19.32 | 8673 | 12.49 | 547.3 | 1969 |
| 3.00 | 36.00 | 0.9144 | 19.43 | 8718 | 12.55 | 550.1 | 1979 |

Sources: Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972
Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, ASCE, Vol. 98, No. IR4, December 1974


Daily Average Flow Rate (gpm)
ATDD Precipitation (in/day)
4000
3000
2000
1000
0
0
2
4
6
8
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Daily Precipitation
BC-NT3


Hourly Average Flow Rate (gpm)
Y-12 W Precipitation (in/day)
3000
2000
1000
0
0
1
2
3
4
5
2/2014
3/14
4/14
5/14
6/2014
7/14
8/14
9/14
10/2014
11/14
12/14
1/15
2/2015
3/15
Y-12 W Daily Precipitation
BC-NT3
SWG-1
SWG-2
SWG-3


Hourly Average Flow Rate (gpm)
Precipitation (in/day)
3000
2000
1000
0
0
1
2
3
4
5
10/1/14
11/1/14
12/1/14
1/1/15
2/1/15
3/1/15
Y-12 W Precip (in)
BC-NT3
SWG-1
SWG-2
SWG-3

# EXHIBIT A.14:
# WEEKLY DOCUMENTATION FOR CONTINUOUS SURFACE WATER AND GROUND WATER MONITORING

This page intentionally left blank.

**EMDF MONITORING**

**NOTES ON DATA DOWNLOADS**

1. No data were downloaded as of 12-01-2014. The first data were downloaded on 12-04-2014.

| Site ID | In-Situ Trolls | | | | | | YSI 600 XLM Sondes | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | Serial # | Device Address | Range (ft) | Monitoring Parameters | Water Level Setup | Depth to Water (ft) | Serial # | Monitoring Parameters | |
| **Shallow Well Locations** | | | | | | | | | |
| GW-969 | 345469 | 1 | 35 | Pressure, level | DTW | 1.93 | 6667 | Temperature, pH, Conductivitiy, DO, and ORP | |
| GW-971 | 355392 | 1 | 35 | | DTW | 13.53 | 1955 | | |
| GW-973 | 206613 | 1 | 35 | | DTW | 9.93 | 8979 | | |
| GW-975 | 230282 | 1 | 35 | | DTW | 6.87 | 16835 | | |
| **Bedrock Well Locations** | | | | | | | | | |
| GW-968 | 156234 | 1 | 69 | Pressure, level | DTW | 0.00 | 12793 | Temperature, pH, Conductivitiy, DO, and ORP | |
| GW-970 | 24871 | 1 | 69 | | DTW | 13.22 | 16661 | | YSI (#24871) not working on 11-25: Switched out |
| GW-972 | 156671 | 1 | 69 | | DTW | 9.08 | 6544 | | |
| GW-974 | 156213 | 1 | 69 | | DTW | 6.25 | 6664 | | |
| GW-976 | 19309 | 1 | 69 | | DTW | 46.2 | 2176 | | |
| **Surface Water Locations (EMDNT3)** | | | | | | **Water Elevation (ft)*** | | | |
| SWG1- East Branch | 253040 | 1 | 35 | Pressure, level | Elevation | 0.06 | 8980 | Temperature, pH, Conductivitiy, DO, and ORP | |
| SWG2- Middle Branch | 322795 | 1 | 35 | | Elevation | 0.03 | 24871 | | |
| SWG3- West Branch | | | | | Elevation | | 9006 | | Level Troll (#322401) not working. Need to replace, also need to deploy new YSI 600 XLM (#9006). |

Note: All YSI 600 XLM sondes calibrated before deployment.

*Used 100 ft as temporary elevation for each flume.

**Troll QC Checks**

| Date: | 11/24/2014 | | | 11/25/2014 | | | Zeroed Troll and Reset | | |
|---|---|---|---|---|---|---|---|---|---|
| Well ID | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference |
| GW-968 | 0.00 | 0.07 | 0.07 | 0.03 | 0.03 | 0 | NC | NC | NC |
| GW-969 | 1.93 | 1.97 | 0.04 | 2.19 | 2.17 | 0.02 | 2.19 | 2.18 | 0.01 |
| GW-970 | 13.22 | 13.21 | 0.01 | 13.67 | 10.23 | 3.44 | 13.69 | 13.67 | 0.02 |
| GW-971 | 13.53 | 13.54 | 0.01 | 14.08 | 13.99 | 0.09 | 14.19 | 14.19 | 0 |
| GW-972 | 9.08 | 9.07 | 0.01 | 9.53 | 9.42 | 0.11 | 9.51 | 9.51 | 0 |
| GW-973 | 9.93 | 9.94 | 0.01 | 6.83 | 6.80 | 0.03 | 10.39 | 10.39 | 0 |
| GW-974 | 6.25 | 6.25 | 0 | 6.83 | 6.80 | 0.03 | 6.84 | 6.79 | 0.05 |
| GW-975 | 6.87 | 6.87 | 0 | 7.50 | 7.47 | 0.03 | 7.49 | 7.51 | 0.02 |
| GW-976 | 46.20 | 46.19 | 0.01 | 46.10 | 46.57 | 0.47 | 46.06 | 45.98 | 0.08 |

| Date: | 11/24/2014 | | | 11/26/2014-Zeroed and Reset | | |
|---|---|---|---|---|---|---|
| Surface Water Site ID | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference |
| SWG-1 (East) | 0.06 | 0.004 | 0.06 | 100.05 | 100.05 | 0 |
| SWG-2 (Middle) | 0.03 | 0.00 | 0.03 | 100.03 | 100.03 | 0 |
| SWG-3 (West) | 0.01 | 0.00 | 0.01 | Bad Cable | | Bad Cable |

Note: All trolls read "FC" with depth readings meaning that they need to be factory calibrated. If they were calibrated, the measurements should be accurate to 100th of a foot.

**EMDF MONITORING**

**NOTES ON DATA DOWNLOADS**

1. There were two data sets for some of the Trolls because several were zeroed and new logs were started in an attempt to get more accurate readings from the Trolls. All of the previous trolls indicated that they were out of factory calibration. New Trolls were installed at all 12 locations on 12-04-2014.
2. Start dates for all data sets are not the same for the 12-04-2014 download. Instruments were deployed and set to begin logging upon being received.

**EMDF MONITORING EQUIPMENT STATUS - As of 12/04/2014**

| Site ID | In-Situ Trolls | | | | | | YSI 600 XLM Sondes | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | Serial # | Device Address | Range (ft) | Monitoring Parameters | Water Level Setup | Depth to Water (ft) | Serial # | Monitoring Parameters | |
| **Shallow Well Locations** | | | | | | | | | |
| GW-969 | 163894 | 1 | 35 | Pressure, level | DTW | 1.30 | 6667 | Temperature, pH, Conductivitiy, DO, and ORP | New FC Troll deployed |
| GW-971 | 169837 | 1 | 35 | | DTW | 12.27 | 1955 | | New FC Troll deployed |
| GW-973 | 152632 | 1 | 35 | | DTW | 9.24 | 8979 | | New FC Troll deployed |
| GW-975 | 19727 | 1 | 35 | | DTW | 6.55 | 16835 | | New FC Troll deployed |
| **Bedrock Well Locations** | | | | | | | | | |
| GW-968 | 122991 | 1 | 69 | Pressure, level | DTW | 0.00 | 12793 | Temperature, pH, Conductivitiy, DO, and ORP | New FC Troll deployed |
| GW-970 | 169354 | 1 | 69 | | DTW | 11.34 | 16661 | | New FC Troll deployed. Replace DO membane on YSI sonde and re-calibrate for all parameters |
| GW-972 | 169305 | 1 | 69 | | DTW | 8.39 | 6544 | | New FC Troll deployed. |
| GW-974 | 169313 | 1 | 69 | | DTW | 5.95 | 6664 | | New FC Troll deployed |
| GW-976 | 169346 | 1 | 69 | | DTW | 45.94 | 2176 | | New FC Troll deployed |
| **Surface Water Locations (EMDNT3)** | | | | | | **Water Elevation (ft)*** | | | |
| SWG1- East Branch | 136867 | 1 | 35 | Pressure, level | Elevation | Not Logged | 8980 | Temperature, pH, Conductivitiy, DO, and ORP | New FC Troll deployed. Replace DO membane on YSI sonde and re-calibrate |
| SWG2- Middle Branch | 376400 | 1 | 69 | | Elevation | 0.03 | 24871 | | New FC Troll Deployed. YSI sonde bad (wet in battery compartment) |
| SWG3- West Branch | 169681 | 1 | 35 | | Elevation | 0.05 | 7323 | | Replaced bad Troll (#322401) with FC Troll on 12/4, replaced bad YSI Sonde (#9006) on 12/1. On 12/5 new sonde fouled with mud, also re-calibrated sonde. |

Notes:

1. All YSI 600 XLM sondes calibrated before deployment.
2. *Used 100 ft as temporary elevation for each surface water flume.
3. Orginally deployed Trolls were replaced with Factory Calibrated (FC) Trolls as indicated by yellow highlight. All original Trolls indicated that they were out of calibration.
4. As of 12/05: Of the seven (7) YSI 650 readers that we have, only three (3) are high memory. One (1) of the high memory readers has a short in it and will not stay on so only two (2) are usable. We cannot use the remaining 4 to download data since they are low memory.
5. We need to return one (1) bad Troll, one (1) bad YSI sonde to Pine, and the unusable low memory readers.

**Troll QC Checks**

| Date: | 11/24/2014 | | | 11/25/2014 | | | Zeroed Troll and Reset | | | 12/4/2014 | | | 12/XX/2014 (New Trolls) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference |
| GW-968 | 0.00 | 0.07 | 0.07 | 0.03 | 0.03 | 0 | NC | NC | NC | 0.00 | 0.07 | 0.07 | | | |
| GW-969 | 1.93 | 1.97 | 0.04 | 2.19 | 2.17 | 0.02 | 2.19 | 2.18 | 0.01 | 1.30 | 1.30 | 0 | | | |
| GW-970 | 13.22 | 13.21 | 0.01 | 13.67 | 10.23 | 3.44 | 13.69 | 13.67 | 0.02 | 11.34 | 11.37 | 0.03 | | | |
| GW-971 | 13.53 | 13.54 | 0.01 | 14.08 | 13.99 | 0.09 | 14.19 | 14.19 | 0 | 12.27 | 12.26 | 0.01 | | | |
| GW-972 | 9.08 | 9.07 | 0.01 | 9.53 | 9.42 | 0.11 | 9.51 | 9.51 | 0 | 8.39 | 8.34 | 0.05 | | | |
| GW-973 | 9.93 | 9.94 | 0.01 | 6.83 | 6.80 | 0.03 | 10.39 | 10.39 | 0 | 9.24 | 9.21 | 0.03 | | | |
| GW-974 | 6.25 | 6.25 | 0 | 6.83 | 6.80 | 0.03 | 6.84 | 6.79 | 0.05 | 5.95 | 5.89 | 0.06 | | | |
| GW-975 | 6.87 | 6.87 | 0 | 7.50 | 7.47 | 0.03 | 7.49 | 7.51 | 0.02 | 6.55 | 6.53 | 0.02 | | | |
| GW-976 | 46.20 | 46.19 | 0.01 | 46.10 | 46.57 | 0.47 | 46.06 | 45.98 | 0.08 | 45.94 | 45.02 | 0.72 | | | |

| Date: | 11/24/2014 | | | 11/26/2014-Zeroed and Reset | | | 12/1/2014 | | | 12/4/2014 | | | 12/XX/2014 (New Trolls) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface Water Site ID | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference |
| SWG-1 (East) | 0.06 | 0.004 | 0.06 | 100.05 | 100.05 | 0 | 100.04 | 100.04 | 0 | NC | NC | NC | | | |
| SWG-2 (Middle) | 0.03 | 0.00 | 0.03 | 100.03 | 100.03 | 0 | 100.04 | 100.04 | 0 | 100.01 | 100.03 | 0.02 | | | |
| SWG-3 (West) | 0.01 | 0.00 | 0.01 | Bad Troll | Bad Troll | Bad Troll | 100.03 | 100.03 | 0 | 100.05 | 100.05 | 0 | | | |

Note: All trolls read "FC" with depth readings indicating that they need to be factory calibrated. If they were calibrated, the measurements should be accurate to 100th of a foot.
Note: All new Factory Calibrated Trolls installed on 12-04-2014, QC for 12-04 is for the OLD Trolls. The initial QC check on the new trolls will be conducted during next download.
NC = No check.
Yellow highlight indicates New Factory Calibrated Troll.

**EMDF MONITORING EQUIPMENT STATUS - As of 12/11/2014**

| Site ID | In-Situ Trolls | | | | | | YSI 600 XLM Sondes | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | Serial # | Device Address | Range (ft) | Monitoring Parameters | Water Level Setup | Depth to Water (ft) | Serial # | Monitoring Parameters | |
| **Shallow Well Locations** | | | | | | | | | |
| GW-969 | 163894 | 1 | 35 | Pressure, level | DTW | 1.39 | 6667 | Temperature, pH, Conductivitiy, DO, and ORP | Zeroed and re-set Level Troll. |
| GW-971 | 169837 | 1 | 35 | | DTW | 9.73 | 1955 | | |
| GW-973 | 152632 | 1 | 35 | | DTW | 7.47 | 8979 | | Zeroed and re-set Level Troll. |
| GW-975 | 19727 | 1 | 35 | | DTW | 6.61 | 16835 | | Zeroed and re-set Level Troll. |
| **Bedrock Well Locations** | | | | | | | | | |
| GW-968 | 122991 | 1 | 69 | Pressure, level | DTW | 0.00 | 12793 | Temperature, pH, Conductivitiy, DO, and ORP | |
| GW-970 | 169354 | 1 | 69 | | DTW | 10.14 | 16661 | | Zeroed and re-set Level Troll. |
| GW-972 | 169305 | 1 | 69 | | DTW | 6.67 | 6544 | | Zeroed and re-set Level Troll. |
| GW-974 | 169313 | 1 | 69 | | DTW | 5.82 | 6664 | | Zeroed and re-set Level Troll. |
| GW-976 | 169346 | 1 | 69 | | DTW | 44.80 | 2176 | | Zeroed and re-set Level Troll. |
| **Surface Water Locations (EMDNT3)** | | | | | | **Water Elevation (ft)[2]** | | | |
| SWG1- East Branch | 136867 | 1 | 35 | Pressure, level | Elevation | Not Recorded | 8980 | Temperature, pH, Conductivitiy, DO, and ORP | DO and ORP readings appear erroneous. Replace DO membrane and recalibrate all probes. DO and ORP at first appear appropriate for flowing surface water but then begin drifting down. Need to replace YSI sonde. Re-set Troll reference to surveyed bottom of flume plus staff gauge |
| SWG2- Middle Branch | 376400 | 1 | 69 | | Elevation | 981.70 | 24871 | | Re-set Troll reference to surveyed bottom of flume plus staff gauge reading. |
| SWG3- West Branch | 169681 | 1 | 35 | | Elevation | 979.71 | 7323 | | Re-set Troll reference to surveyed bottom of flume plus staff gauge reading. |

Notes:

1. All YSI 600 XLM sondes calibrated before deployment.
2. Used surveyed "bottom" elevation for each surface water flume.

**Troll QC Checks**

| Date: | 11/24/2014 | | | 11/25/2014 | | | Zeroed Troll and Reset | | | 12/4/2014 | | | 12/11/2014 (New Trolls) | | | 12/17/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference |
| GW-968 | 0.00 | 0.07 | 0.07 | 0.03 | 0.03 | 0 | NC | NC | NC | 0.00 | 0.07 | 0.07 | 0.0 | 0.0 | 0 | | | 0.0 |
| GW-969 | 1.93 | 1.97 | 0.04 | 2.19 | 2.17 | 0.02 | 2.19 | 2.18 | 0.01 | 1.30 | 1.30 | 0 | 1.39 | 1.35 | 0.04 | | | 0.0 |
| GW-970 | 13.22 | 13.21 | 0.01 | 13.67 | 10.23 | 3.44 | 13.69 | 13.67 | 0.02 | 11.34 | 11.37 | 0.03 | 10.14 | 9.19 | 0.95 | | | 0.0 |
| GW-971 | 13.53 | 13.54 | 0.01 | 14.08 | 13.99 | 0.09 | 14.19 | 14.19 | 0 | 12.27 | 12.26 | 0.01 | 9.73 | 9.73 | 0 | | | 0.0 |
| GW-972 | 9.08 | 9.07 | 0.01 | 9.53 | 9.42 | 0.11 | 9.51 | 9.51 | 0 | 8.39 | 8.34 | 0.05 | 6.67 | 6.68 | 0.01 | | | 0.0 |
| GW-973 | 9.93 | 9.94 | 0.01 | 6.83 | 6.80 | 0.03 | 10.39 | 10.39 | 0 | 9.24 | 9.21 | 0.03 | 7.47 | 7.56 | 0.09 | | | 0.0 |
| GW-974 | 6.25 | 6.25 | 0 | 6.83 | 6.80 | 0.03 | 6.84 | 6.79 | 0.05 | 5.95 | 5.89 | 0.06 | 5.82 | 5.66 | 0.16 | | | 0.0 |
| GW-975 | 6.87 | 6.87 | 0 | 7.50 | 7.47 | 0.03 | 7.49 | 7.51 | 0.02 | 6.55 | 6.53 | 0.02 | 6.61 | 6.59 | 0.02 | | | 0.0 |
| GW-976 | 46.20 | 46.19 | 0.01 | 46.10 | 46.57 | 0.47 | 46.06 | 45.98 | 0.08 | 45.94 | 45.02 | 0.72 | 44.80 | 44.90 | 0.10 | | | 0.0 |
| | | | | | | | | | | | | | | | | FILL THIS OUT | FILL THIS OUT | |

| Date: | 11/24/2014 | | | 11/26/2014-Zeroed and Reset | | | 12/1/2014 | | | 12/4/2014 | | | 12/11/2014 (New Trolls) | | | 12/17/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface Water Site ID | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft) | Difference | Elevation (ft) (Staff Gauge + SW elevation) | Troll Water Elevation (ft) | Difference |
| SWG-1 (East) | 0.06 | 0.004 | 0.06 | 100.05 | 100.05 | 0 | 100.04 | 100.04 | 0 | NC | NC | NC | 0.04 | 100.04 | 0 | 975.06 | | 975.06 |
| SWG-2 (Middle) | 0.03 | 0.00 | 0.03 | 100.03 | 100.03 | 0 | 100.04 | 100.04 | 0 | 100.01 | 100.03 | 0.02 | 0.04 | 100.04 | 0 | 981.66 | | 981.66 |
| SWG-3 (West) | 0.01 | 0.00 | 0.01 | Bad Troll | Bad Troll | Bad Troll | 100.03 | 100.03 | 0 | 100.05 | 100.05 | 0 | 0.03 | 100.03 | 0 | 979.68 | | 979.68 |
| | | | | | | | | | | | | | | | | | FILL THIS OUT | |

Note: All new Factory Calibrated Trolls installed on 12-04-2014. First QC check for new Trolls conducted on 12-11-14.
NC = No check.

| | | FILL THIS OUT | |
|---|---|---|---|
| | Bottom of Flume Elevation (ft) | Staff Gauge Measurement (ft) | |
| SWG-1 | 975.06 | | 975.06 |
| SWG-2 | 981.66 | | 981.66 |
| SWG-3 | 979.68 | | 979.68 |

EMDF Monitoring Equipment Spreadsheet

**EMDF MONITORING EQUIPMENT STATUS - WEEK ENDING 12/17/2014**

| Site ID | In-Situ Trolls | | | | | | YSI 600 XLM Sondes | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | Serial # | Device Address | Range (ft) | Monitoring Parameters | Water Level Setup | Depth to Water (ft) | Serial # | Monitoring Parameters | |
| **Shallow Well Locations** | | | | | | | | | |
| GW-969 | 163894 | 1 | 35 | Pressure, level | DTW | 1.94 | 6667 | Temperature, pH, Conductivitiy, DO, and ORP | Calibrate YSI sonde. |
| GW-971 | 169837 | 1 | 35 | | DTW | 13.00 | 1955 | | Zeroed and re-set Level Troll. Calibrate YSI sonde. |
| GW-973 | 152632 | 1 | 35 | | DTW | 9.50 | 8979 | | Calibrate YSI sonde. |
| GW-975 | 19727 | 1 | 35 | | DTW | 8.06 | 16835 | | Calibrate YSI sonde. |
| **Bedrock Well Locations** | | | | | | | | | |
| GW-968 | 122991 | 1 | 69 | Pressure, level | DTW | 0.00 | 12793 | Temperature, pH, Conductivitiy, DO, and ORP | Calibrate YSI sonde. Replace DO membrane. |
| GW-970 | 169354 | 1 | 69 | | DTW | 13.15 | 16661 | | Zeroed and re-set Level Troll. Calibrate YSI sonde. |
| GW-972 | 169305 | 1 | 69 | | DTW | 8.67 | 6544 | | Calibrate YSI sonde. |
| GW-974 | 169313 | 1 | 69 | | DTW | 7.43 | 6664 | | Zeroed and re-set Level Troll. Calibrate YSI sonde. |
| GW-976 | 169346 | 1 | 69 | | DTW | 44.65 | 2176 | | Zero and re-set Troll. Calibrate YSI sonde. Replace DO membrane. |
| **Surface Water Locations (EMDNT3)** | | | | | | **Water Elevation (ft)[1]** | | | |
| SWG1- East Branch | 136867 | 1 | 35 | Pressure, level | Elevation | 975.10 | 8980 | Temperature, pH, Conductivitiy, DO, and ORP | Calibrate YSI sonde. |
| SWG2- Middle Branch | 376400 | 1 | 69 | | Elevation | 981.69 | 24871 | | Calibrate YSI sonde. |
| SWG3- West Branch | 169681 | 1 | 35 | | Elevation | 979.71 | 7323 | | Calibrate YSI sonde. |

Notes:

1. Used surveyed "bottom" elevation for each surface water flume.

**Troll QC Checks**

| Date: | 11/24/2014 | | | 11/25/2014 | | | Zeroed Troll and Reset | | | 12/4/2014 | | | 12/11/2014 (New Trolls) | | | 12/17/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference |
| GW-968 | 0.00 | 0.07 | 0.07 | 0.03 | 0.03 | 0 | NC | NC | NC | 0.00 | 0.07 | 0.07 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 |
| GW-969 | 1.93 | 1.97 | 0.04 | 2.19 | 2.17 | 0.02 | 2.19 | 2.18 | 0.01 | 1.30 | 1.30 | 0 | 1.39 | 1.35 | 0.04 | 1.94 | 1.94 | 0 |
| GW-970 | 13.22 | 13.21 | 0.01 | 13.67 | 10.23 | 3.44 | 13.69 | 13.67 | 0.02 | 11.34 | 11.37 | 0.03 | 10.14 | 9.19 | 0.95 | 13.15 | 12.95 | 0.20 |
| GW-971 | 13.53 | 13.54 | 0.01 | 14.08 | 13.99 | 0.09 | 14.19 | 14.19 | 0 | 12.27 | 12.26 | 0.01 | 9.73 | 9.73 | 0 | 13.00 | 12.98 | 0.02 |
| GW-972 | 9.08 | 9.07 | 0.01 | 9.53 | 9.42 | 0.11 | 9.51 | 9.51 | 0 | 8.39 | 8.34 | 0.05 | 6.67 | 6.68 | 0.01 | 8.67 | 8.67 | 0 |
| GW-973 | 9.93 | 9.94 | 0.01 | 6.83 | 6.80 | 0.03 | 10.39 | 10.39 | 0 | 9.24 | 9.21 | 0.03 | 7.47 | 7.56 | 0.09 | 9.50 | 9.50 | 0 |
| GW-974 | 6.25 | 6.25 | 0 | 6.83 | 6.80 | 0.03 | 6.84 | 6.79 | 0.05 | 5.95 | 5.89 | 0.06 | 5.82 | 5.66 | 0.16 | 7.43 | 7.49 | 0.06 |
| GW-975 | 6.87 | 6.87 | 0 | 7.50 | 7.47 | 0.03 | 7.49 | 7.51 | 0.02 | 6.55 | 6.53 | 0.02 | 6.61 | 6.59 | 0.02 | 8.06 | 8.06 | 0 |
| GW-976 | 46.20 | 46.19 | 0.01 | 46.10 | 46.57 | 0.47 | 46.06 | 45.98 | 0.08 | 45.94 | 45.02 | 0.72 | 44.80 | 44.90 | 0.10 | 44.65 | 44.58 | 0.07 |

| Date: | 11/24/2014 | | | 11/26/2014-Zeroed and Reset | | | 12/1/2014 | | | 12/4/2014 | | | 12/11/2014 (New Trolls) | | | 12/17/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface Water Site ID | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft) | Difference | Elevation (ft) (Staff Gauge + SW elevation) | Troll Water Elevation (ft) | Difference |
| SWG-1 (East) | 0.06 | 0.004 | 0.06 | 100.05 | 100.05 | 0 | 100.04 | 100.04 | 0 | NC | NC | NC | 0.04 | 100.04 | 0 | 975.10 | 975.1 | 0 |
| SWG-2 (Middle) | 0.03 | 0.00 | 0.03 | 100.03 | 100.03 | 0 | 100.04 | 100.04 | 0 | 100.01 | 100.03 | 0.02 | 0.04 | 100.04 | 0 | 981.69 | 981.69 | 0 |
| SWG-3 (West) | 0.01 | 0.00 | 0.01 | Bad Troll | Bad Troll | Bad Troll | 100.03 | 100.03 | 0 | 100.05 | 100.05 | 0 | 0.03 | 100.03 | 0 | 979.71 | 979.71 | 0 |

Note: All new Factory Calibrated Trolls installed on 12-04-2014. First QC check for new Trolls conducted on 12-11-14.
NC = No check.

| | Bottom of Flume Elevation (ft) | Staff Gauge Measurement (ft) | |
|---|---|---|---|
| SWG-1 | 975.06 | 0.04 | 975.10 |
| SWG-2 | 981.66 | 0.03 | 981.69 |
| SWG-3 | 979.68 | 0.03 | 979.71 |
| | | **Fill this Out** | |

**EMDF MONITORING**

**NOTES ON DATA DOWNLOADS**

**12-23-2014**

1. Monitoring data spreadsheets for surface water locations SWG-1, SWG-2 and SWG-3 contain columns which calculate flow in CFS and GPM. The formulas for calculating CFS and GPM flow were obtained from the *Open Channel Flow Flume Discharge Tables* (Vendor cut sheets).

EMDF Monitoring Equipment Spreadsheet

**EMDF MONITORING EQUIPMENT STATUS - WEEK ENDING 12/23/2014**

| Site ID | In-Situ Trolls | | | | | | YSI 600 XLM Sondes | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | Serial # | Device Address | Range (ft) | Monitoring Parameters | Water Level Setup | Depth to Water (ft) | Serial # | Monitoring Parameters | |
| **Shallow Well Locations** | | | | | | | | | |
| GW-969 | 163894 | 1 | 35 | Pressure, level | DTW | 1.8 | 6667 | Temperature, pH, Conductivitiy, DO, and ORP | |
| GW-971 | 169837 | 1 | 35 | | DTW | 14.26 | 1955 | | Zeroed and re-set Level Troll. Replace DO membrane and calibrate. |
| GW-973 | 152632 | 1 | 35 | | DTW | 9.89 | 8979 | | |
| GW-975 | 19727 | 1 | 35 | | DTW | 8.49 | 16835 | | Zero and re-set Troll. |
| **Bedrock Well Locations** | | | | | | | | | |
| GW-968 | 122991 | 1 | 69 | Pressure, level | DTW | 0.00 | 12793 | Temperature, pH, Conductivitiy, DO, and ORP | Pulled and re-deployed instruments (additional 5 ft stainless-steel riser installed on well). |
| GW-970 | 169354 | 1 | 69 | | DTW | 13.86 | 16661 | | |
| GW-972 | 169305 | 1 | 69 | | DTW | 9.08 | 6544 | | Zeroed and re-set Level Troll. Replace DO membrane and calibrate. |
| GW-974 | 169313 | 1 | 69 | | DTW | 7.76 | 6664 | | Zeroed and re-set Level Troll. Replace DO membrane and calibrate. |
| GW-976 | 169346 | 1 | 69 | | DTW | 44.7 | 2176 | | Zero and re-set Troll. |
| **Surface Water Locations (EMDNT3)** | | | | | | **Water Elevation (ft)[1]** | | | |
| SWG1- East Branch | 136867 | 1 | 35 | Pressure, level | Elevation | 975.13 | 8980 | Temperature, pH, Conductivitiy, DO, and ORP | Zero and re-set Troll. |
| SWG2- Middle Branch | 376400 | 1 | 69 | | Elevation | 981.70 | 24871 | | |
| SWG3- West Branch | 169681 | 1 | 35 | | Elevation | 979.72 | 7323 | | |

Notes:

1. M&W Drilling on site to install 5 ft stainless-steel riser at GW-968. Also, install lanyards on well caps at GW970, GW972, and GW-976.

**Troll QC Checks**

| Date: | 11/24/2014 | | | 11/25/2014 | | | Zeroed Troll and Reset | | | 12/4/2014 | | | 12/11/2014 (New Trolls) | | | 12/17/2014 | | | 12/23/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference | Water Level Indicator Depth to Water (ft) | Troll Depth to Water (ft) | Difference |
| GW-968 | 0.00 | 0.07 | 0.07 | 0.03 | 0.03 | 0 | NC | NC | NC | 0.00 | 0.07 | 0.07 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.00 | 0.07 | -0.07 |
| GW-969 | 1.93 | 1.97 | 0.04 | 2.19 | 2.17 | 0.02 | 2.19 | 2.18 | 0.01 | 1.30 | 1.30 | 0 | 1.39 | 1.35 | 0.04 | 1.94 | 1.94 | 0 | 1.80 | 1.79 | 0.01 |
| GW-970 | 13.22 | 13.21 | 0.01 | 13.67 | 10.23 | 3.44 | 13.69 | 13.67 | 0.02 | 11.34 | 11.37 | 0.03 | 10.14 | 9.19 | 0.95 | 13.15 | 12.95 | 0.20 | 13.86 | 13.65 | 0.21 |
| GW-971 | 13.53 | 13.54 | 0.01 | 14.08 | 13.99 | 0.09 | 14.19 | 14.19 | 0 | 12.27 | 12.26 | 0.01 | 9.73 | 9.73 | 0 | 13.00 | 12.98 | 0.02 | 14.26 | 14.23 | 0.03 |
| GW-972 | 9.08 | 9.07 | 0.01 | 9.53 | 9.42 | 0.11 | 9.51 | 9.51 | 0 | 8.39 | 8.34 | 0.05 | 6.67 | 6.68 | 0.01 | 8.67 | 8.67 | 0 | 9.08 | 9.05 | 0.03 |
| GW-973 | 9.93 | 9.94 | 0.01 | 6.83 | 6.80 | 0.03 | 10.39 | 10.39 | 0 | 9.24 | 9.21 | 0.03 | 7.47 | 7.56 | 0.09 | 9.50 | 9.50 | 0 | 9.89 | 9.86 | 0.03 |
| GW-974 | 6.25 | 6.25 | 0 | 6.83 | 6.80 | 0.03 | 6.84 | 6.79 | 0.05 | 5.95 | 5.89 | 0.06 | 5.82 | 5.66 | 0.16 | 7.43 | 7.49 | 0.06 | 7.76 | 7.69 | 0.07 |
| GW-975 | 6.87 | 6.87 | 0 | 7.50 | 7.47 | 0.03 | 7.49 | 7.51 | 0.02 | 6.55 | 6.53 | 0.02 | 6.61 | 6.59 | 0.02 | 8.06 | 8.06 | 0 | 8.49 | 8.44 | 0.05 |
| GW-976 | 46.20 | 46.19 | 0.01 | 46.10 | 46.57 | 0.47 | 46.06 | 45.98 | 0.08 | 45.94 | 45.02 | 0.72 | 44.80 | 44.90 | 0.10 | 44.65 | 44.58 | 0.07 | 44.70 | 44.96 | -0.26 |
| | | | | | | | | | | | | | | | | | | | Fill this Out | Fill this Out | |

| Date: | 11/24/2014 | | | 11/26/2014-Zeroed and Reset | | | 12/1/2014 | | | 12/4/2014 | | | 12/11/2014 (New Trolls) | | | 12/17/2014 | | | 12/23/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface Water Site ID | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft)* | Difference | Staff Measurement (ft) | Troll Water Elevation (ft) | Difference | Elevation (ft) (Staff Gauge + SW elevation) | Troll Water Elevation (ft) | Difference | Elevation (ft) (Staff Gauge + SW elevation) | Troll Water Elevation (ft) | Difference |
| SWG-1 (East) | 0.06 | 0.004 | 0.06 | 100.05 | 100.05 | 0 | 100.04 | 100.04 | 0 | NC | NC | NC | 0.04 | 100.04 | 0 | 975.13 | 975.1 | 0 | 975.13 | 975.12 | 0.01 |
| SWG-2 (Middle) | 0.03 | 0.00 | 0.03 | 100.03 | 100.03 | 0 | 100.04 | 100.04 | 0 | 100.01 | 100.03 | 0.02 | 0.04 | 100.04 | 0 | 981.7 | 981.69 | 0 | 981.70 | 981.70 | 0.00 |
| SWG-3 (West) | 0.01 | 0.00 | 0.01 | Bad Troll | Bad Troll | Bad Troll | 100.03 | 100.03 | 0 | 100.05 | 100.05 | 0 | 0.03 | 100.03 | 0 | 979.72 | 979.71 | 0 | 979.72 | 979.72 | 0.00 |
| | | | | | | | | | | | | | | | | | | | | Fill this Out | |

Note: All new Factory Calibrated Trolls installed on 12-04-2014. First QC check for new Trolls conducted on 12-11-14.
NC = No check.

| | Bottom of Flume Elevation (ft) | Staff Gauge Measurement (ft) | |
|---|---|---|---|
| SWG-1 | 975.06 | 0.07 | 975.13 |
| SWG-2 | 981.66 | 0.04 | 981.7 |
| SWG-3 | 979.68 | 0.04 | 979.72 |
| | | Fill this Out | |

**EMDF MONITORING**

**NOTES ON DATA DOWNLOADS**

**12-29-2014**

1. Monitoring data spreadsheets for surface water locations SWG-1, SWG-2 and SWG-3 contain columns which calculate flow in CFS and GPM. The formulas for calculating CFS and GPM flow were obtained from the *Open Channel Flow Flume Discharge Tables* (Vendor cut sheets).

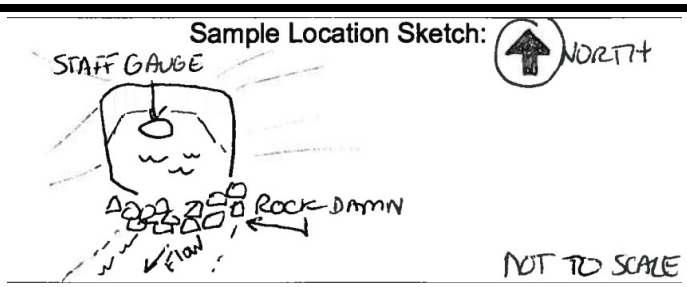
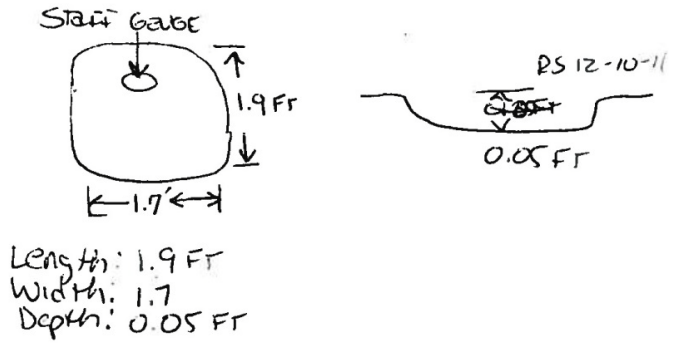
# EXHIBIT A.15:
# DOCUMENTATION FOR WEEKLY SURFACE WATER OBSERVATIONAL MONITORING

This page intentionally left blank.

ALLIANT

# Surface Water Monitoring Location

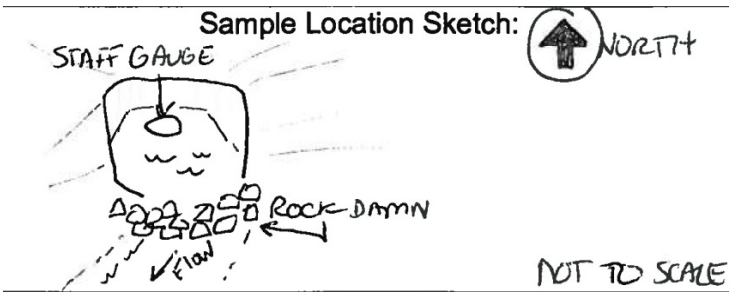
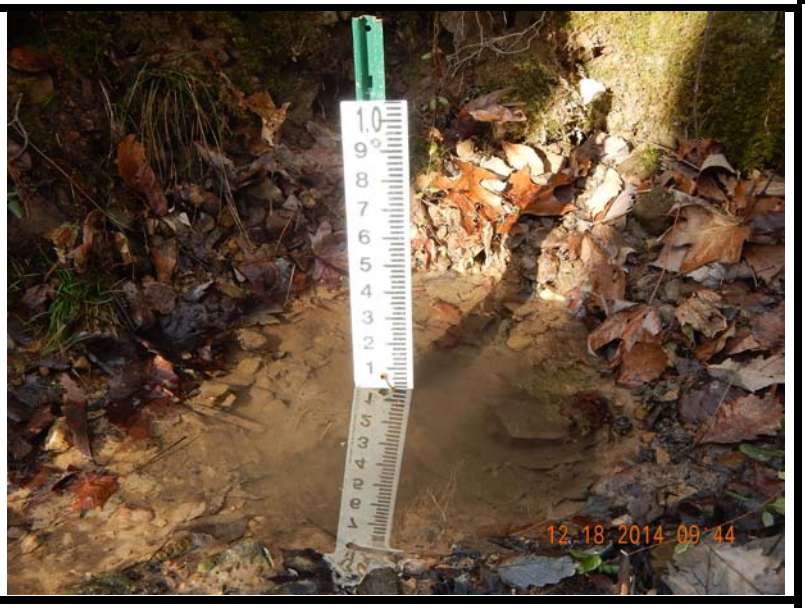
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 |   |
| Date Measured: 12/10/14 | |
| Time Measured: 1322 | |
| | |
| **Field Observations** |   |
| Elevation (gauge): 0.05 ft (1058.32 ft msl) | |
| pH: 6.72 | |
| Temp: 10.46°C | |
| ORP: 155 mV | |
| D.O.: 6.39 mg/L | |
| Turbidity: Over range | |
| Water Clarity Observed: Clear | Photograph Log #:12/10/2014 – 0.28.JPG |
| Flow Measurement: Very little flow <1.0 GPM | Measurement Equipment: Horiba U52 |
| Air Temperature: ° F: 39 | |
| Weather: Cold, Cloudy, Damp | |
| Comments: Conductivity = 0.086 mS/cm<br><br>NOTE: Turbidity was over range due to cleaning out leaves and debris from the location. Water was clear on arrival. | |
| | |
| Field Technician: (Print) Richard Stout, Carson Vick | Date: 12/10/2014 |

ALLIANT

# Surface Water Monitoring Location

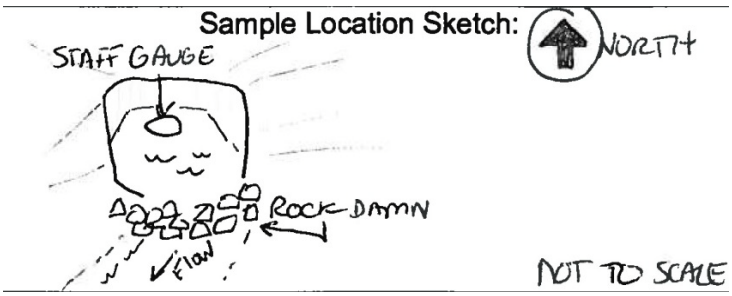
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 12/18/14 | |
| Time Measured: 0945 | |
| | |
| **Field Observations** |   |
| Elevation (gauge): 0.04 (1,057.37 ft msl) | |
| pH: 6.96 | |
| Temp: 8.93 | |
| ORP: 199 | |
| D.O.: 11.32 | |
| Turbidity: 694 (Stirred up water due to excavation of monitoring pool) | |
| Conductivity: 0.093 mS/cm | Photograph Log #: 12/18/14 – 037.jpg |
| Flow Measurement: <1 gpm | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba – 52 #WIV35Y5U |
| Weather: Partly cloudy, dry, Air Temperature: F: 34° F | |
| Comments: Improved water quality monitoring pool by excavation | |
| | |
| Field Technician: (Print) Mark Maki, Ronnie Phillips | Date: 12/18/14 |

ALLIANT

# Surface Water Monitoring Location

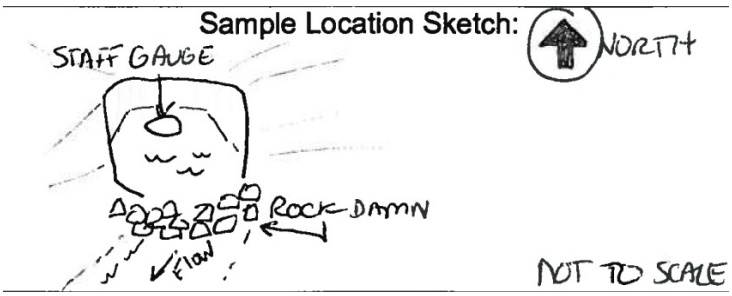
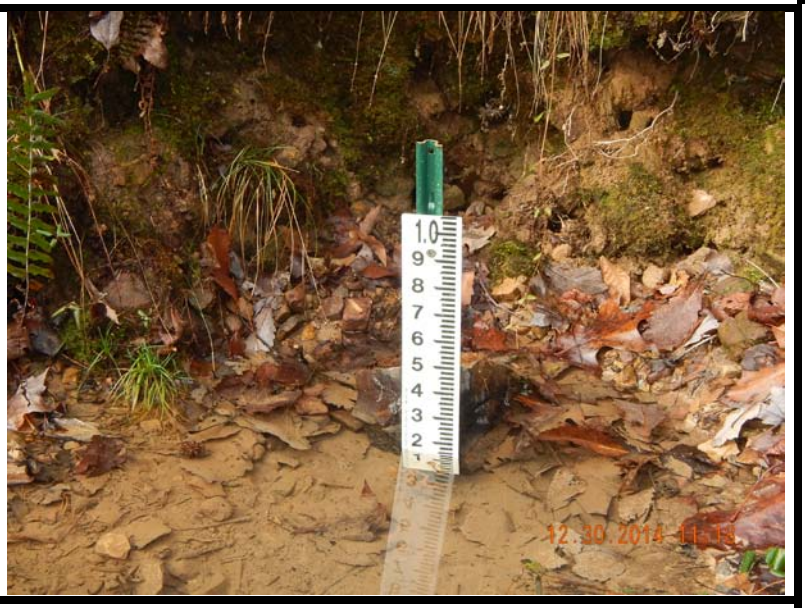
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 12/23/14 | |
| Time Measured: 1125 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.10 (1,058.37 ft msl) | |
| pH: 7.13 | |
| Temp: 10.49° C | |
| ORP: 160 | |
| D.O.: 8.25 | |
| Turbidity: 2.0 | |
| Conductivity: 0.093 mS/cm | Photograph Log #: 12/23/2014 - 044.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba –U-52 #WIV35Y5U |
| Weather: Overcast, Air Temperature: 55° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Phillips | Date: 12/23/14 |

ALLIANT

# Surface Water Monitoring Location

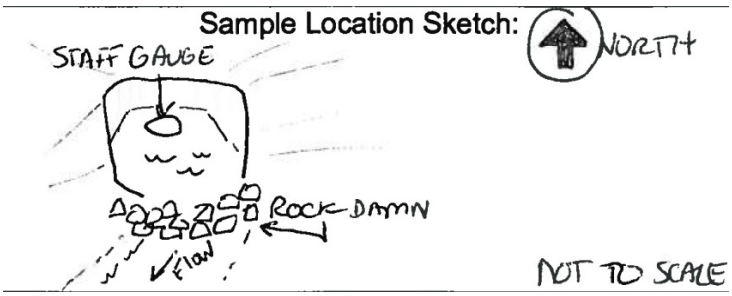
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 12/30/14 | |
| Time Measured: 1116 | |
| | |
| **Field Observations** |  |
| Elevation (gauge): 0.18 (1,058.45 ft msl) | |
| pH: 6.72 | |
| Temp: 9.7° C | |
| ORP: 203 | |
| D.O.: 8.18 mg/L | |
| Turbidity: 6.0 NTU | |
| Conductivity: 0.063 mS/cm | Photograph Log #: 12/30/2014 - 052.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba –U-52 #WIV35Y5U |
| Weather: Partly sunny, Air Temperature: 39° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print) Carson Vick, Richard Stout | Date: 12/30/14 |

ALLIANT

# Surface Water Monitoring Location

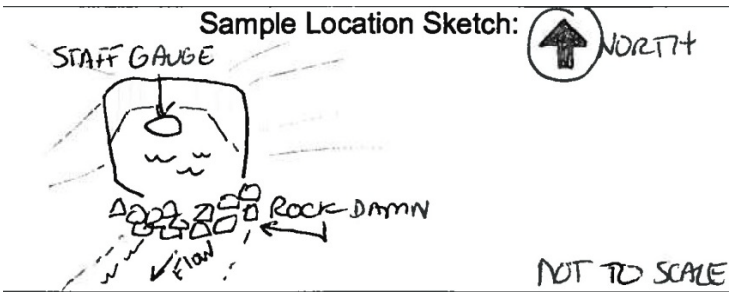
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 01/07/15 | |
| Time Measured: 1206 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.16 (1,058.43 ft msl) | |
| pH: 6.80 | |
| Temp: 9.35° C | |
| ORP: 192 | |
| D.O.: 10.53 mg/L | |
| Turbidity: 10.1 NTU | |
| Conductivity: 0.061 mS/cm | Photograph Log #: 01/07/15 - 059.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba –U-52 #WIV35Y5U |
| Weather: Cleary, Air Temperature: 26° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

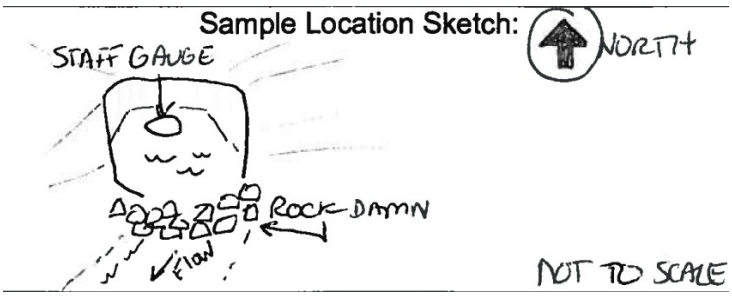
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 01/14/15 | |
| Time Measured: 1110 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.20 (1,058.43 ft msl) | |
| pH: 6.63 | |
| Temp: 8.235° C | |
| ORP: 213 | |
| D.O.: 10.89 mg/L | |
| Turbidity: 4.9 NTU | |
| Conductivity: 0.053 mS/cm | Photograph Log #: 01/14/15 - 065.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba –U-52 #WIV35Y5U |
| Weather: Overcast, Air Temperature: 38° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/14/15 |

ALLIANT

# Surface Water Monitoring Location

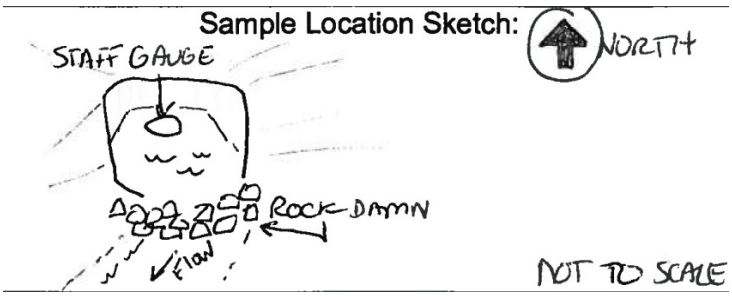
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 01/21/15 | |
| Time Measured: 1025 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.13 (1,058.40 ft msl) | |
| pH: 6.86 | |
| Temp: 9.55° C | |
| ORP: 184 | |
| D.O.: 8.21 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.084 mS/cm | Photograph Log #: 01/21/15 - 078.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba –U-52 #WIV35Y5U |
| Weather: Clear, Sunny, Air Temperature: 50° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/21/15 |

ALLIANT

# Surface Water Monitoring Location

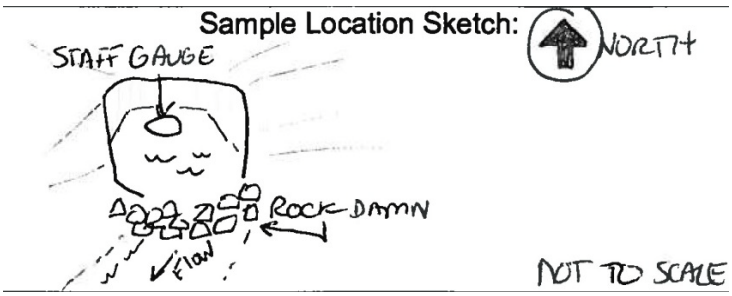
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 01/29/15 | |
| Time Measured: 1030 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.10 (1,058.37 ft msl) | |
| pH: 6.29 | |
| Temp: 8.02° C | |
| ORP: 199 | |
| D.O.: 10.38 mg/L | |
| Turbidity: 7.5 NTU | |
| Conductivity: 0.071 mS/cm | Photograph Log #: 01/29/15 – 096.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba –U-52 #WIV35Y5U |
| Weather: Rain, Air Temperature: 38° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print)<br>Jack Strader & Daniel Edds | Date: 01/29/15 |

ALLIANT

# Surface Water Monitoring Location

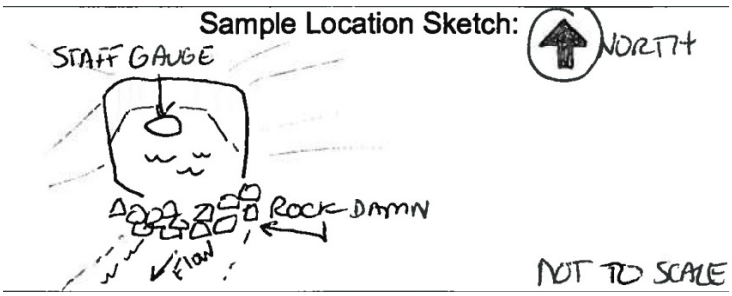
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 02/05/15 | |
| Time Measured: 1016 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.12 (1,058.29 ft msl) | |
| pH: 6.77 | |
| Temp: 7.82° C | |
| ORP: 211 | |
| D.O.: 11.88 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.076 mS/cm | Photograph Log #: 02/05/15 – 113.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Calm, Cold, Air Temperature: 31° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print)<br>Jack Strader. Seth Howard | Date: 02/05/15 |

ALLIANT

# Surface Water Monitoring Location

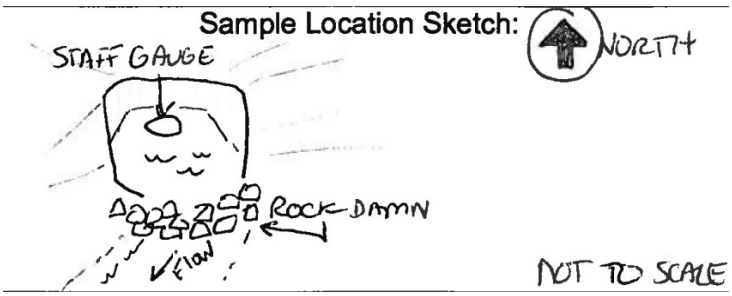
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 02/11/15 | |
| Time Measured: 0945 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.06 (1,058.33 ft msl) | |
| pH: 6.59 | |
| Temp: 7.92° C | |
| ORP: 215 | |
| D.O.: 12.37 mg/L | |
| Turbidity: 2.4 NTU | |
| Conductivity: 0.087 mS/cm | Photograph Log #: 02/11/15 – 130.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Calm, Cold, Air Temperature: 30° F | |
| Comments: Flow measure estimated and not possible due to low flow conditions. | |
| | |
| Field Technician: (Print)<br>Jack Strader. Daniel Edds | Date: 02/11/15 |

ALLIANT

# Surface Water Monitoring Location

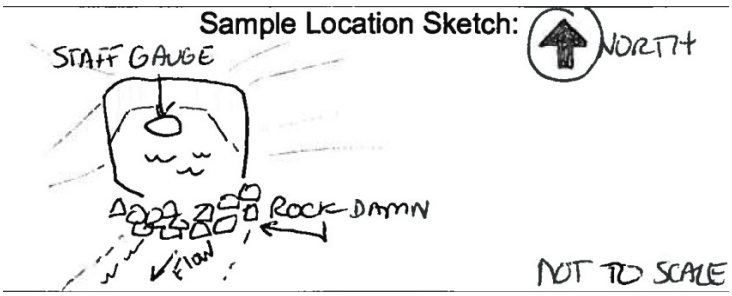
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 02/20/15 | |
| Time Measured: 1154 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.12 (1,058.29 ft msl) | |
| pH: 6.61 | |
| Temp: 7.75° C | |
| ORP: 150 | |
| D.O.: 9.67 mg/L | |
| Turbidity: 2.7 NTU | |
| Conductivity: 0.091 mS/cm | Photograph Log #: 02/20/15 – E-149.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Calm, Cold, Air Temperature: 15° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print)<br>Jack Strader & Daniel Edds | Date: 02/20/15 |

ALLIANT

# Surface Water Monitoring Location

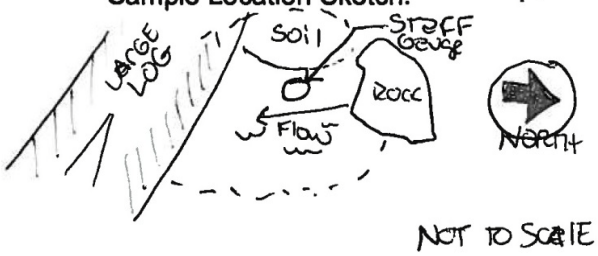
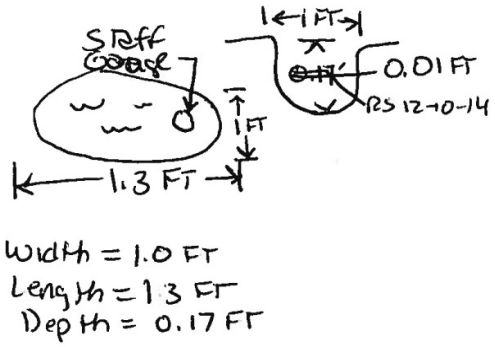
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT2-SP1 | Sample Location Sketch:   |
| Date Measured: 02/27/15 | |
| Time Measured: 1016 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.16 (1,058.43 ft msl) | |
| pH: 6.21 | |
| Temp: 6.58° C | |
| ORP: 204 | |
| D.O.: 14.21 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.053 mS/cm | Photograph Log #: 02/27/15 – 175.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Calm, Cold, Air Temperature: 27° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technician: (Print)<br>Jack Strader & Daniel Edds | Date: 02/27/15 |

ALLIANT

# Surface Water Monitoring Location

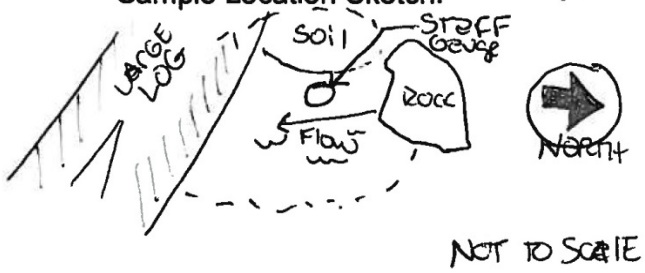
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 12/10/14 | |
| Time Measured: 1146 | |
| | |
| **Field Observations** |   |
| Elevation (gauge): 0.01 ft (1041.25 ft msl) | |
| pH: 6.33 | |
| Temp: 11.75°C | |
| ORP: 186 mV | |
| D.O.: 8.60 mg/L | |
| Turbidity: 0.0 NTU | |
| Water Clarity Observed: Clear | Photograph Log #:12/10/2014- 0.24.JPG |
| Flow Measurement: Very little flow <1.0 GPM | Measurement Equipment: Horiba U52 |
| Air Temperature: ° F: 39 | |
| Weather: Cold and Cloudy, Damp | |
| Comments: Conductivity = 0.064 mS/cm<br><br>NOTE: Turbidity was over range due to cleaning out leaves and debris from the location. Water was clear on arrival. | |
| | |
| Field Technician: (Print) Richard Stout, Carson Vick | Date: 12/10/2014 |

ALLIANT

# Surface Water Monitoring Location

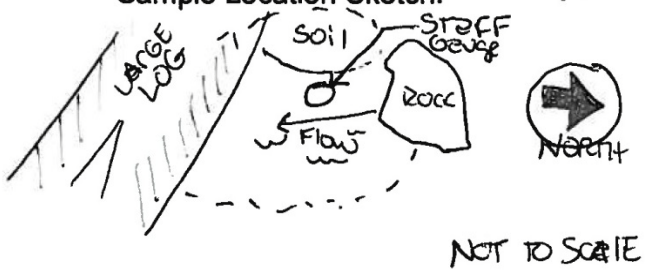
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 12/18/14 | |
| Time Measured: 0915 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.06 (1,040.36 ft msl) | |
| pH: 6.66 | |
| Temp: 11.34 | |
| ORP: 276 | |
| D.O.: 10.27 | |
| Turbidity: 752 disturbed due to excavation. (Clear before <10 NTU) | |
| Conductivity: 0.084 mS/cm | Photograph Log #: 12/18/2014 – 038.jpg |
| Flow Measurement: >1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Partly cloudy, dry, cool, no wind to breezy, pressure – 30.28", Air Temperature: F: 34° F | |
| Comments: Used shovel to dry out water quality monitoring pool at spring | |
| | |
| Field Technician: (Print) Mark Maki, Ronnie Phillips | Date: 12/18/14 |

ALLIANT

# Surface Water Monitoring Location

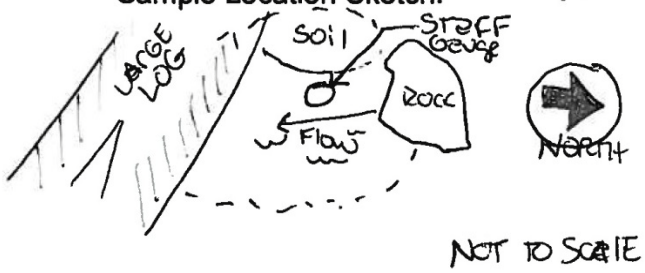
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 12/23/14 | |
| Time Measured: 1050 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.05 (1,041.29 ft msl) | |
| pH: 6.92 | |
| Temp: 11.81 | |
| ORP: 141 | |
| D.O.: 8.97 | |
| Turbidity: 1.2 | |
| Conductivity: 0.074 mS/cm | Photograph Log #: 12/23/2014 – 043.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Air Temperature: 55° F | |
| Comments: Flow measurement not possible due to low flow. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Phillips | Date: 12/23/14 |

ALLIANT

# Surface Water Monitoring Location

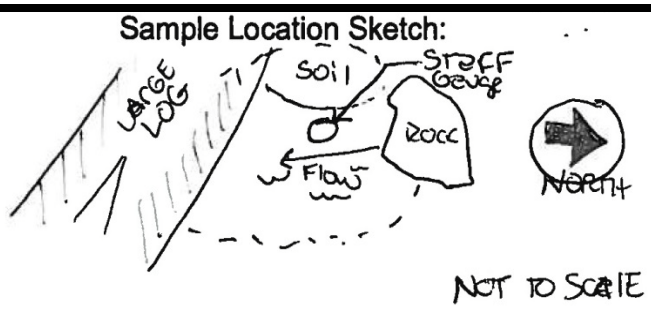
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 12/30/14 | |
| Time Measured: 1047 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.05 (1041.26 ft msl) | |
| pH: 6.92 | |
| Temp: 11.7° C | |
| ORP: 190 | |
| D.O.: 8.21 mg/L | |
| Turbidity: 10.4 NTU | |
| Conductivity: 0.021 mS/cm | Photograph Log #: 12/30/2014 – 051.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Partly cloudy, Air Temperature: 37° F | |
| Comments: Flow measurement not possible due to low flow. | |
| | |
| Field Technician: (Print) Carson Vick, Richard Stout | Date: 12/30/14 |

ALLIANT

# Surface Water Monitoring Location

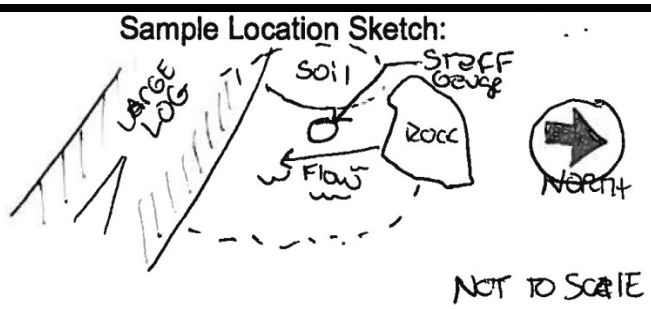
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 01/07/15 | |
| Time Measured: 1135 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.10 (1041.34 ft msl) | |
| pH: 6.59 | |
| Temp: 10.71° C | |
| ORP: 178 | |
| D.O.: 7.09 mg/L | |
| Turbidity: 7.5 NTU | |
| Conductivity: 0.048 mS/cm | Photograph Log #: 01/07/15 - 057.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Air Temperature: 26° F | |
| Comments: Flow measurement not possible due to low flow. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

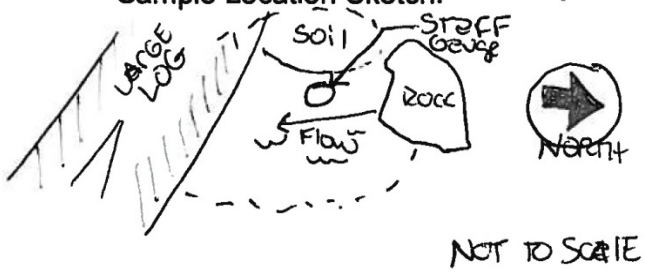
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 01/14/15 | |
| Time Measured: 1135 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.17 (1041.41 ft msl) | |
| pH: 6.36 | |
| Temp: 9.67° C | |
| ORP: 213 | |
| D.O.: 8.44 mg/L | |
| Turbidity: 8.7 NTU | |
| Conductivity: 0.047 mS/cm | Photograph Log #: 01/14/15 - 064.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Air Temperature: 38° F | |
| Comments: Flow measurement not possible due to low flow. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

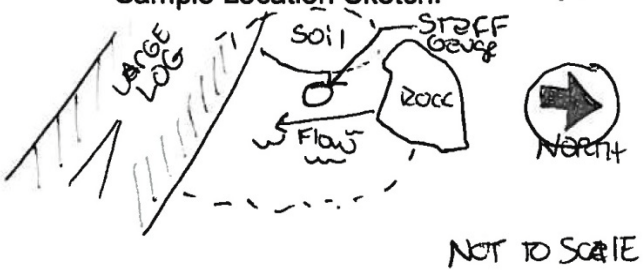
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 01/21/15 | |
| Time Measured: 1145 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.08 (1041.32 ft msl) | |
| pH: 6.46 | |
| Temp: 11.63° C | |
| ORP: 259 | |
| D.O.: 13.41 mg/L | |
| Turbidity: 3.6 NTU | |
| Conductivity: 0.070 mS/cm | Photograph Log #: 01/21/15 - 080.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Sunny, Air Temperature: 55° F | |
| Comments: Flow measurement not possible due to low flow. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/21/15 |

ALLIANT

# Surface Water Monitoring Location

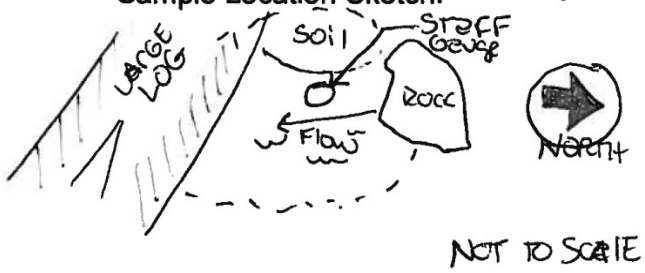
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 01/29/15 | |
| Time Measured: 1110 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.09 (1041.33 ft msl) | |
| pH: 6.52 | |
| Temp: 10.65° C | |
| ORP: 160 | |
| D.O.: 8.85 mg/L | |
| Turbidity: 10.9 NTU | |
| Conductivity: 0.057 mS/cm | Photograph Log #: 01/29/15 - 098.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cold, Light Rain, Air Temperature: 39° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technicians: (Print)<br>Jack Strader & Daniel Edds | Date: 01/29/15 |

ALLIANT

# Surface Water Monitoring Location

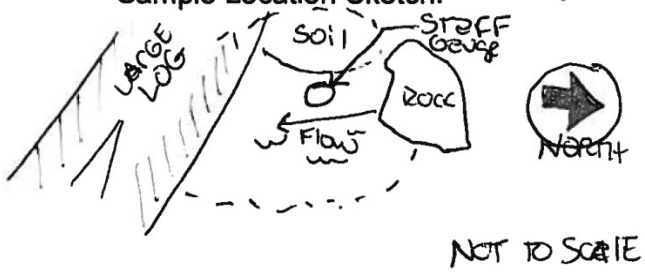
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 02/05/15 | |
| Time Measured: 0945 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.09 (1041.33 ft msl) | |
| pH: 6.53 | |
| Temp: 8.9° C | |
| ORP: 189 | |
| D.O.: 9.25 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.058 mS/cm | Photograph Log #: 02/05/15 - 112.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Cold, Calm, Air Temperature: 29° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technicians: (Print)<br>Jack Strader, Seth Howard | Date: 02/05/15 |

ALLIANT

# Surface Water Monitoring Location

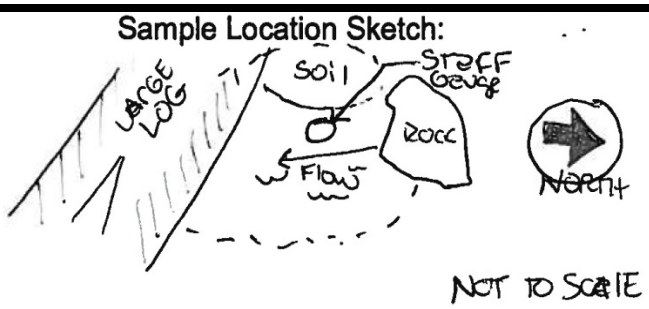
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 02/11/15 | |
| Time Measured: 1005 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.07 (1041.31 ft msl) | |
| pH: 6.85 | |
| Temp: 10.21° C | |
| ORP: 192 | |
| D.O.: 10.74 mg/L | |
| Turbidity: 2.9 NTU | |
| Conductivity: 0.066 mS/cm | Photograph Log #: 02/11/15 - 131.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Cold, Calm, Air Temperature: 31° F | |
| Comments: Flow measure estimated, not possible due to low flow conditions. | |
| | |
| Field Technicians: (Print)<br>Jack Strader, Daniel Edds | Date: 02/11/15 |

ALLIANT

# Surface Water Monitoring Location

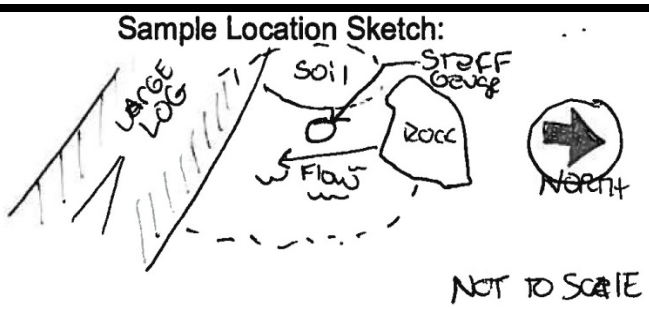
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 02/20/15 | |
| Time Measured: 1242 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.06 (1041.30 ft msl) | |
| pH: 6.88 | |
| Temp: 9.5° C | |
| ORP: 174 | |
| D.O.: 8.43 mg/L | |
| Turbidity: 1.4 NTU | |
| Conductivity: 0.073 mS/cm | Photograph Log #: 02/20/15 - 150.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Cold, Calm, Air Temperature: 29° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technicians: (Print)<br>Jack Strader & Daniel Edds | Date: 02/20/15 |

ALLIANT

# Surface Water Monitoring Location

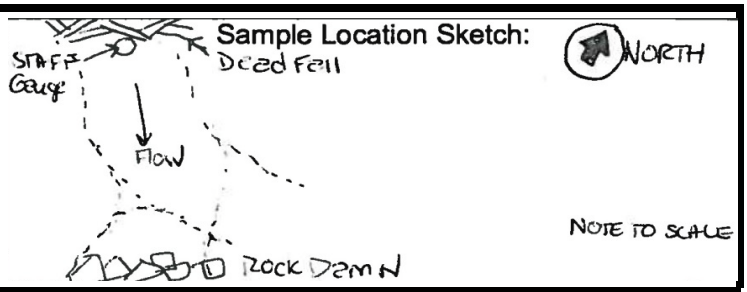
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP1 | Sample Location Sketch:   |
| Date Measured: 02/27/15 | |
| Time Measured: 1050 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.14 (1041.38 ft msl) | |
| pH: 6.39 | |
| Temp: 2.96° C | |
| ORP: 184 | |
| D.O.: 16.87 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.062 mS/cm | Photograph Log #: 02/27/15 - 176.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Cold, Calm, Air Temperature: 30° F | |
| Comments: Flow measure not possible due to low flow conditions. | |
| | |
| Field Technicians: (Print)<br>Jack Strader & Daniel Edds | Date: 02/27/15 |

ALLIANT

# Surface Water Monitoring Location

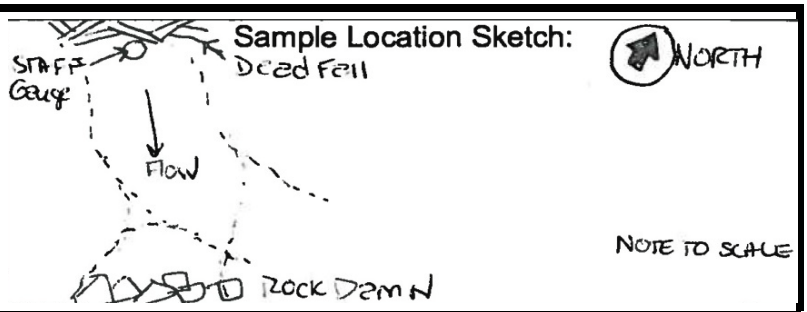
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 12/10/14 | |
| Time Measured: 1043 | |
| | |
| **Field Observations** | WIDTH = ~1 FT<br>Length = 3 FT<br>Depth = .005 FT (Ave depth from 3 measurements) |
| Elevation (gauge): 0.05 ft (1043.38 ft msl) | |
| pH: 6.09 (not enough water to read) | |
| Temp: 7.58°C | |
| ORP: 147 mV | |
| D.O.: 7.50 mg/L | |
| Turbidity: 0.0 NTU | |
| Water Clarity Observed: Clear | Photograph Log #: 12/10/2014 - 014.JPG |
| Flow Measurement: <1.0 GPM | Measurement Equipment: Horiba U52 |
| Air Temperature: ° F: 39 | |
| Weather: Cold, Cloudy | |
| Comments: Conductivity = 0.064 mS/cm<br><br>NOTE: There is not enough water to get an accurate temperature reading. | |
| | |
| Field Technician: (Print) Richard Stout, Carson Vick | Date: 12/10/2014 |

ALLIANT

# Surface Water Monitoring Location

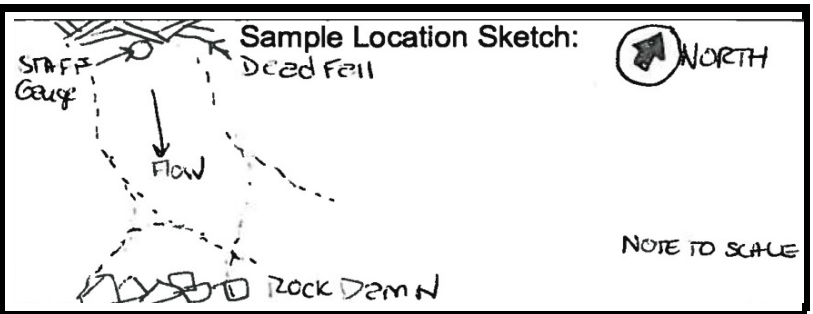
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 12/17/2014 | |
| Time Measured: 1545 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.04 (1,042.43 ft msl) | |
| pH: 6.60 | |
| Temp: 9.78 | |
| ORP: 212 | |
| D.O.: Not recorded | |
| Turbidity: 0.0 | |
| Conductivity: 0.046 mS/cm | Photograph Log #: 12/17/2014 - 034.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Partly Cloudy with slight breeze, Air Temperature: 46° F | |
| Comments: Used shovel to improve measurement pool | |
| | |
| Field Technician: (Print) Mark Maki, Ronnie Phillips | Date: 12/17/14 |

ALLIANT

# Surface Water Monitoring Location

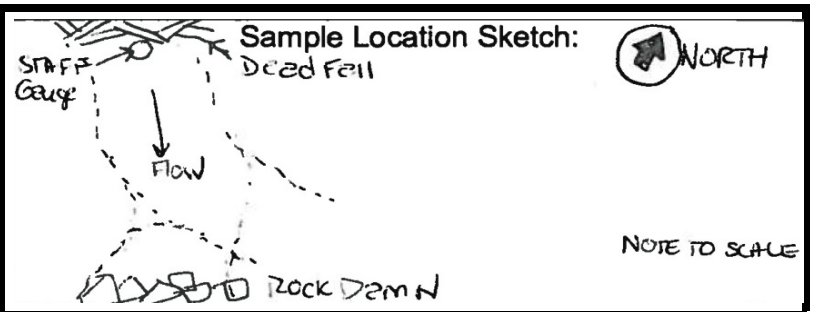
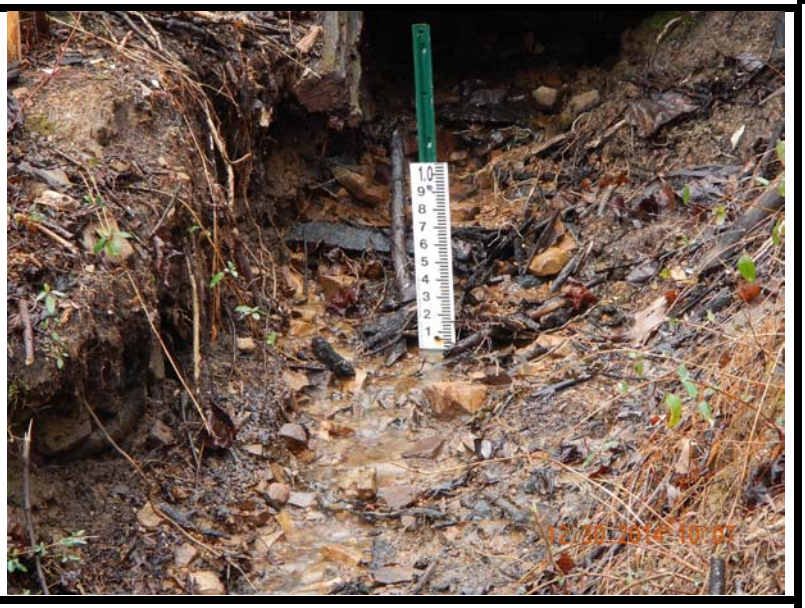
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 12/23/2014 | |
| Time Measured: 0927 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.02 (1,043.35 ft msl) | |
| pH: 6.54 | |
| Temp: 10.15° C | |
| ORP: 196 | |
| D.O.: 9.2 | |
| Turbidity: 17.5 | |
| Conductivity: 0.066 mS/cm | Photograph Log #: 12/23/2014 - 039.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Overcast, Air Temperature: 52° F | |
| Comments: Flow measurement not possible. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Phillips | Date: 12/23/14 |

ALLIANT

# Surface Water Monitoring Location

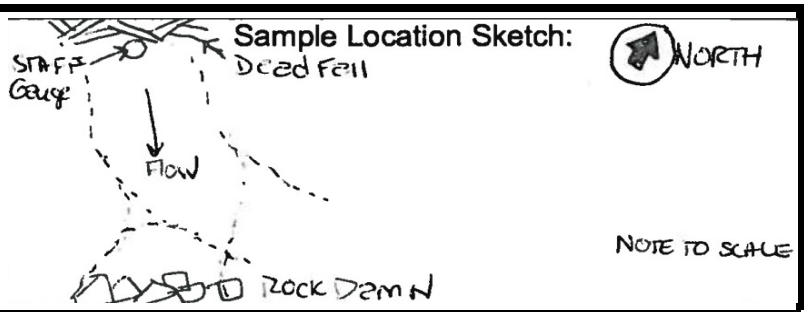
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 12/30/2014 | |
| Time Measured: 1001 | |
| | |
| **Field Observations** |  |
| Elevation (gauge): 0.01 (1,043.34 ft msl) | |
| pH: 6.30 | |
| Temp: 10.47° C | |
| ORP: 201 | |
| D.O.: 7.76 mg/L | |
| Turbidity: 5.8 NTU | |
| Conductivity: 0.066 mS/cm | Photograph Log #: 12/30/2014 - 049.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cloudy, rainy, mist,, Air Temperature: 37° F | |
| Comments: Flow measurement not possible. | |
| | |
| Field Technician: (Print) Carson Vick, Richard Stout | Date: 12/30/14 |

ALLIANT

# Surface Water Monitoring Location

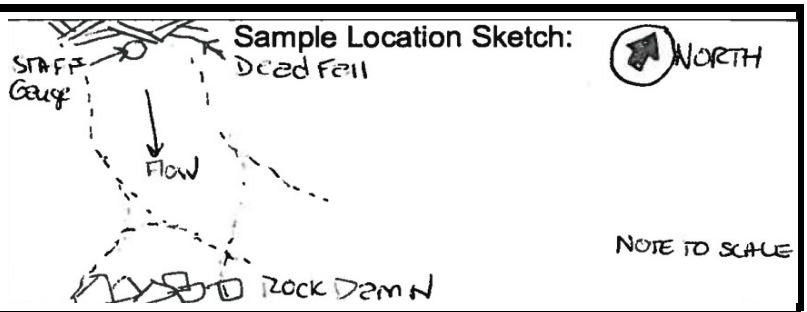
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 01/07/15 | |
| Time Measured: 0945 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.00 (1,043.33 ft msl) | |
| pH: 6.21 | |
| Temp: 10.43° C | |
| ORP: 221 | |
| D.O.: 10.06 mg/L | |
| Turbidity:16.8 NTU | |
| Conductivity: 0.045 mS/cm | Photograph Log #: 01/07/15 - 053.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Air Temperature: 26° F | |
| Comments: Flow measurement not possible. Not able to determine velocity due to low flow at spring. High runoff has eroded stream base below staff gauge. Silt had filled up measurement pool behind rock dam, requiring removal. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

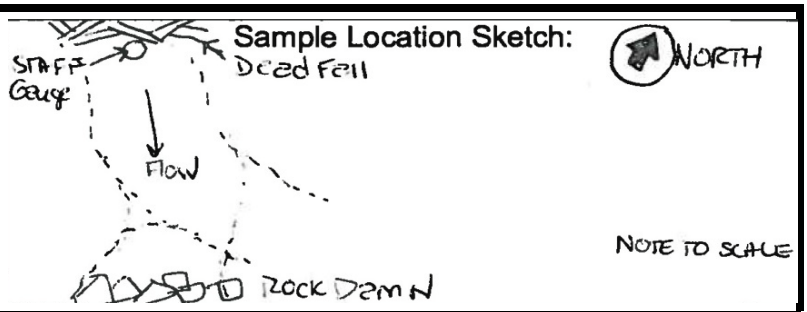
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 01/14/15 | |
| Time Measured: 0900 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.00 (1,043.33 ft msl) | |
| pH: 4.93 | |
| Temp: 9.10° C | |
| ORP: 310 | |
| D.O.: 8.80 mg/L | |
| Turbidity: 4.7 NTU | |
| Conductivity: 0.091 mS/cm | Photograph Log #: 01/14/15 - 060.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Air Temperature: 36° F | |
| Comments: Flow measurement not possible. Not able to determine velocity due to low flow at spring. High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/14/15 |

ALLIANT

# Surface Water Monitoring Location

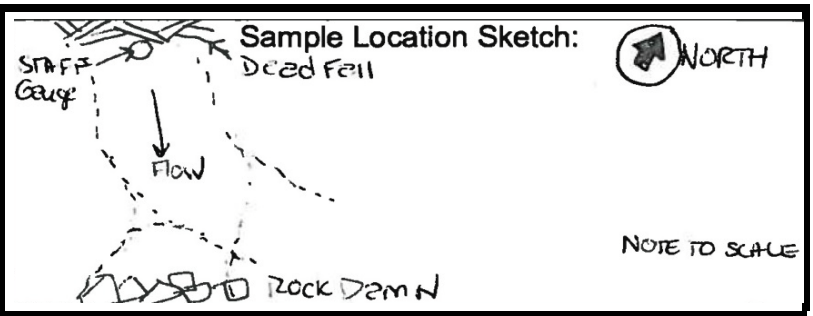
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 01/21/15 | |
| Time Measured: 0850 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.00 (1,043.33 ft msl) | |
| pH: 6.24 | |
| Temp: 9.10° C | |
| ORP: 219 | |
| D.O.: 9.04 mg/L | |
| Turbidity: 1.1 NTU | |
| Conductivity: 0.051 mS/cm | Photograph Log #: 01/21/15 - 075.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Clear, Calm, Air Temperature: 48° F | |
| Comments: Flow measurement not possible. High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/21/15 |

ALLIANT

# Surface Water Monitoring Location

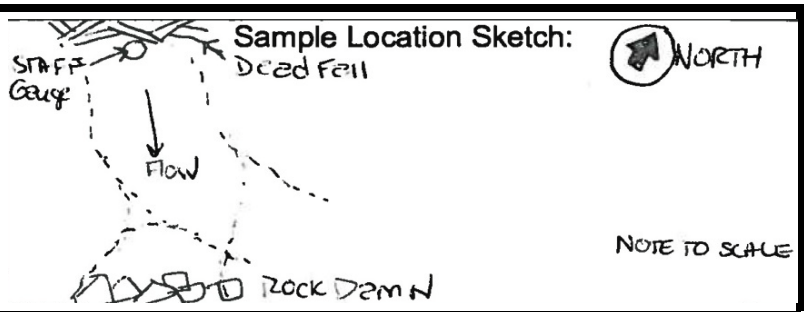
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 01/29/15 | |
| Time Measured: 0930 | |
| | |
| **Field Observations** | |
| Elevation (gauge): <0.00 (1,043.33 ft msl) | |
| pH: 6.20 | |
| Temp: 8.75° C | |
| ORP: 220 | |
| D.O.: 11.20 mg/L | |
| Turbidity: 28.4 NTU | |
| Conductivity: 0.049 mS/cm | Photograph Log #: 01/29/15 - 093.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cold , Overcast, Air Temperature: 37° F | |
| Comments: Flow measurement not possible. High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technicians: (Print)<br>Jack Strader, Daniel Edds | Date: 01/29/15 |

ALLIANT

# Surface Water Monitoring Location

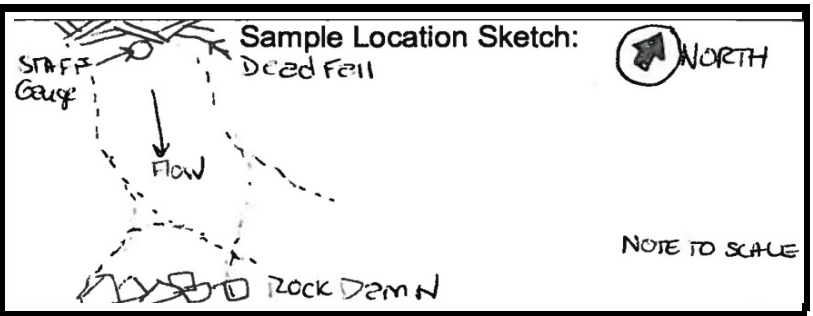
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 02/05/15 | |
| Time Measured: 0910 | |
| | |
| **Field Observations** | |
| Elevation (gauge): <0.00 (1,043.33 ft msl) | |
| pH: 6.28 | |
| Temp: 7.12° C | |
| ORP: 253 | |
| D.O.: 9.14 mg/L | |
| Turbidity: 5.5 NTU | |
| Conductivity: 0.052 mS/cm | Photograph Log #: 02/05/15 - 110.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cold , Clear, Air Temperature: 29° F | |
| Comments: Flow measurement not possible. High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technicians: (Print)<br>Jack Strader, Seth Howard | Date: 02/05/15 |

ALLIANT

# Surface Water Monitoring Location

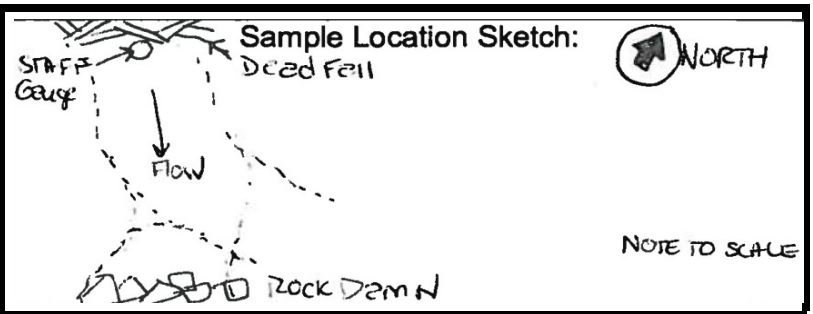
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 02/11/15 | |
| Time Measured: 0915 | |
| | |
| **Field Observations** | |
| Elevation (gauge): <0.00 (1,043.33 ft msl) | |
| pH: 6.21 | |
| Temp: 7.70° C | |
| ORP: 192 | |
| D.O.: 10.06 mg/L | |
| Turbidity: 4.0 NTU | |
| Conductivity: 0.051 mS/cm | Photograph Log #: 02/11/15 - 129.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cold , Clear, Air Temperature: 29° F | |
| Comments: Flow measurement not possible. High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technicians: (Print)<br>Jack Strader, Daniel Edds | Date: 02/11/15 |

ALLIANT

# Surface Water Monitoring Location

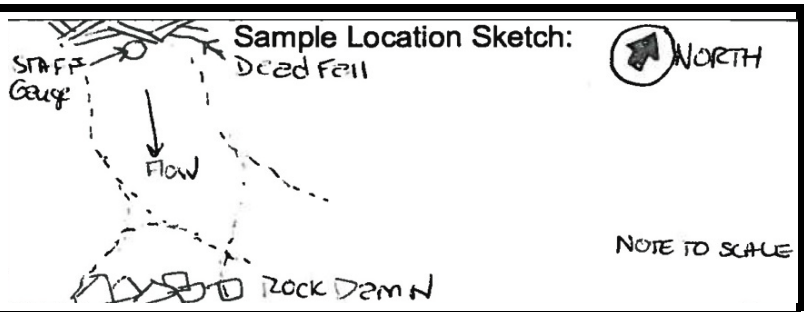
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 02/20/15 | |
| Time Measured: 1115 | |
| | |
| **Field Observations** | |
| Elevation (gauge): <0.00 (1,043.33 ft msl) | |
| pH: 6.15 | |
| Temp: 6.05° C | |
| ORP: 181 | |
| D.O.: 11.96 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.054 mS/cm | Photograph Log #: 02/20/15 - 145.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cold , Calm, Clear, Air Temperature: 15° F | |
| Comments: Flow measurement not possible due to low flow conditions (flow estimated to be less than 1 gallon per minute (GPM)). High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technicians: (Print)<br>Jack Strader & Daniel Edds | Date: 02/20/15 |

ALLIANT

# Surface Water Monitoring Location

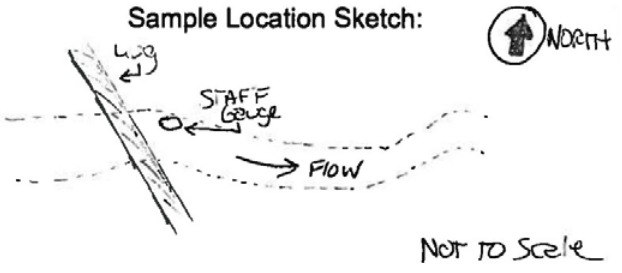
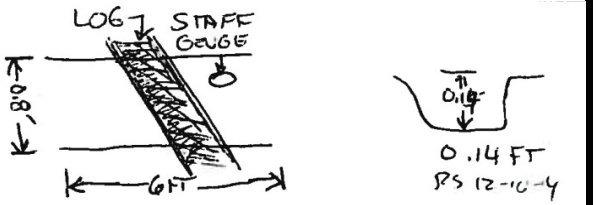
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-SP2 |   |
| Date Measured: 02/27/15 | |
| Time Measured: 0934 | |
| | |
| **Field Observations** | |
| Elevation (gauge): <0.00 (1,043.33 ft msl) | |
| pH: 5.92 | |
| Temp: 7.86° C | |
| ORP: 231 | |
| D.O.: 11.65 mg/L | |
| Turbidity: 0.0 NTU | |
| Conductivity: 0.044 mS/cm | Photograph Log #: 02/27/15 - 173.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Cold , Calm, Clear, Air Temperature: 26° F | |
| Comments: Flow measurement not possible due to low flow conditions (flow estimated to be less than 1 gallon per minute (GPM)). High runoff has eroded stream base below staff gauge. | |
| | |
| Field Technicians: (Print)<br>Jack Strader & Daniel Edds | Date: 02/20/15 |

ALLIANT

# Surface Water Monitoring Location

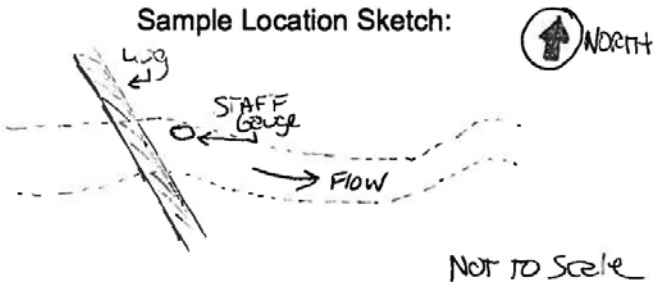
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 12/10/14 | |
| Time Measured: 1108 | |
| | |
| **Field Observations** |   |
| Elevation (gauge): 0.14 (1010.11 ft msl) | |
| pH: 5.28 | |
| Temp: 6.22°C | |
| ORP: 186 mV | Length: 6 FT<br>Width: 0.8' (Ave of 3 measurements)<br>Depth: 0.14 FT (after clean out & Ave of 3 measurements)<br>Time for object to Flow 6 FT: 9 seconds for an object to Flow 6 FT (Based on ave of 3 measurements) |
| D.O.: 12.04 mg/L | |
| Turbidity: 80 NTU | |
| Water Clarity Observed: Clear | Photograph Log #:12/10/2014 20.jpg |
| Flow Measurement: 0.075 CFS (0.56 GPM) | Measurement Equipment: Horiba U52 |
| Air Temperature: ° F: 39 | |
| Weather: Cold, Cloudy, Damp | |
| Comments: Conductivity = 0.0 mS/cm<br><br>Turbidity was elevated due to stirring up of the water. Otherwise the water was clear. Not enough water to get an accurate temperature reading. | |
| | Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>CFS = 0.8 ft x 0.14 ft X 0.67 ft/sec<br>CFS = 0.075 |
| Field Technician: (Print) Richard Stout, Carson Vick | Date: 12/10/14 |

ALLIANT

# Surface Water Monitoring Location

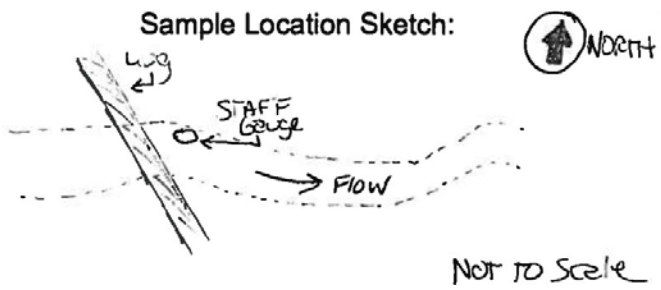
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 12/17/14 | |
| Time Measured: 1615 | |
| | |
| **Field Observations** | Water is 1 inch deep, channel 6" wide, Flow rate (Q) is 0.5 ft/sec.<br><br>No photograph taken. |
| Elevation (gauge): 0.14 (1,009.07 ft msl) | |
| pH: 6.47 | |
| Temp: 8.53°C | |
| ORP: 153 | |
| D.O.: 11.90 mg/L | |
| Turbidity: 48.6 NTU | |
| Conductivity: 0.070 mS/cm | Photograph Log #: No photograph taken. |
| Flow Measurement: 0.02 CFS (0.156 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Partly cloudy, dry slight breeze | |
| Comments: Used shovel to improve water quality measurement pool.<br>Air Temperature: ° F: 46°<br><br>Stream flow (CFS) = Cross Sectional Area (ft2) * Average Velocity (ft/sec)<br>CFS = 0.5 ft x 0.083 ft X 0.5 ft/sec<br>CFS = 0.020 | |
| | |
| Field Technician: (Print) Mark Maki / Ronnie Phillips | Date: 12/17/14 |

ALLIANT

# Surface Water Monitoring Location

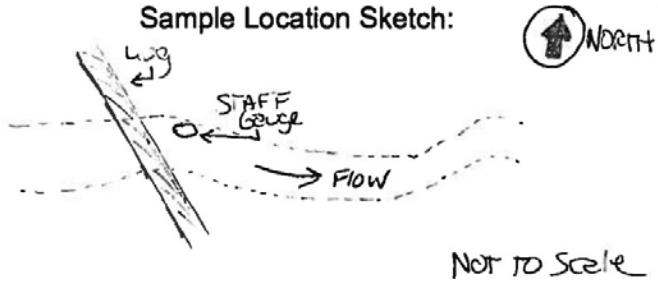
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 12/23/14 | |
| Time Measured: 1035 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.00 (1,009.97 ft msl) | |
| pH: 6.59 | |
| Temp: 9.11°C | |
| ORP: 149 | |
| D.O.: 9.36 mg/L | |
| Turbidity: 7.3 NTU | |
| Conductivity: 0.068 mS/cm | Photograph Log #: 12/23/14 – 042.jpg |
| Flow Measurement: Not recorded | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 53° F | |
| Comments:<br>Stream flow (CFS) = Cross Sectional Area (ft2) * Average Velocity (ft/sec) | |
| | |
| Field Technician: (Print) Jack Strader / Ronnie Phillips | Date: 12/23/14 |

ALLIANT

# Surface Water Monitoring Location

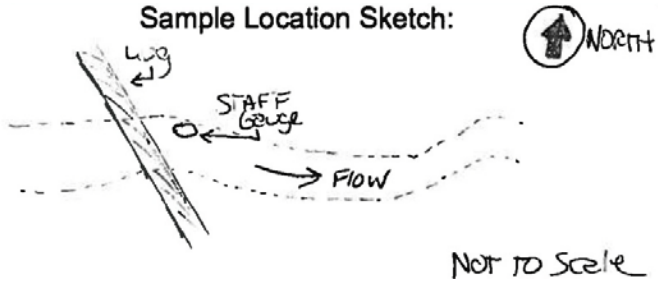
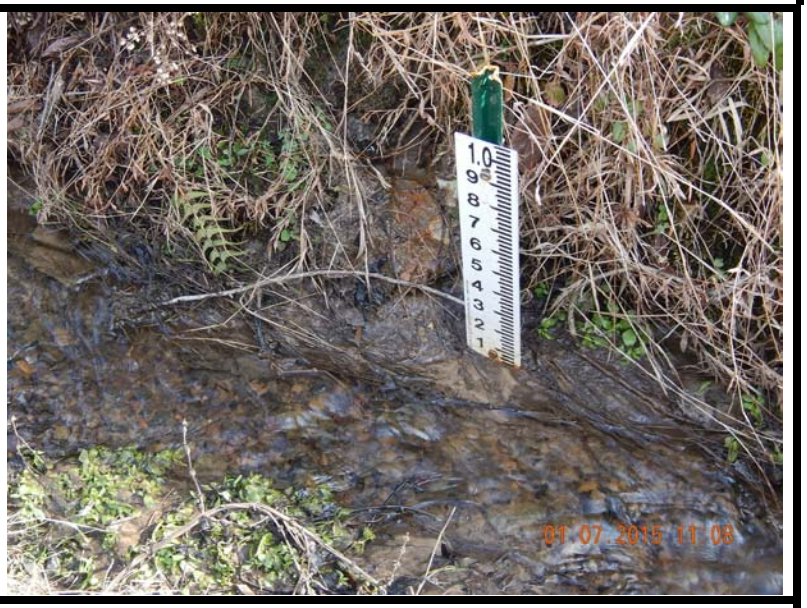
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 12/30/14 | |
| Time Measured: 1028 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.04 (1,010.01 ft msl) | |
| pH: 6.17 | |
| Temp: 9.36°C | |
| ORP: 187 | |
| D.O.: 10.0 mg/L | |
| Turbidity: 28.0 NTU | |
| Conductivity: 0.047 mS/cm | Photograph Log #: 12/23/14 – 042.jpg |
| Flow Measurement: 0.10 CFS (45.8 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Partly Cloudy, Air Temperature: 37° F | |
| Comments:<br><br>Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>Flow rate measured at 3 ft in 4 sec (velocity = 0.75 ft/sec)<br>Depth = 0.17 ft<br>Width = 0.8 ft | |
| | |
| Field Technician: (Print) Carson Vick, Richard Stout | Date: 12/30/14 |

ALLIANT

# Surface Water Monitoring Location

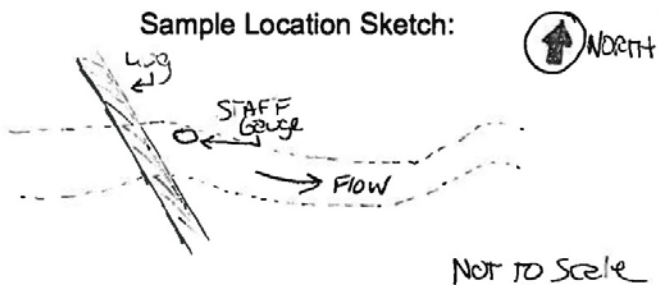
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 01/07/15 | |
| Time Measured: 1115 | |
| | |
| **Field Observations** |   |
| Elevation (gauge): 0.04 (1,010.01 ft msl) | |
| pH: 6.31 | |
| Temp: 7.10°C | |
| ORP: 180 | |
| D.O.: 8.85 mg/L | |
| Turbidity: 17.0 NTU | |
| Conductivity: 0.044 mS/cm | Photograph Log #: 01/07/15 – 056.jpg |
| Flow Measurement: 0.10 CFS (44.88 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 26° F | |
| Comments:<br><br>Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>Flow rate measured at 1 ft in 1 sec (velocity = 1 ft/sec)<br>Depth = 0.125ft<br>Width = 0.8 ft | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

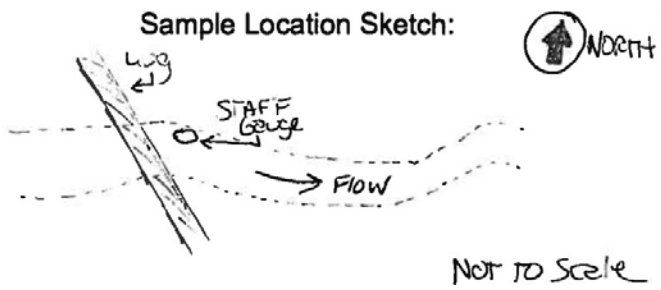
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 01/14/15 | |
| Time Measured: 0950 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.06 (1,010.03 ft msl) | |
| pH: 6.21 | |
| Temp: 8.24°C | |
| ORP: 201 | |
| D.O.: 10.34 mg/L | |
| Turbidity: 9.4 NTU | |
| Conductivity: 0.043 mS/cm | Photograph Log #: 01/14/15 – 063.jpg |
| Flow Measurement: 0.10 CFS (44.88 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 36° F | |
| Comments: Flow rate measured at 1 ft in 1 sec (velocity = 1 ft/sec), Depth = 0.125 ft, Width = 0.8 ft<br>Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>Stream flow (CFS) = 0.10 $ft^2$ x 1 ft/sec = 0.1 CFS = 44.88 GPM | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/14/15 |

ALLIANT

# Surface Water Monitoring Location

Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 01/21/15 | |
| Time Measured: 1100 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.03 (1,010.00 ft msl) | |
| pH: 5.97 | |
| Temp: 8.95°C | |
| ORP: 227 | |
| D.O.: 14.89 mg/L | |
| Turbidity: 2.4 NTU | |
| Conductivity: 0.058 mS/cm | Photograph Log #: 01/21/15 – 079.jpg |
| Flow Measurement: 0.134 CFS (44.88 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Sunny, Air Temperature: 52° F | |
| Comments: Flow rate measured at 2 ft in 1 sec (velocity = 2 ft/sec), Depth = 0.083 ft, Width = 0.8 ft<br>Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>Stream flow (CFS) = 0.067 $ft^2$ x 2 ft/sec = 0.134 CFS = 60.14 GPM | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/21/15 |

ALLIANT

# Surface Water Monitoring Location

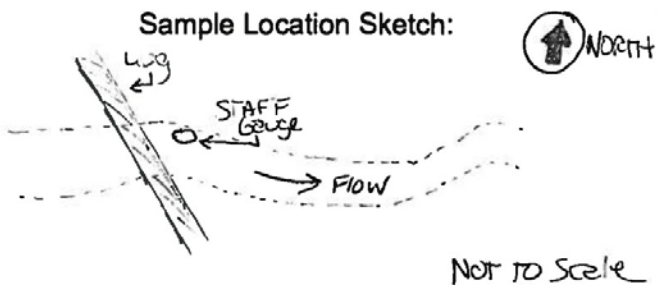
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST1

Date Measured: 01/29/15

Time Measured: 1057

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.04 (1,010.01 ft msl)

pH: 6.40

Temp: 6.16°C

ORP: 151

D.O.: 11.51 mg/L

Turbidity: 7.4 NTU

Conductivity: 0.054 mS/cm

Photograph Log #: 01/29/15 – 097.jpg

Flow Measurement: 0.033 CFS (15.0 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Rainy, Air Temperature: 39° F

Stream Flow Calculations:

| Width (in) | Depth (in) | AREA ($in^2$) | AREA ($ft^2$) 1 $ft^2$ / 144 $in^2$ | RATE (ft/sec) | FLOW $ft^3$/sec Area $ft^2$ * Rate | FLOW (gal/sec) 7.48 gal / $ft^3$ | FLOW (**gal/min**) 60 sec / 1 min |
|---|---|---|---|---|---|---|---|
| 9.60 | 0.50 | 4.80 | 0.033 | 1.00 | 0.033 | 0.25 | **15.0** |

Field Technician: (Print)
Jack Strader, Daniel Edds

Date: 01/29/15

ALLIANT

# Surface Water Monitoring Location

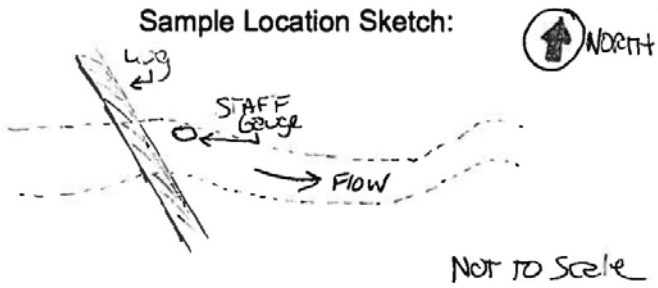
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST1

Date Measured: 02/05/15

Time Measured: 0930

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.04 (1,010.01 ft msl)

pH: 6.40

Temp: 5.97°C

ORP: 240

D.O.: 10.52 mg/L

Turbidity: 11.8 NTU

Conductivity: 0.042 mS/cm

Photograph Log #: 02/05/15 – 111.jpg

Flow Measurement: 0.033 CFS (15.0 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Calm, Air Temperature: 30° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min)= gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST1** | 7.00 | 0.75 | 1.00 | 5.25 | 0.036 | **0.036** | 0.27 | **16.4** |

Field Technician: (Print)
Jack Strader, Seth Howard

Date: 02/05/15

ALLIANT

# Surface Water Monitoring Location

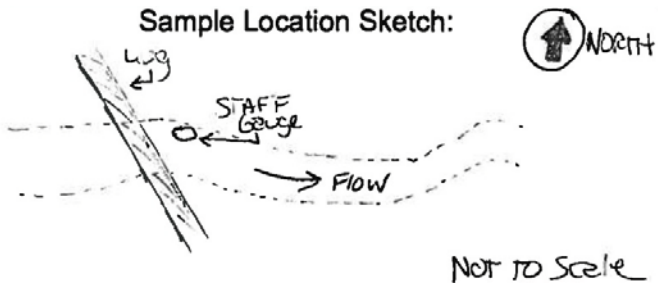
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST1

Date Measured: 02/11/15

Time Measured: 1025

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.07 (1,010.04 ft msl)

pH: 6.93

Temp: 6.94°C

ORP: 196

D.O.: 15.08 mg/L

Turbidity: 10.5 NTU

Conductivity: 0.060 mS/cm

Photograph Log #: 02/11/15 – 132.jpg

Flow Measurement: 0.036 CFS (16.4 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Calm, Air Temperature: 32° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min)= gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST1** | 7.00 | 0.75 | 1.00 | 5.25 | 0.036 | **0.036** | 0.27 | **16.4** |

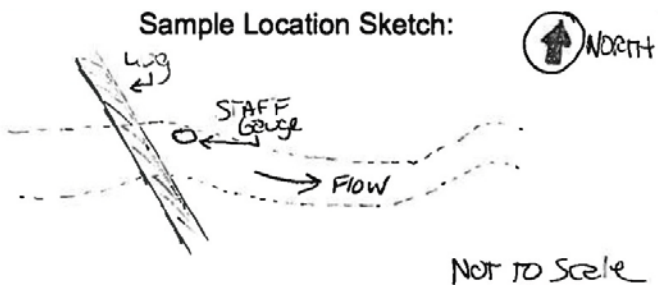
Field Technician: (Print)
Jack Strader, Daniel Edds

Date: 02/11/15

ALLIANT

# Surface Water Monitoring Location

Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST1 | Sample Location Sketch:   |
| Date Measured: 02/20/15 | |
| Time Measured: 1133 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.07 (1,010.04 ft msl) | |
| pH: 6.46 | |
| Temp: 2.15°C | |
| ORP: 165 | |
| D.O.: 10.73 mg/L | |
| Turbidity: 0.1 NTU | |
| Conductivity: 0.053 mS/cm | Photograph Log #: 02/20/15 – 146.jpg |
| Flow Measurement: See notes | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Calm, Air Temperature: 16° F | |
| Notes: No flow calculations due to presence of ice on water surface. | |
| | |
| Field Technician: (Print)<br>Jack Strader & Daniel Edds | Date: 02/20/15 |

ALLIANT

# Surface Water Monitoring Location

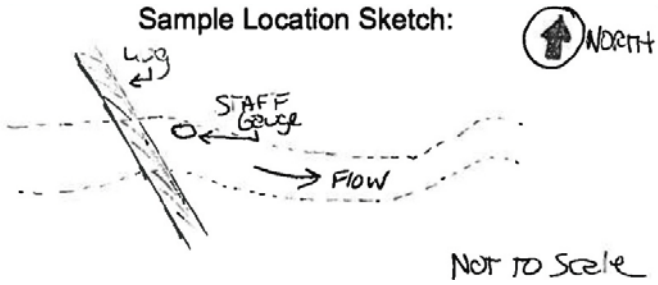
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST1

Date Measured: 02/27/15

Time Measured: 0955

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.07 (1,010.04 ft msl)

pH: 5.95

Temp: 5.56°C

ORP: 230

D.O.: 12.24 mg/L

Turbidity: 5.7 NTU

Conductivity: 0.046 mS/cm

Photograph Log #: 02/27/15 – 174.jpg

Flow Measurement:
0.097 cu ft / sec or 43.6 gal / min

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Calm, Air Temperature: 26° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min) = gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST1** | 7.00 | 2.00 | 1.00 | 14.00 | 0.097 | **0.097** | 0.73 | **43.6** |

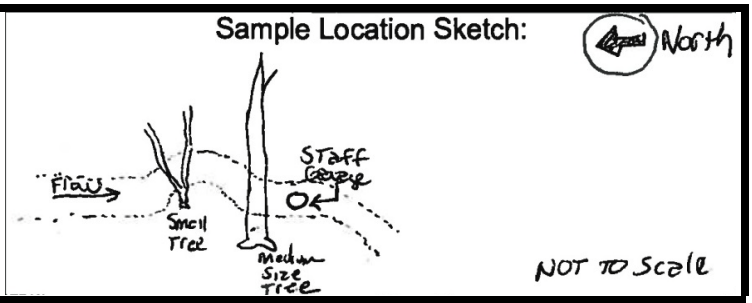
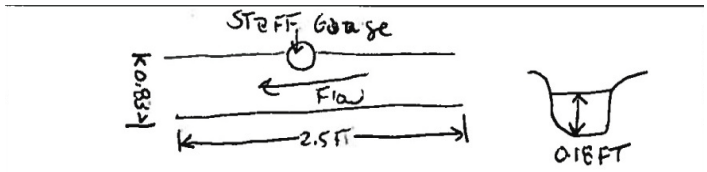
Field Technician: (Print)
Jack Strader & Daniel Edds

Date: 02/27/15

ALLIANT

# Surface Water Monitoring Location

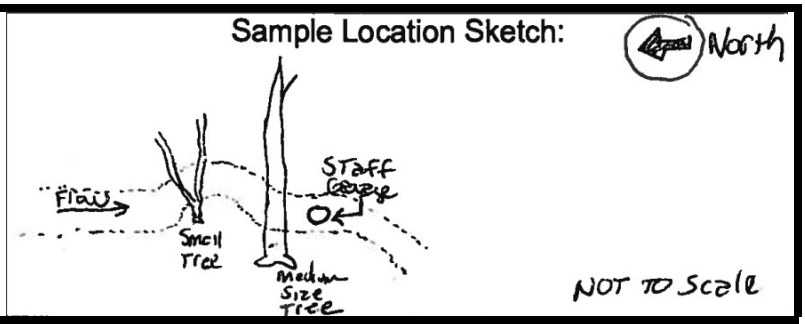
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 12/10/14 | |
| Time Measured: 1008 | |
| | |
| **Field Observations** |   |
| Elevation (gauge): 0.18 ft (993.12 ft msl) | Length = 2.5 FT<br>Width = 0.93 FT (Ave of 3 measurements)<br>Depth = 0.18 FT<br>Time for object to Flow 2.5 FT = 7 sec (From 3 readings - Average) |
| pH: 5.21 | |
| Temp: 8.18°C | |
| ORP: 219 mV | |
| D.O.: 11.70 mg/L | |
| Turbidity: 84 NTU | |
| Water Clarity Observed: Clear | Photograph Log #: |
| Flow Measurement: 0.54 CFS (0.4 GPM) | Measurement Equipment: Horiba U52 |
| Air Temperature: ° F: 39 | |
| Weather: Cold, Cloudy, Damp | |
| Comments: Conductivity = 0.0 mS/cm<br><br>NOTE: Low water – Temperature reading may be air temp. | |
| | Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>CFS = 0.83 ft X 0.18 ft X 0.36 ft/sec<br>CFS = 0.54 |
| Field Technician: (Print) Richard Stout, Carson Vick | Date: 12/10/2014 |

ALLIANT

# Surface Water Monitoring Location

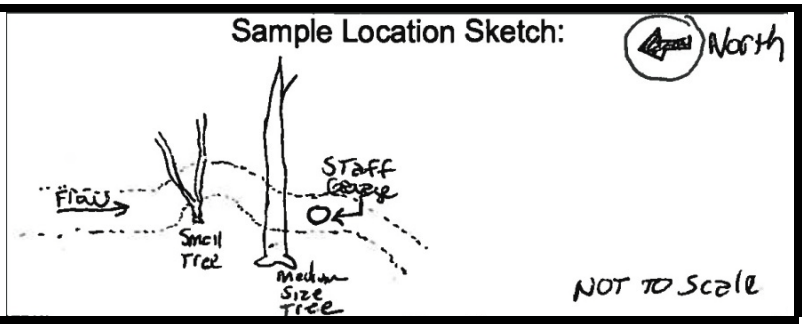
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 12/17/2014 | |
| Time Measured: 1545 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.14 (992.14 ft msl) | |
| pH: 6.60 | |
| Temp: 8.35 | |
| ORP: 212 97 | |
| D.O.: 10.97 | |
| Turbidity: 0.0 | |
| Conductivity: 0.090 mS/cm | Photograph Log #: 12/17/2014 – 035.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Partly Cloudy, dry, light breeze, Air Temperature: 46° F | |
| Comments: Used shovel to improve measurement pool | |
| | |
| Field Technician: (Print) Mark Maki, Ronnie Phillips | Date: 12/17/14 |

ALLIANT

# Surface Water Monitoring Location

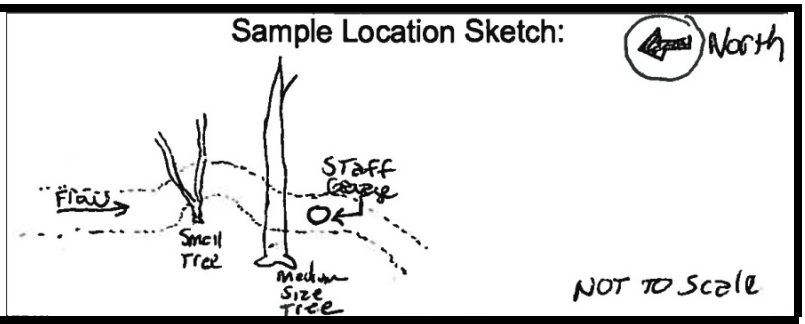
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 12/23/2014 | |
| Time Measured: 1010 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.15 (993.04 ft msl) | |
| pH: 6.48 | |
| Temp: 8.67 | |
| ORP:131 | |
| D.O.: 7.17 | |
| Turbidity: 23.3 | |
| Conductivity: 0.056 mS/cm | Photograph Log #: 12/23/2014 – 041.jpg |
| Flow Measurement: <1 GPM | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Overcast, Air Temperature: 46° F | |
| Comments: | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Phillips | Date: 12/23/14 |

ALLIANT

# Surface Water Monitoring Location

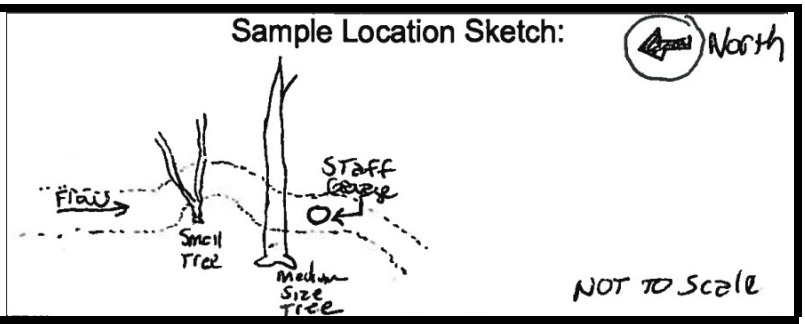
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 12/30/2014 | |
| Time Measured: 0934 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.15 (993.10 ft msl) | |
| pH: 5.87 | |
| Temp: 8.31° C | |
| ORP: 142 | |
| D.O.: 7.57 mg/Ll | |
| Turbidity: 17.3 NTU | |
| Conductivity: 0.061 mS/cm | Photograph Log #: 12/23/2014 – 047.jpg |
| Flow Measurement: 0.028 CFS (12.6 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Overcast, rainy, Air Temperature: 36° F | |
| Comments: Average measured flow rate is 3 ft in 8 sec. (velocity = 0.375 ft/sec), water depth 0.15 ft, width is 0.5 ft | |
| | |
| Field Technician: (Print) Carson Vick, Richard Stout | Date: 12/30/14 |

ALLIANT

# Surface Water Monitoring Location

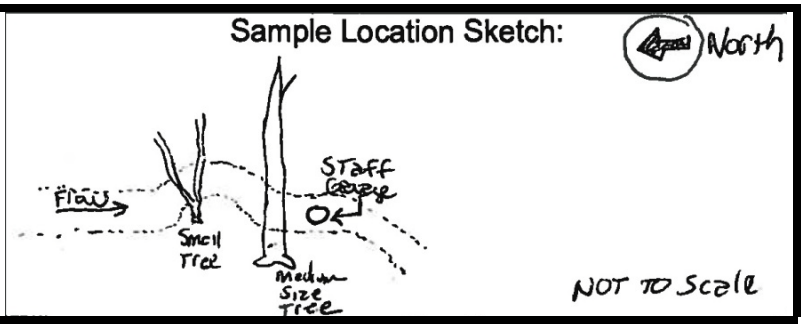
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 01/07/15 | |
| Time Measured: 1045 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.15 (993.09 ft msl) | |
| pH: 6.19 | |
| Temp: 5.17° C | |
| ORP: 183 | |
| D.O.: 7.71 mg/L | |
| Turbidity: 13.0 NTU | |
| Conductivity: 0.045 mS/cm | Photograph Log #: 01/07/15 - 055.jpg |
| Flow Measurement: 0.026 CFS (11.7 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 26° F | |
| Comments: Average measured flow rate is 1 ft in 2 sec. (velocity = 0.5 ft/sec), water depth 0.104 ft, width is 0.5 ft | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

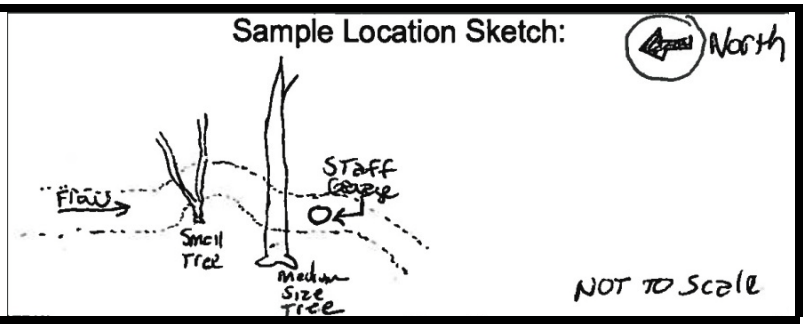
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 01/14/15 | |
| Time Measured: 0930 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.14 (993.08 ft msl) | |
| pH: 6.01 | |
| Temp: 5.66° C | |
| ORP: 192 | |
| D.O.: 9.16 mg/L | |
| Turbidity: 8.3 NTU | |
| Conductivity: 0.048 mS/cm | Photograph Log #: 01/14/15 - 062.jpg |
| Flow Measurement: 0.024 CFS (10.77 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 26° F | |
| Comments: Average measured flow rate is 2 ft in 6 sec. (velocity = 0.33 ft/sec), water depth 0.146 ft, width is 0.5 ft<br>Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>Stream flow (CFS) = 0.73 $ft^2$ x 0.33 ft/sec = 0.024 CFS = 10.77 GPM | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST2 | Sample Location Sketch:   |
| Date Measured: 01/21/15 | |
| Time Measured: 0910 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.15 (993.09 ft msl) | |
| pH: 6.17 | |
| Temp: 6.01° C | |
| ORP: 153 | |
| D.O.: 7.75 mg/L | |
| Turbidity: 2.1 NTU | |
| Conductivity: 0.049 mS/cm | Photograph Log #: 01/21/15 - 076.jpg |
| Flow Measurement: 0.042 CFS (18.85 GPM) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Sunny, Air Temperature: 48° F | |
| Comments: Average measured flow rate is 1 ft / 1 sec. (velocity = 1.0 ft/sec), water depth 0.083 ft, width is 0.5 ft<br>Stream flow (CFS) = Cross Sectional Area ($ft^2$) * Average Velocity (ft/sec)<br>Stream flow (CFS) = 0.042 $ft^2$ x 1.0 ft/sec = 0.042 CFS = 18.85 GPM | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/21/15 |

ALLIANT

# Surface Water Monitoring Location

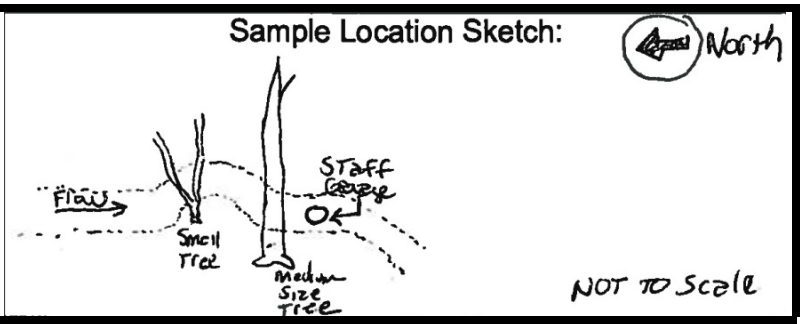
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST2

Date Measured: 01/29/15

Time Measured: 0939

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.12 (993.06 ft msl)

pH: 6.16

Temp: 5.02° C

ORP: 148

D.O.: 12.56 mg/L

Turbidity: 11 NTU

Conductivity: 0.047 mS/cm

Photograph Log #: 01/29/15 - 095.jpg

Flow Measurement: 0.042 CFS (18.6 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Cold, Rainy, Air Temperature: 39° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | AREA ($in^2$) | AREA ($ft^2$) 1 $ft^2$ / 144 $in^2$ | RATE (ft/sec) | FLOW $ft^3$/sec Area $ft^2$ * Rate | FLOW (gal/sec) 7.48 gal / $ft^3$ | FLOW (**gal/min**) 60 sec / 1 min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST2** | **9.96** | **1.50** | 14.94 | 0.104 | **0.40** | 0.042 | 0.31 | **18.6** |

Field Technician: (Print)
Jack Strader, Daniel Edds

Date: 01/29/15

ALLIANT

# Surface Water Monitoring Location

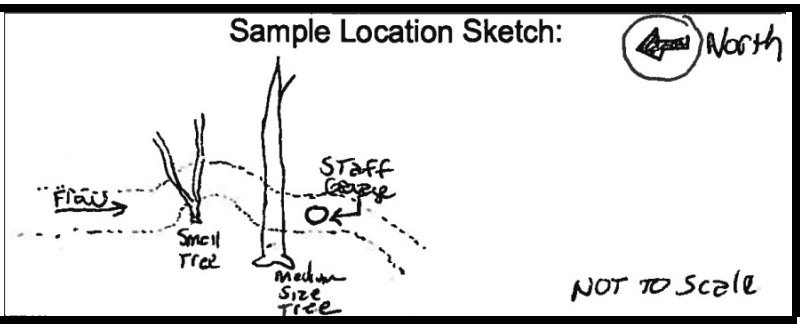
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST2

Date Measured: 02/05/15

Time Measured: 0852

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.11 (993.05 ft m)

pH: 5.70

Temp: 4.31° C

ORP: 188

D.O.: 9.07 mg/L

Turbidity: 1.8 NTU

Conductivity: 0.081 mS/cm

Photograph Log #: 02/05/15 - 108.jpg

Flow Measurement: 0.038 CFS (16.8 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Cold, Rainy, Air Temperature: 39° F

Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min)= gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST2** | **9.00** | **3.00** | **0.20** | 27.00 | 0.188 | **0.038** | 0.28 | **16.8** |

Field Technician: (Print)
Jack Strader, Seth Howard

Date: 2/5/15

ALLIANT

# Surface Water Monitoring Location

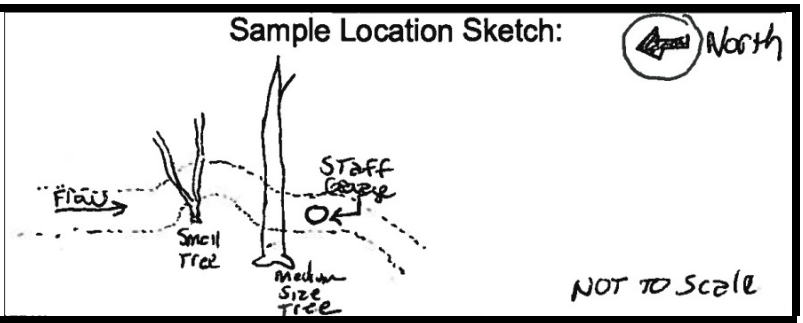
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST2

Date Measured: 02/11/15

Time Measured: 0847

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.12 (993.08 ft m)

pH: 5.86

Temp: 3.18° C

ORP: 170

D.O.: 13.94 mg/L

Turbidity: 5.0 NTU

Conductivity: 0.080 mS/cm

Photograph Log #: 02/11/15 - 127.jpg

Flow Measurement: 0.017 CFS (7.5 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Cold, Clear, Air Temperature: 28° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min)= gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST2** | **6.00** | **2.00** | **0.20** | 12.00 | 0.083 | **0.017** | 0.12 | **7.5** |

Field Technician: (Print)
Jack Strader, Daniel Edds

Date: 2/11/15

ALLIANT

# Surface Water Monitoring Location

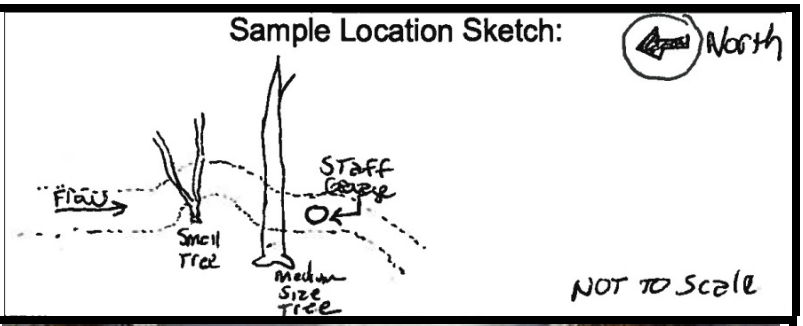
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST2

Date Measured: 02/20/15

Time Measured: 1102

Sample Location Sketch:




## Field Observations

Elevation (gauge): 0.12 (993.06 ft m)

pH: 5.86

Temp: 0.92° C

ORP: 197

D.O.: 9.28 mg/L

Turbidity: 32.2 NTU

Conductivity: 0.067 mS/cm

Photograph Log #: 2/20/15 -144.jpg

Flow Measurement: 0.025 CFS (11.2 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Cold, Air Temperature: 5° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min)= gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST2** | **9.00** | **2.00** | **0.20** | 18.00 | 0.125 | **0.025** | 0.19 | **11.2** |

Field Technician: (Print)
Jack Strader & Daniel Edds

Date: 2/20/15

ALLIANT

# Surface Water Monitoring Location

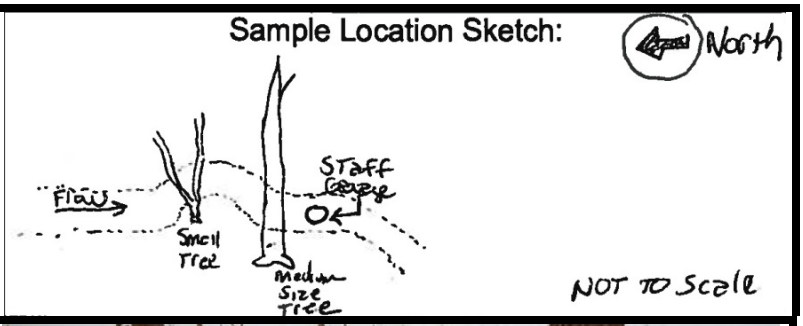
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST2

Date Measured: 02/27/15

Time Measured: 0919

Sample Location Sketch:




## Field Observations

Elevation (gauge): 0.10 (993.04 ft m)

pH: 5.46

Temp: 3.20° C

ORP: 267

D.O.: 12.85 mg/L

Turbidity: 6.7 NTU

Conductivity: 0.064 mS/cm

Photograph Log #: 2/27/15 -171.jpg

Flow Measurement: 0.027 CFS (16.2 GPM)

Measurement Equipment: Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Calm, Air Temperature: 26° F

Stream Flow Calculations:

| Location | Width (in) | Depth (in) | Rate (ft/sec) | AREA ($in^2$) | $in^2$*1 $ft^2$/144 $in^2$= ($ft^2$) | $ft^2$ * ft/sec = $ft^3$/sec | $ft^3$/sec * 7.48 gal/ $ft^3$ = (gal/sec) | gal/sec *60 sec/1 min)= gal/min |
|---|---|---|---|---|---|---|---|---|
| **NT3-ST2** | **9.00** | **1.75** | **0.33** | 15.75 | 0.109 | **0.036** | 0.27 | **16.2** |

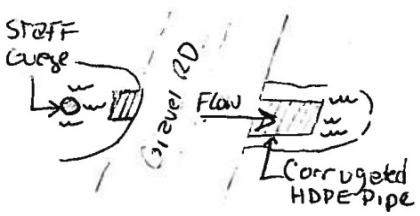
Field Technician: (Print)
Jack Strader & Daniel Edds

Date: 2/27/15

ALLIANT

# Surface Water Monitoring Location

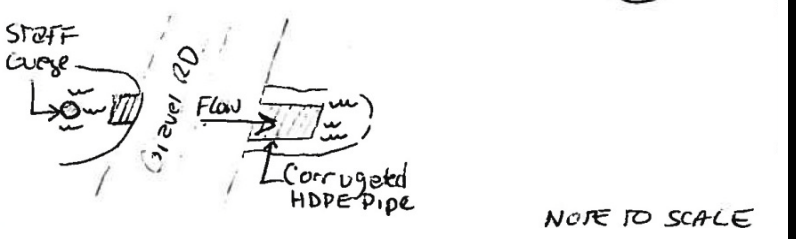
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 12/10/14 | |
| Time Measured: 0932 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.14 ft (1006.04 ft msl) | |
| pH: 5.97 | |
| Temp: 9.10 C | |
| ORP: 256 mV | |
| D.O.: 11.37 mg/L | |
| Turbidity: 8 NTU | |
| Water Clarity Observed: Clear | Photograph Log #: 12/10/2014 - 02.JPG |
| Flow Measurement: (7.5 L/Min) (1.98 GPM) (0.26 CFS) | Measurement Equipment: Horiba U52 |
| Air Temperature: ° F: 39 | |
| Weather: Cloudy and cold. Slight rain earlier | |
| Comments: Conductivity = 0.0 mS/cm<br>Stream flow measured from measuring culvert stream flow into 1 L cup. | |
| | |
| Field Technician: (Print) Richard Stout, Carson Vick | Date: 12/10/2014 |

ALLIANT

# Surface Water Monitoring Location

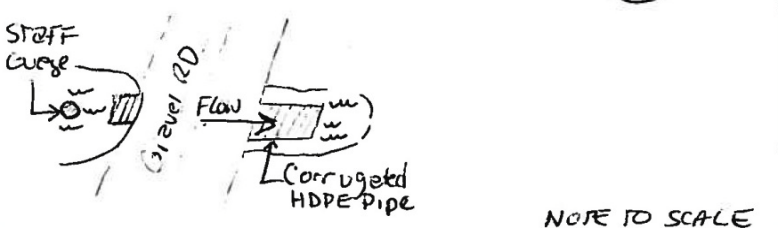
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 12/17/14 | |
| Time Measured: 1527 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.10 (1,005.06 ft msl) | |
| pH: 5.95 | |
| Temp: 8.26 | |
| ORP: 316 | |
| D.O.: 8.69 | |
| Turbidity: 0.0 | |
| Conductivity: 0.052 mS/cm | Photograph Log #: 12/17/2014 033.jpg |
| Flow Measurement: (1.5 L/m) (0.4 GPM) (0.053 CFS) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Slight breeze, Air Temperature: 46° F | |
| Comments: 20 sec to fill ½ liter container = 1.5 L/min | |
| | |
| Field Technician: (Print) Mark Maki, Ronnie Phillips | Date: 12/17/14 |

ALLIANT

# Surface Water Monitoring Location

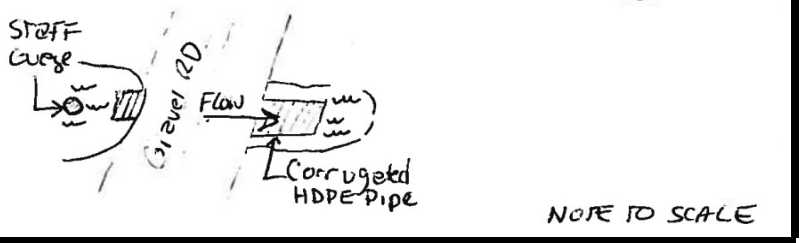
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 12/23/14 | |
| Time Measured: 0948 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.10 (1,006.00 ft msl) | |
| pH: 6.69 | |
| Temp: 8.84 | |
| ORP: 199 | |
| D.O.: 9.51 | |
| Turbidity: 28.3 | |
| Conductivity: 0.048 mS/cm | Photograph Log #: 12/23/2014 - 040.jpg |
| Flow Measurement: (0.15 L/s) (2.38 GPM) (0.005 CFS) | Measurement Equipment: |
| Water Clarity Observed: Clear | Horiba U-52 #WIV35Y5U |
| Weather: Overcast, Air Temperature: 53° F | |
| Comments: 0.15 L / sec fill rate = 2.38 GPM = 0.005 CFS | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Phillips | Date: 12/23/14 |

ALLIANT

# Surface Water Monitoring Location

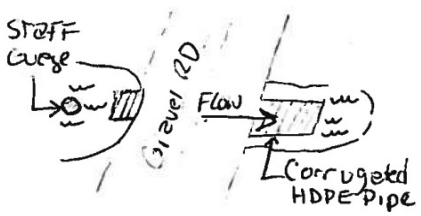
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 12/30/14 | |
| Time Measured: 0916 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.11 (1,006.01 ft msl) | |
| pH:5.69 | |
| Temp: 8.72° C | |
| ORP: 282 | |
| D.O.: 13.44 mg/L | |
| Turbidity: 139 NTU | |
| Conductivity: 0.038 mS/cm | Photograph Log #: 12/23/2014 - 046.jpg |
| Flow Measurement: (750 ml/ sec) (11.9 GPM) (0.027 CFS) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Cloudy, rainy, Air Temperature: 36° F | |
| Comments: 750 mL / sec fill rate | |
| | |
| Field Technician: (Print) Carson Vick, Richard Stout | Date: 12/30/14 |

ALLIANT

# Surface Water Monitoring Location

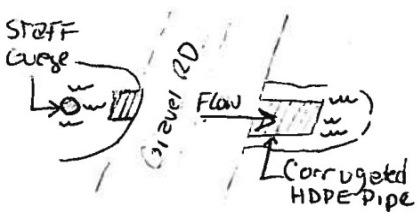
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 01/07/15 | |
| Time Measured: 1035 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.0 (1,005.90 ft msl) | |
| pH:5.69 | |
| Temp: 8.72° C | |
| ORP: 282 | |
| D.O.: 13.44 mg/L | |
| Turbidity: 139 NTU | |
| Conductivity: 0.038 mS/cm | Photograph Log #: 01/07/15 – 054.jpg |
| Flow Measurement: (24 oz / 2 sec) = (5.625 GPM) = (0.013 CFS) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 26° F | |
| Comments: 12 oz / sec fill rate x 0.46875 US gallons per minute = 5.625 GPM<br>Water measurement pool had to be cleared of silt after heavy rains.<br>Runoff eroded EMDNT3 stream base at ST3 location, leaving base of staff gauge above water level. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/07/15 |

ALLIANT

# Surface Water Monitoring Location

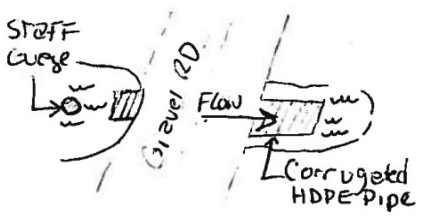
Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 01/14/15 | |
| Time Measured: 0915 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.0 (1,005.90 ft msl) | |
| pH:5.69 | |
| Temp: 7.43° C | |
| ORP: 264 | |
| D.O.: 10.58 mg/L | |
| Turbidity: 3.9 NTU | |
| Conductivity: 0.039 mS/cm | Photograph Log #: 01/14/15 – 061.jpg |
| Flow Measurement: (0.750 L/sec) = (11.89 GPM) = (0.026 CFS) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 36° F | |
| Comments: 0.750 L / sec fill rate = 11.89 GPM = 0.26 CFS<br>Runoff eroded EMDNT3 stream base at ST3 location, leaving base of staff gauge above water level. | 0.026 cfs |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/14/15 |

ALLIANT

# Surface Water Monitoring Location

Project Name: EMDF Phase I Site Characterization  Project #: 4301

| | |
|---|---|
| Site Location: EMDNT3-ST3 | Sample Location Sketch:   |
| Date Measured: 01/21/15 | |
| Time Measured: 0930 | |
| | |
| **Field Observations** | |
| Elevation (gauge): 0.06 (1,005.96 ft msl) | |
| pH:6.35 | |
| Temp: 6.78° C | |
| ORP: 181 | |
| D.O.: 9.70 mg/L | |
| Turbidity: 3.6 NTU | |
| Conductivity: 0.041 mS/cm | Photograph Log #: 01/21/15 – 077.jpg |
| Flow Measurement: (0.750 L/ 3 sec) = 0.250L / sec = (3.96 GPM) = (0.009 CFS) | Measurement Equipment: Horiba U-52 #WIV35Y5U |
| Water Clarity Observed: Clear | |
| Weather: Clear, Air Temperature: 36° F | |
| Comments: 0.250 L / sec fill rate = 3.96 GPM = 0.009 CFS<br><br>Runoff eroded EMDNT3 stream base at ST3 location, leaving base of staff gauge above water level. | |
| | |
| Field Technician: (Print) Jack Strader, Ronnie Philips | Date: 01/21/15 |

ALLIANT

# Surface Water Monitoring Location

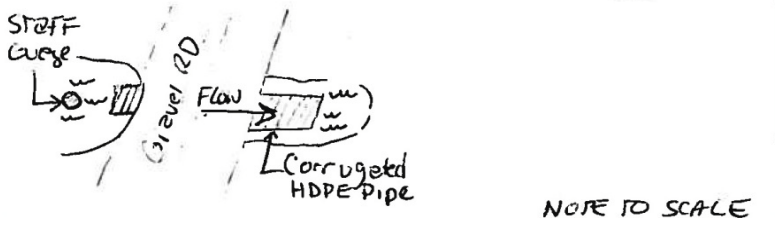
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST3

Date Measured: 01/29/15

Time Measured: 0922

Sample Location Sketch:




## Field Observations

Elevation (gauge): 0.00 (1,005.96 ft msl)

pH: 5.97

Temp: 5.61° C

ORP: 265

D.O.: 12.79 mg/L

Turbidity: 0 NTU

Conductivity: 0.050 mS/cm

Photograph Log #: 01/29/15 – 094.jpg

Flow Measurement: (0.750 L/ 3 sec) = 0.250L / sec = (3.96 GPM) = (0.009 CFS)

Measurement Equipment:

Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Air Temperature: 36° F

Comments:

| Location | VOLUME (ml) | VOLUME (gal) | RATE (sec) | RATE gal * Rate gal / sec | RATE Rate * 60 sec / 1 min (gal/min) | RATE 7.48 gal / $ft^3$ ($Ft^3$/sec) |
|---|---|---|---|---|---|---|
| **NT3-ST3** | 750.00 | 0.198 | 3.00 | 0.066 | 3.96 | 0.009 |

Field Technician: (Print)
Jack Strader, Daniel Edds

Date: 01/29/15

ALLIANT

# Surface Water Monitoring Location

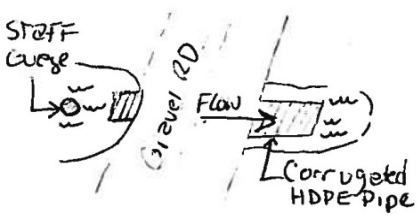
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST3

Date Measured: 02/05/15

Time Measured: 0859

Sample Location Sketch:




## Field Observations

Elevation (gauge): 0.00 (1,005.96 ft msl)

pH: 6.03

Temp: 5.12° C

ORP: 241

D.O.: 11.15 mg/L

Turbidity: 0 NTU

Conductivity: 0.048 mS/cm

Photograph Log #: 02/05/15 – 109.jpg

Flow Measurement: (0.750 L/ 2.5 sec) = 4.76 GPM = 0.011 CFS

Water Clarity Observed: Clear

Measurement Equipment:

Horiba U-52 #WIV35Y5U

Weather: Overcast, Calm, Air Temperature: 29° F

Calculations:

| Location | Volume (ml) | Rate (sec) | ml * 0.00026417 gal/ml = (gal) | gal/Rate = (gal/sec) | gal/sec * 60 sec/1 min = (gal/min) | gal/sec *7.48 gal/ft$^3$= (ft$^3$/sec) |
|---|---|---|---|---|---|---|
| **NT3-ST3** | 750.00 | 2.50 | 0.198 | 0.079 | **4.76** | **0.011** |

Field Technician: (Print)
Jack Strader, Seth Howard

Date: 05/05/15

ALLIANT

# Surface Water Monitoring Location

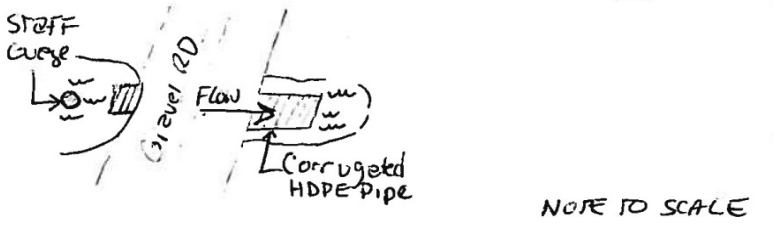
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST3

Date Measured: 02/11/15

Time Measured: 0901

Sample Location Sketch:




**Field Observations**

Elevation (gauge): 0.00 (1,005.90 ft msl)

pH: 6.16

Temp: 4.5° C

ORP: 191

D.O.: 12.14 mg/L

Turbidity: 2.8 NTU

Conductivity: 0.044 mS/cm

Photograph Log #: 02/11/15 – 128.jpg

Flow Measurement: (0.750 L/ 3 sec) = GPM = 0.009 CFS

Measurement Equipment:

Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Calm, Air Temperature: 29° F

Calculations:

Stream Flow Calculations:

| Location | Volume (ml) | Rate (sec) | ml * 0.00026417 gal/ml = (gal) | gal/Rate = (gal/sec) | gal/sec * 60 sec/1 min = (gal/min) | gal/sec *7.48 gal/ft$^3$= (ft$^3$/sec) |
|---|---|---|---|---|---|---|
| **NT3-ST3** | 750.00 | 3.00 | 0.198 | 0.066 | **3.96** | **0.009** |

Field Technician: (Print)
Jack Strader, Daniel Edds

Date: 02/11/15

ALLIANT

# Surface Water Monitoring Location

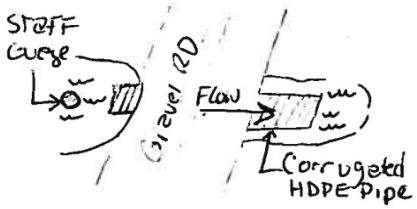
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST3

Date Measured: 02/20/15

Time Measured: 1051

Sample Location Sketch:




## Field Observations

Elevation (gauge): 0.00 (1,005.90 ft msl)

pH: 5.76

Temp: 1.71° C

ORP: 273

D.O.: 15.26 mg/L

Turbidity: 1.8 NTU

Conductivity: 0.068 mS/cm

Photograph Log #: 02/20/15 – 143.jpg

Flow Measurement: (0.750 L/ 1 sec) = 11.89 GPM = 0.026 CFS

Water Clarity Observed: Clear

Measurement Equipment:

Horiba U-52 #WIV35Y5U

Weather: Clear, Calm, Air Temperature: 5° F

Calculations:

Stream Flow Calculations:

| Location | Volume (ml) | Rate (sec) | ml * 0.00026417 gal/ml = (gal) | gal/Rate = (gal/sec) | gal/sec * 60 sec/1 min = (gal/min) | gal/sec *7.48 gal/ft$^3$= (ft$^3$/sec) |
|---|---|---|---|---|---|---|
| **NT3-ST3** | 750.00 | 1.00 | 0.198 | 0.198 | **11.89** | **0.026** |

Field Technician: (Print)
Jack Strader & Daniel Edds

Date: 02/20/15

ALLIANT

# Surface Water Monitoring Location

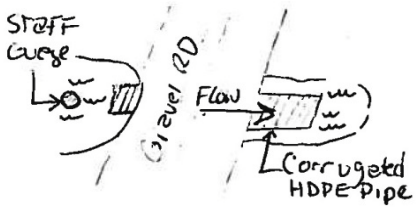
Project Name: EMDF Phase I Site Characterization  Project #: 4301

Site Location: EMDNT3-ST3

Date Measured: 02/27/15

Time Measured: 0929

Sample Location Sketch:




## Field Observations

Elevation (gauge): 0.00 (1,005.90 ft msl)

pH: 5.85

Temp: 4.19° C

ORP: 237

D.O.: 14.41 mg/L

Turbidity: 0.0 NTU

Conductivity: 0.044 mS/cm

Photograph Log #: 02/20/15 – 172.jpg

Flow Measurement: (0.750 L/ 1 sec) = 11.89 GPM = 0.026 CFS

Measurement Equipment:

Horiba U-52 #WIV35Y5U

Water Clarity Observed: Clear

Weather: Clear, Calm, Air Temperature: 26° F

Calculations:

Stream Flow Calculations:

| Location | Volume (ml) | Rate (sec) | ml * 0.00026417 gal/ml = (gal) | gal/Rate = (gal/sec) | gal/sec * 60 sec/1 min = (gal/min) | gal/sec *7.48 gal/ft$^3$= (ft$^3$/sec) |
|---|---|---|---|---|---|---|
| **NT3-ST3** | 750.00 | 1.00 | 0.198 | 0.198 | **11.89** | **0.026** |

Field Technician: (Print)
Jack Strader & Daniel Edds

Date: 02/27/15

| OBSERVATIONAL MONITORING LOCATION FLOW STATISTICS | | | |
|---|---|---|---|
| **Site** | **Statistics** | **Flow CFS** | **Flow GPM** |
| EMDNT3-ST1 | Average | 0.073 | 32.7 |
| | Maximum | 0.134 | 60.1 |
| | Minimum | 0.020 | 8.98 |
| | Baseflow Average | 0.056 | 25.0 |
| | | | |
| EMDNT3-ST2 | Average | 0.033 | 14.9 |
| | Maximum | 0.054 | 24.2 |
| | Minimum | 0.017 | 7.6 |
| | Baseflow Average | 0.034 | 15.1 |
| | | | |
| EMDNT3-ST3 | Average | 0.01 | 6.22 |
| | Maximum | 0.027 | 11.9 |
| | Minimum | 0.001 | 0.40 |
| | Baseflow Average | 0.007 | 3.1 |
| | | | |

Baseflow averages are based on stream flow recession curves among the lowest of the four low runoff periods on December 17, 2014, and January 21 & 29, and February 11, 2015.

| **OBSERVATIONAL MONITORING LOCATION EMDNT2-SP1** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOTE: Spring was modifed by creating a small rock dam just below original natural spring to create a small basin for monitoring | | | | | | | | | | | | |
| Spring is 1.7 ft wide, 1.9 ft long, and 0.05 ft deep; Staff gage is set at northern edge of spring | | | | | | | | | | | | |
| Site | Date | Time | WSE ft | pH | Temp DegC | ORP | D.O. (mg/L) | Turbidity (NTU) | Conductivity (mS/cm) | Flow GPM | Water Clarity | Air T DegF |
| EMDNT2-SP1 | 12/10/2014 | 1322 | 0.05 | 6.72 | 10.46 | 155 | 6.39 | Over | 0.086 | <1 | Clear | 39 |
| EMDNT2-SP1 | 12/18/2014 | 945 | 0.04 | 6.96 | 8.93 | 199 | 11.32 | 694 | 0.093 | <1 | Artificially Disturbed | 34 |
| EMDNT2-SP1 | 12/23/2014 | 1125 | 0.10 | 7.13 | 10.49 | 160 | 8.25 | 2.0 | 0.093 | <1 | Clear | 55 |
| EMDNT2-SP1 | 12/30/2014 | 1116 | 0.18 | 6.72 | 9.70 | 203 | 8.18 | 6.0 | 0.063 | <1 | Clear | 39 |
| EMDNT2-SP1 | 1/7/2015 | 1206 | 0.16 | 6.8 | 9.35 | 192 | 10.53 | 10.1 | 0.061 | <1 | Clear | 26 |
| EMDNT2-SP1 | 1/14/2015 | 1110 | 0.20 | 6.63 | 8.24 | 213 | 10.89 | 4.9 | 0.053 | <1 | Clear | 38 |
| EMDNT2-SP1 | 1/21/2015 | 1025 | 0.13 | 6.86 | 9.55 | 184 | 8.21 | 0.0 | 0.084 | <1 | Clear | 50 |
| EMDNT2-SP1 | 1/29/2015 | 1030 | 0.10 | 6.29 | 8.02 | 199 | 10.38 | 7.5 | 0.071 | <1 | Clear | 38 |
| EMDNT2-SP1 | 2/5/2015 | 1016 | 0.12 | 6.77 | 7.82 | 211 | 11.88 | 0.0 | 0.076 | <1 | Clear | 31 |
| EMDNT2-SP1 | 2/11/2015 | 945 | 0.06 | 6.59 | 7.92 | 215 | 12.37 | 2.4 | 0.087 | <1 | Clear | 30 |
| EMDNT2-SP1 | 2/20/2015 | 1154 | 0.12 | 6.61 | 7.75 | 150 | 9.67 | 2.7 | 0.091 | <1 | Clear | 15 |
| EMDNT2-SP1 | 2/27/2015 | 1016 | 0.16 | 6.21 | 6.58 | 204 | 14.21 | 0.0 | 0.053 | <1 | Clear | 27 |
| | | | Avge | 6.69 | 8.73 | 190 | 10.19 | 66.33 | 0.076 | <1 | Clear | 35 |
| | | | Max | 7.13 | 10.49 | 215 | 14.21 | 10.1 | 0.093 | <1 | Clear | 55 |
| | | | Min | 6.21 | 6.58 | 150 | 6.39 | 0.0 | 0.053 | <1 | Clear | 15 |

P:\3.0 Working File\3.2 ENV\EMDF Site Characterization\Phase I Site Characterization\Ph I SC Report\Exhibits for Ph I Rpt\A15 Observ Mon Docs\Source Files\EMDF Obs Mon Tables

| **OBSERVATIONAL MONITORING LOCATION EMDNT3-SP1** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring is 1.0 ft wide, 1.3 ft long, and 0.17 ft deep; Staff gage is set near north edge of natural spring basin | | | | | | | | | | | | |
| Site | Date | Time | WSE ft | pH | Temp DegC | ORP | D.O. (mg/L) | Turbidity (NTU) | Conductivity (mS/cm) | Flow GPM | Water Clarity | Air T DegF |
| EMDNT3-SP1 | 12/10/2014 | 1146 | 0.01 | 6.33 | 11.75 | 186 | 8.60 | 0.0 | 0.064 | <1 | Clear | 39 |
| EMDNT3-SP1 | 12/18/2014 | 915 | 0.06 | 6.66 | 11.34 | 276 | 10.27 | <10 | 0.084 | <1 | Clear | 34 |
| EMDNT3-SP1 | 12/23/2014 | 1050 | 0.05 | 6.92 | 11.81 | 141 | 8.97 | 1.2 | 0.074 | <1 | Clear | 55 |
| EMDNT3-SP1 | 12/30/2014 | 1047 | 0.05 | 6.92 | 11.70 | 190 | 8.21 | 10.4 | 0.021 | <1 | Clear | 37 |
| EMDNT3-SP1 | 1/7/2015 | 1135 | 0.10 | 6.59 | 10.71 | 178 | 7.09 | 7.5 | 0.048 | <1 | Clear | 26 |
| EMDNT3-SP1 | 1/14/2015 | 1135 | 0.17 | 6.36 | 9.67 | 213 | 8.44 | 8.7 | 0.047 | <1 | Clear | 38 |
| EMDNT3-SP1 | 1/21/2015 | 1145 | 0.08 | 6.46 | 11.63 | 259 | 13.41 | 3.6 | 0.070 | <1 | Clear | 55 |
| EMDNT3-SP1 | 1/29/2015 | 1110 | 0.09 | 6.52 | 10.65 | 160 | 8.85 | 10.9 | 0.057 | <1 | Clear | 39 |
| EMDNT3-SP1 | 2/5/2015 | 945 | 0.09 | 6.53 | 8.90 | 189 | 9.25 | 0.0 | 0.058 | <1 | Clear | 29 |
| EMDNT3-SP1 | 2/11/2015 | 1005 | 0.07 | 6.85 | 10.21 | 192 | 10.74 | 2.9 | 0.066 | <1 | Clear | 31 |
| EMDNT3-SP1 | 2/20/2015 | 1242 | 0.06 | 6.88 | 9.50 | 174 | 8.43 | 1.4 | 0.073 | <1 | Clear | 29 |
| EMDNT3-SP1 | 2/27/2015 | 1050 | 0.14 | 6.39 | 2.96 | 184 | 16.87 | 0.0 | 0.062 | <1 | Clear | 30 |
| | | | Avge | 6.62 | 10.07 | 195 | 9.93 | 4.2 | 0.060 | <1 | Clear | 37 |
| | | | Max | 6.92 | 11.81 | 276 | 16.87 | 10.9 | 0.084 | <1 | Clear | 55 |
| | | | Min | 6.33 | 2.96 | 141 | 7.09 | 0.0 | 0.021 | <1 | Clear | 26 |

| **OBSERVATIONAL MONITORING LOCATION EMDNT3-SP2** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOTE: Spring area was originally covered in trees/brush from May 2013 blowdown; area was cleared and channel shoveled out to create a small basin for monitoring | | | | | | | | | | | | |
| Spring is 1.0 ft wide, 3 ft long, and 0.05 ft avge depth; | | | | | | | | | | | | |
| Site | Date | Time | WSE ft | pH | Temp DegC | ORP | D.O. (mg/L) | Turbidity (NTU) | Conductivity (mS/cm) | Flow GPM | Water Clarity | Air T DegF |
| EMDNT3-SP2 | 12/10/2014 | 1043 | 0.05 | 6.09? | 7.58? | 147 | 7.50 | 0.0 | 0.064 | <1 | Clear | 39 |
| EMDNT3-SP2 | 12/17/2014 | 1545 | 0.04 | 6.60 | 9.78 | 212 | NR | 0.0 | 0.046 | <1 | Clear | 46 |
| EMDNT3-SP2 | 12/23/2014 | 927 | 0.02 | 6.54 | 10.15 | 196 | 9.20 | 17.5 | 0.066 | <1 | Clear | 52 |
| EMDNT3-SP2 | 12/30/2014 | 1001 | 0.01 | 6.30 | 10.47 | 201 | 7.76 | 5.8 | 0.066 | <1 | Clear | 37 |
| EMDNT3-SP2 | 1/7/2015 | 945 | 0.00 | 6.21 | 10.43 | 221 | 10.06 | 16.8 | 0.045 | <1 | Clear | 26 |
| EMDNT3-SP2 | 1/14/2015 | 900 | 0.00 | 4.93 | 9.10 | 310 | 8.80 | 4.7 | 0.091 | <1 | Clear | 36 |
| EMDNT3-SP2 | 1/21/2015 | 850 | 0.00 | 6.24 | 9.10 | 219 | 9.04 | 1.1 | 0.051 | <1 | Clear | 48 |
| EMDNT3-SP2 | 1/29/2015 | 930 | 0.00 | 6.20 | 8.75 | 220 | 11.20 | 28.4 | 0.049 | <1 | Clear | 37 |
| EMDNT3-SP2 | 2/5/2015 | 910 | 0.00 | 6.28 | 7.12 | 253 | 9.14 | 5.5 | 0.052 | <1 | Clear | 29 |
| EMDNT3-SP2 | 2/11/2015 | 915 | 0.00 | 6.21 | 7.70 | 192 | 10.06 | 4.0 | 0.051 | <1 | Clear | 29 |
| EMDNT3-SP2 | 2/20/2015 | 1115 | 0.00 | 6.15 | 6.05 | 181 | 11.96 | 0.0 | 0.054 | <1 | Clear | 15 |
| EMDNT3-SP2 | 2/27/2015 | 934 | 0.00 | 5.92 | 7.86 | 231 | 11.65 | 0.0 | 0.044 | <1 | Clear | 26 |
| | | | Avge | 6.14 | 8.77 | 215 | 9.67 | 7.6 | 0.057 | <1 | Clear | 35 |
| | | | Max | 6.60 | 10.47 | 310 | 11.96 | 28.4 | 0.091 | <1 | Clear | 52 |
| | | | Min | 4.93 | 6.05 | 147 | 7.50 | 0.0 | 0.044 | <1 | Clear | 15 |

P:\3.0 Working File\3.2 ENV\EMDF Site Characterization\Phase I Site Characterization\Ph I SC Report\Exhibits for Ph I Rpt\A15 Observ Mon Docs\EMDFSpringSeepObs wlw

**OBSERVATIONAL MONITORING LOCATION EMDNT3-ST1**

NOTE: Location is along main stream channel of NT-3 - See Figure 1 in Phase I report for surveyed location. Channel was not disturbed for monitoring.

Stream channel is 1-2 ft wide and entrenched 2-3 ft deep at this location; width of running water varies with runoff

Staff gage was located along east edge of channel under baseflow conditions

| Site | Date | Time | WSE ft | pH | Temp DegC | ORP | D.O. (mg/L) | Turbidity (NTU) | Conductivity (mS/cm) | Flow CFS | Flow GPM | Water Clarity | Air T DegF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EMDNT3-ST1 | 12/10/2014 | 1108 | IGR | 5.28 | 6.22 | 186 | 12.04 | NAR | 0.064 | 0.075 | 33.7 | Clear | 39 |
| EMDNT3-ST1 | 12/17/2014 | 1615 | IGR? | 6.47 | 8.53 | 153 | 11.90 | 48.6 | 0.070 | 0.020 | 9.0 | Clear | 46 |
| EMDNT3-ST1 | 12/23/2014 | 1035 | 0.00? | 6.59 | 9.11 | 149 | 9.36 | 7.3 | 0.068 | NR | NR | Clear | 53 |
| EMDNT3-ST1 | 12/30/2014 | 1028 | 0.04 | 6.17 | 9.36 | 187 | 10.0 | 28.0 | 0.047 | 0.1 | 44.9 | Clear | 37 |
| EMDNT3-ST1 | 1/7/2015 | 1115 | 0.04 | 6.31 | 7.10 | 180 | 8.85 | 17.0 | 0.044 | 0.1 | 44.9 | Clear | 26 |
| EMDNT3-ST1 | 1/14/2015 | 950 | 0.06 | 6.21 | 8.24 | 201 | 10.34 | 9.4 | 0.043 | 0.1 | 44.9 | Clear | 26 |
| EMDNT3-ST1 | 1/21/2015 | 1100 | 0.03 | 5.97 | 8.95 | 227 | 14.89 | 2.4 | 0.058 | 0.134 | 60.1 | Clear | 52 |
| EMDNT3-ST1 | 1/29/2015 | 1057 | 0.04 | 6.40 | 6.16 | 151 | 11.51 | 7.4 | 0.054 | 0.033 | 14.8 | Clear | 39 |
| EMDNT3-ST1 | 2/5/2015 | 930 | 0.04 | 6.40 | 5.97 | 240 | 10.52 | 11.8 | 0.042 | 0.033 | 14.8 | Clear | 30 |
| EMDNT3-ST1 | 2/11/2015 | 1025 | 0.07 | 6.93 | 6.94 | 196 | 15.08 | 10.5 | 0.060 | 0.036 | 16.2 | Clear | 32 |
| EMDNT3-ST1 | 2/20/2015 | 1133 | 0.07 | 6.46 | 2.15 | 165 | 10.73 | 0.1 | 0.053 | NR ice | NR ice | Clear | 16 |
| EMDNT3-ST1 | 2/27/2015 | 955 | 0.07 | 5.95 | 5.56 | 230 | 12.24 | 5.7 | 0.046 | 0.097 | 43.5 | Clear | 26 |
| | | | Avge | 6.35 | 7.10 | 189 | 11.41 | 10.0 | 0.054 | 0.073 | 32.7 | Clear | 34 |
| | | | Max | 6.93 | 9.36 | 240 | 15.08 | 48.6 | 0.070 | 0.134 | 60.1 | Clear | 53 |
| | | | Min | 5.28 | 2.15 | 149 | 8.85 | 0.1 | 0.042 | 0.020 | 8.98 | Clear | 16 |

NOTES:

NAR - Not accurately recorded when water was clear

IGR - Incorrect gage reading

NR - not recorded

NOTES:

Variations in staff gage readings are inconsistent with flow rate variations suggesting inaccurate flow measurements

Limited number and accuracy of stream dimensions & flow parameters used for flow calculations suggest flow rates are very approximate

P:\3.0 Working File\3.2 ENV\EMDF Site Characterization\Phase I Site Characterization\Ph I SC Report\Exhibits for Ph I Rpt\A15 Observ Mon Docs\Source Files\EMDF Obs Mon Tables

| **OBSERVATIONAL MONITORING LOCATION EMDNT3-ST2** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOTE: Location is along west tributary stream channel of NT-3 - See Figure 1 in Phase I report for surveyed location. Channel was not disturbed for monitoring. | | | | | | | | | | | | | |
| Stream channel is ~0.83 ft wide and barely entrenched ~0.2-0.4 ft deep at this location; width of running water varies with runoff | | | | | | | | | | | | | |
| Staff gage was located along west edge of channel under baseflow conditions | | | | | | | | | | | | | |
| Site | Date | Time | WSE ft | pH | Temp DegC | ORP | D.O. (mg/L) | Turbidity (NTU) | Conductivity (mS/cm) | Flow CFS | Flow GPM | Water Clarity | Air T DegF |
| EMDNT3-ST2 | 12/10/2014 | 1008 | 0.18 | 5.21 | 8.18 | 219 | 11.70 | 84.0 | NR | 0.054 | 24.2 | Clear | 39 |
| EMDNT3-ST2 | 12/17/2014 | 1545 | 0.14 | 6.6 | 8.35 | 213 | 10.97 | 0? | 0.090 | ND | ND | Clear? | 39 |
| EMDNT3-ST2 | 12/23/2014 | 1010 | 0.15 | 6.48 | 8.67 | 131 | 7.17 | 23.3 | 0.056 | ND | ND | Clear | 46 |
| EMDNT3-ST2 | 12/30/2014 | 934 | 0.15 | 5.87 | 8.31 | 142 | 7.57 | 17.3 | 0.061 | 0.028 | 12.6 | Clear | 36 |
| EMDNT3-ST2 | 1/7/2015 | 1045 | 0.15 | 6.19 | 5.17 | 183 | 7.71 | 13.0 | 0.045 | 0.026 | 11.7 | Clear | 26 |
| EMDNT3-ST2 | 1/14/2015 | 930 | 0.14 | 6.01 | 5.66 | 192 | 9.16 | 8.3 | 0.048 | 0.024 | 10.8 | Clear | 26 |
| EMDNT3-ST2 | 1/21/2015 | 910 | 0.15 | 6.17 | 6.01 | 153 | 7.75 | 2.1 | 0.049 | 0.042 | 18.8 | Clear | 48 |
| EMDNT3-ST2 | 1/29/2015 | 939 | 0.12 | 6.16 | 5.02 | 148 | 12.56 | 11.0 | 0.047 | 0.042 | 18.8 | Clear | 39 |
| EMDNT3-ST2 | 2/5/2015 | 852 | 0.11 | 5.7 | 4.31 | 188 | 9.07 | 1.8 | 0.081 | 0.038 | 17.1 | Clear | 39 |
| EMDNT3-ST2 | 2/11/2015 | 847 | 0.12 | 5.86 | 3.18 | 170 | 13.94 | 5.0 | 0.080 | 0.017 | 7.6 | Clear | 28 |
| EMDNT3-ST2 | 2/20/2015 | 1102 | 0.12 | 5.86 | 0.92 | 197 | 9.28 | 32.2 | 0.067 | 0.025 | 11.2 | Clear | 5 |
| EMDNT3-ST2 | 2/27/2015 | 919 | 0.1 | 5.46 | 3.2 | 267 | 12.85 | 6.7 | 0.064 | 0.036 | 16.2 | Clear | 26 |
| | | | Avge | 6.03 | 5.35 | 184 | 9.89 | 18.6 | 0.063 | 0.033 | 14.9 | Clear | 33 |
| | | | Max | 6.60 | 8.67 | 267 | 13.94 | 84 | 0.090 | 0.054 | 24.2 | Clear | 48 |
| | | | Min | 5.21 | 0.92 | 131 | 7.17 | 1.8 | 0.045 | 0.017 | 7.6 | Clear | 5 |
| | | | | | | | | | | | | | |
| NOTES: | | | | | | | | | | | | | |
| ND - not determined/not calculated | | | | | | | | | | | | | |
| ? - water appears turbid in photo - data of questionable certainty | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

P:\3.0 Working File\3.2 ENV\EMDF Site Characterization\Phase I Site Characterization\Ph I SC Report\Exhibits for Ph I Rpt\A15 Observ Mon Docs\Source Files\EMDF Obs Mon Tables

| **OBSERVATIONAL MONITORING LOCATION EMDNT3-ST3** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOTE: Location is along west tributary stream channel of NT-3 just above the HDPE culvert under the road leading to EMWMF well GW-916 - See Figure 1 in Phase I report for surveyed location. Channel was not disturbed for monitoring. | | | | | | | | | | | | | | |
| Stream channel not measured by Alliant but is ~0.5-1.0 ft wide at staff gage, entrenched ~0.3-0.6 ft deep at this location; width of running water varies with runoff but typically appears to be ~0.5-1.0 ft wide | | | | | | | | | | | | | | |
| Staff gage was located in the center of the small stream channel under baseflow conditions | | | | | | | | | | | | | | |
| Flow rates were measured at downstream end of culvert roughly 15 ft south of staff gage location using 1L cup and watch so flows are fairly accurate | | | | | | | | | | | | | | |
| Site | Date | Time | WSE ft | pH | Temp DegC | ORP | D.O. (mg/L) | Turbidity (NTU) | Conductivity (mS/cm) | Flow LPM | Flow CFS | Flow GPM | Water Clarity | Air T DegF |
| EMDNT3-ST3 | 12/10/2014 | 932 | 0.14 | 5.97 | 9.10 | 256 | 11.37 | 8.0 | NR | 7.5 | 0.0044 | 1.98 | Clear | 39 |
| EMDNT3-ST3 | 12/17/2014 | 1527 | 0.10 | 5.95 | 8.26 | 316 | 8.69 | 0? | 0.052 | 1.5 | 0.00088 | 0.40 | Clear | 46 |
| EMDNT3-ST3 | 12/23/2014 | 948 | 0.10 | 6.69 | 8.84 | 199 | 9.51 | 28.3 | 0.048 | 9.0 | 0.0053 | 2.38 | Clear | 53 |
| EMDNT3-ST3 | 12/30/2014 | 916 | 0.11 | 5.69 | 8.72 | 282 | 13.44 | 139.0 | 0.038 | 45.0 | 0.0265 | 11.90 | Clear | 36 |
| EMDNT3-ST3 | 1/7/2015 | 1035 | 0.00 Gage eroded | 5.69 | 8.72 | 282 | 13.44 | 139.0 | 0.038 | 21.3 | 0.0125 | 5.63 | Clear | 26 |
| EMDNT3-ST3 | 1/14/2015 | 915 | 0.00 | 5.69 | 7.43 | 264 | 10.58 | 3.9 | 0.039 | 45.0 | 0.0265 | 11.90 | Clear | 36 |
| EMDNT3-ST3 | 1/21/2015 | 930 | 0.06 | 6.35 | 6.78 | 181 | 9.70 | 3.6 | 0.041 | 15.0 | 0.0088 | 3.96 | Clear | 36 |
| EMDNT3-ST3 | 1/29/2015 | 922 | 0.00 | 5.97 | 5.61 | 265 | 12.79 | 0.0 | 0.05 | 15.0 | 0.0088 | 3.96 | Clear | 36 |
| EMDNT3-ST3 | 2/5/2015 | 859 | 0.00 | 6.03 | 5.12 | 241 | 11.15 | 0.0 | 0.048 | 18.0 | 0.0106 | 4.76 | Clear | 29 |
| EMDNT3-ST3 | 2/11/2015 | 901 | 0.00 | 6.16 | 4.5 | 191 | 12.14 | 2.8 | 0.044 | 15.0 | 0.0088 | 3.96 | Clear | 29 |
| EMDNT3-ST3 | 2/20/2015 | 1051 | 0.00 | 5.76 | 1.71 | 273 | 15.26 | 1.8 | 0.068 | 45.0 | 0.0265 | 11.90 | Clear | 5 |
| EMDNT3-ST3 | 2/27/2015 | 929 | 0.00 | 5.85 | 4.19 | 237 | 14.41 | 0.0 | 0.044 | 45.0 | 0.0265 | 11.90 | Clear | 5 |
| | | | Avge | 6.01 | 6.39 | 246 | 11.73 | 18.7 | 0.047 | 23.53 | 0.01 | 6.22 | Clear | 31 |
| | | | Max | 6.69 | 9.1 | 316 | 15.26 | 139 | 0.068 | 45.00 | 0.027 | 11.9 | Clear | 53 |
| | | | Min | 5.69 | 1.71 | 181 | 8.69 | 0.0 | 0.038 | 1.50 | 0.001 | 0.40 | Clear | 5 |
| | | | | | | | | | | | | | | |
| NOTES: | | | | | | | | | | | | | | |
| Gage data modified after 1/7/15 from stream channel erosion and gage location; gage data appear to have no relevance to stream flow rates | | | | | | | | | | | | | | |
| Shaded data appear to be in error and not modified from previous measurement event | | | | | | | | | | | | | | |
| Shaded values are excluded from statistics | | | | | | | | | | | | | | |

P:\3.0 Working File\3.2 ENV\EMDF Site Characterization\Phase I Site Characterization\Ph I SC Report\Exhibits for Ph I Rpt\A15 Observ Mon Docs\EMDFSpringSeepObs wlw

**Surface Water Level Measurements and Water Level Elevations**
**EMDF Phase 1 Site Characterzation**

## Alliant Corporation

| *Surface Water Location ID* | *Date* | *Time* | *Elevations for Flume bottom and Staff Gage 0.00 ft mark (ft MSL)* | *Staff Gauge Water Level (ft)* | *Surface Water Elevation ft MSL)* | |
|---|---|---|---|---|---|---|
| SWG-1 (East) | 12/11/14 | 1109 | 975.06 | 0.04 | 975.10 | |
| | 12/17/14 | 1535 | | 0.04 | 975.10 | |
| | 12/23/14 | 1305 | | 0.07 | 975.13 | |
| | 12/29/14 | 1235 | | 0.13 | 975.19 | |
| | 1/7/15 | 1233 | | 0.08 | 975.14 | |
| SWG-2 (Middle) | 12/11/14 | 1240 | 981.66 | 0.04 | 981.70 | |
| | 12/17/14 | 1622 | | 0.03 | 981.69 | |
| | 12/23/14 | 1329 | | 0.04 | 981.70 | |
| | 12/29/14 | 1258 | | 0.04 | 981.70 | |
| | 1/7/15 | 1247 | | 0.03 | 981.69 | |
| SWG-3 (West) | 12/11/14 | 805 | 979.68 | 0.03 | 979.71 | |
| | 12/17/14 | 1100 | | 0.03 | 979.71 | |
| | 12/23/14 | 952 | | 0.04 | 979.72 | |
| | 12/29/14 | 954 | | 0.09 | 979.77 | |
| | 1/7/15 | 941 | | 0.06 | 979.74 | |
| EMDNT3-ST1 | 12/10/14 | 1108 | 1009.97 | 0.04 | 1010.01 | wlw corrected 0.14 reading to 0.04 on 1/12/15 |
| | 12/17/14 | 1615 | | 0.04 | 1010.01 | wlw corrected gage height from 2.0 to 1.6 ft on 1/12/15 |
| | 12/23/14 | 1035 | | 0.00 | 1009.97 | |
| | 12/30/14 | 1028 | | 0.04 | 1010.01 | |
| | | | | | | |
| EMDNT3-ST2 | 12/10/14 | 1008 | 992.94 | 0.18 | 993.12 | |
| | 12/17/14 | 1545 | | 0.14 | 993.08 | |
| | 12/23/14 | 1010 | | 0.15 | 993.09 | |
| | 12/30/14 | 934 | | 0.16 | 993.10 | |
| | | | | | | |
| EMDNTST3-ST3 | 12/10/14 | 0932 | 1005.90 | 0.14 | 1006.04 | |
| | 12/17/14 | 1527 | | 0.10 | 1006.00 | |
| | 12/23/14 | 948 | | 0.10 | 1006.00 | |
| | 12/30/14 | 916 | | 0.11 | 1006.01 | |
| | | | | | | |
| EMDNTS3-SP1 | 12/10/14 | 1146 | 1041.24 | 0.01 | 1041.25 | |
| | 12/18/14 | 0915 | | 0.06 | 1041.30 | |
| | 12/23/14 | 1050 | | 0.05 | 1041.29 | |
| | 12/30/14 | 1047 | | 0.02 | 1041.26 | |
| | | | | | | |
| EMDNT3-SP2 | 12/10/14 | 1043 | 1043.33 | 0.05 | 1043.38 | |
| | 12/17/14 | 1545 | | 0.04 | 1043.37 | |
| | 12/23/14 | 927 | | 0.02 | 1043.35 | |
| | 12/30/14 | 1001 | | 0.01 | 1043.34 | |
| | | | | | | |
| EMDNT2-SP1 | 12/10/14 | 1322 | 1058.27 | 0.05 | 1058.32 | |
| | 12/17/14 | 945 | | 0.04 | 1058.31 | |
| | 12/23/14 | 1125 | | 0.10 | 1058.37 | |
| | 12/30/14 | 1116 | | 0.18 | 1058.45 | |

# EXHIBIT A.16:
# BWSC PHASE I SURVEYING DATA

This page intentionally left blank.

# PHASE I ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY

Monitoring Wells and Surface Water Monitoring Stations (As-builts)
File No. 35908-00
December 10, 2014

| Point No. | North | East | Elevation | Description |
|---|---|---|---|---|
| 1 | 30955.06 | 48367.28 | 996.33 | CONTROL POINT |
| 2 | 30862.81 | 48368.31 | 984.28 | CONTROL POINT |
| 3 | 31276.25 | 48594.27 | 1018.21 | CONTROL POINT |
| 4 | 31083.33 | 48522.57 | 1006.41 | CONTROL POINT |
| 5 | 31003.57 | 48473.80 | 999.30 | CONTROL POINT |
| 6 | 31196.40 | 48673.10 | 1005.42 | CMP |
| 7 | 31192.95 | 48703.46 | 1005.16 | CMP |
| 8 | 31206.70 | 48755.18 | 1009.22 | BM3 |
| 9 | 31147.81 | 48762.76 | 1001.08 | CMP |
| 10 | 31166.58 | 48771.63 | 1001.20 | CMP |
| 11 | 30692.14 | 48717.71 | 978.06 | FLUME - EMDNT3-SWG1 Top Surface |
| 12 | 30691.02 | 48714.74 | 978.04 | FLUME - EMDNT3-SWG1 Top Surface |
| 13 | 30691.69 | 48708.87 | 978.02 | FLUME - EMDNT3-SWG1 Top Surface |
| 14 | 30688.46 | 48709.21 | 978.13 | FLUME - EMDNT3-SWG1 Top Surface |
| 15 | 30689.67 | 48714.77 | 978.04 | FLUME - EMDNT3-SWG1 Top Surface |
| 16 | 30688.89 | 48717.91 | 978.06 | FLUME - EMDNT3-SWG1 Top Surface |
| 17 | 31112.08 | 48789.94 | 1005.16 | GW-975(S) - Top of casing (TOC) |
| 18 | 31111.33 | 48789.40 | 1003.01 | CONCRETE GW-975(S) |
| 19 | 31110.19 | 48788.28 | 1002.52 | GROUND GW-975(S) |
| 20 | 31103.27 | 48796.37 | 1002.80 | GROUND GW-974(I) |
| 21 | 31104.66 | 48798.11 | 1003.19 | CONCRETE GW-974(I) |
| 22 | 31105.66 | 48798.68 | 1005.38 | GW-974(I) TOC |
| 23 | 31539.77 | 48968.13 | 1072.98 | GW-969(S) TOC |
| 24 | 31538.57 | 48967.60 | 1070.67 | CONCRETE GW-969(S) |
| 25 | 31537.46 | 48966.88 | 1070.45 | GROUND GW-969(S) |
| 26 | 31533.07 | 48978.08 | 1070.21 | GROUND GW-968(I) |
| 27 | 31534.74 | 48978.68 | 1070.39 | CONCRETE GW-968(I) |
| 28 | 31535.57 | 48979.13 | 1072.52 | GW-968(I) TOC |
| 29 | 31268.37 | 49092.12 | 1026.96 | GW-973(S) TOC |
| 30 | 31268.13 | 49091.30 | 1024.68 | CONCRETE GW-973(S) |
| 31 | 31268.40 | 49089.76 | 1024.46 | GROUND GW-973(S) |
| 32 | 31259.47 | 49089.66 | 1023.55 | GROUND GW-972(I) |
| 33 | 31259.19 | 49090.96 | 1023.75 | CONCRETE GW-972(I) |
| 34 | 31259.06 | 49091.99 | 1026.20 | GW-972(I) TOC |
| 35 | 31323.84 | 49394.29 | 1011.03 | EMDNT3-ST1 Top of Staff Gage |
| 36 | 31323.86 | 49394.06 | 1009.79 | GROUND EMDNT3-ST1 |
| 37 | 31392.01 | 49560.23 | 1043.11 | GW-971(S) TOC |
| 38 | 31391.24 | 49560.72 | 1040.81 | CONCRETE GW-971(S) |
| 39 | 31389.56 | 49560.80 | 1040.69 | GROUND GW-971(S) |
| 40 | 31389.83 | 49569.21 | 1040.93 | GROUND GW-970(I) |
| 41 | 31391.54 | 49568.97 | 1041.20 | CONCRETE GW-970(I) |
| 42 | 31392.90 | 49568.45 | 1043.17 | GW-970(I) TOC |
| 43 | 30831.10 | 49397.44 | 1068.17 | GW-977(S) TOC |
| 44 | 30830.22 | 49397.44 | 1065.84 | CONCRETE GW-977(S) |

# PHASE I ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY

Monitoring Wells and Surface Water Monitoring Stations (As-builts)
File No. 35908-00
December 10, 2014

| Point No. | North | East | Elevation | Description |
|---|---|---|---|---|
| 45 | 30828.76 | 49397.48 | 1065.63 | GROUND GW-977(S) |
| 46 | 30835.17 | 49395.01 | 1065.84 | GROUND GW-976(I) |
| 47 | 30836.66 | 49394.66 | 1066.15 | CONCRETE GW-976(I) |
| 48 | 30838.21 | 49394.31 | 1068.41 | GW-976(I) TOC |
| 49 | 30462.47 | 48385.02 | 985.14 | BM1 |
| 50 | 30415.87 | 48186.72 | 990.56 | BM2 |
| 51 | 30035.01 | 47315.71 | 959.76 | MON (89-Y-116) |
| 52 | 31105.24 | 50945.20 | 1047.53 | CONTROL POINT |
| 53 | 31256.29 | 51147.14 | 1045.03 | CONTROL POINT |
| 54 | 31838.75 | 51133.26 | 1057.81 | GROUND EMDNT2-SP1 |
| 55 | 31838.79 | 51133.36 | 1059.33 | EMDNT2-SP1 Top Stake/Staff Gage |
| 56 | 30884.59 | 49402.75 | 1063.61 | CONTROL POINT |
| 57 | 30892.47 | 49521.20 | 1059.86 | CONTROL POINT |
| 58 | 30267.60 | 47770.97 | 978.67 | MON |
| 59 | 31620.35 | 49464.21 | 1042.30 | EMDNT3-SP1 Top Stake/Staff Gage |
| 60 | 30798.29 | 48322.21 | 982.69 | FLUME - EMDNT3-SWG3 Top Surface |
| 61 | 30795.30 | 48321.83 | 982.69 | FLUME - EMDNT3-SWG3 Top Surface |
| 62 | 30789.92 | 48323.75 | 982.75 | FLUME - EMDNT3-SWG3 Top Surface |
| 63 | 30789.37 | 48320.48 | 982.72 | FLUME - EMDNT3-SWG3 Top Surface |
| 64 | 30794.90 | 48320.49 | 982.72 | FLUME - EMDNT3-SWG3 Top Surface |
| 65 | 30797.73 | 48318.97 | 982.72 | FLUME - EMDNT3-SWG3 Top Surface |
| 66 | 30796.94 | 48319.70 | 979.68 | EMDNT3-SWG3-BOTTOM @ Stilling Well |
| 67 | 30796.98 | 48319.47 | 982.67 | EMDNT3-SWG3-TOP @ Stilling Well |
| 68 | 30968.34 | 48570.14 | 983.13 | FLUME - EMDNT3-SWG2 Top Surface |
| 69 | 30967.11 | 48565.99 | 983.14 | FLUME - EMDNT3-SWG2 Top Surface |
| 70 | 30965.35 | 48566.51 | 983.15 | FLUME - EMDNT3-SWG2 Top Surface |
| 71 | 30966.96 | 48570.71 | 983.15 | FLUME - EMDNT3-SWG2 Top Surface |
| 72 | 30968.01 | 48569.96 | 981.66 | EMDNT3-SWG2-BOTTOM @ Stilling Well |
| 73 | 30968.24 | 48569.92 | 983.17 | EMDNT3-SWG2-TOP @ Stilling Well |
| 74 | 30691.90 | 48717.20 | 975.06 | EMDNT3-SWG1-BOTTOM@ Stilling Well |
| 75 | 30692.03 | 48717.62 | 978.05 | EMDNT3-SWG1-TOP @ Stilling Well |
| 76 | 31288.91 | 48338.21 | 1008.84 | CONTROL POINT |
| 77 | 31285.90 | 48318.97 | 1005.74 | GROUND EMDNT3-ST3 |
| 78 | 31286.25 | 48318.99 | 1006.96 | EMDNT3-ST3 Top Stake/Staff Gage |
| 79 | 31611.98 | 48367.41 | 1042.83 | GROUND EMDNT3-SP2 |
| 80 | 31612.20 | 48367.33 | 1044.39 | EMDNT3-SP2 Top Stake/Staff Gage |
| 81 | 31225.46 | 48335.53 | 1003.12 | CONTROL POINT |
| 82 | 31117.56 | 48351.86 | 992.68 | GROUND EMDNT3-ST2 |
| 83 | 31117.73 | 48351.76 | 994.00 | EMDNT3-ST2 Top Stake/Staff Gage |
| Notes: | Coordinates and elevations in the Y-12 system based on monuments: | | | |
| | **89-Y-117** | | **89-Y-116** | |
| | N-30267.585 | | N-30035.012 | |
| | E-47770.947 | | E-47315.707 | |
| | EL-978.67 | | EL-959.76 | |

# EXHIBIT A.17:
# PHASE I WASTE DISPOSAL DOCUMENTATION

This page intentionally left blank.

# ORR Landfill Shipping Form

**ALL FIELDS MUST BE COMPLETED. ENTER NO CLASSIFIED INFORMATION ON THIS FORM.**

| Project Shipment No | Date Shipped | Document ID No |
|---|---|---|
| EMDF-121614-001 | 12/17/2014 | EMDF-001 |

**Generation Process Information**

| Generator's Name | Badge Number | Generator's Phone No. | Generator's Company |
|---|---|---|---|
| Scott Edmonds | 070687 | 865-803-6810 | UCOR LLC EMWMF on behalf of U.S. DOE |

| WBS Subproject | Origin Site and Facility | Radiological Area? | | |
|---|---|---|---|---|
| 1.12.02.03.03.01 - EMWMF Waste Ops | Y-12, EMWMF | | | Yes |
| | | | X | No |

| Physical Form | Master Profile No. / Rev. | TDEC Approval Letter No. |
|---|---|---|
| Solid | S-020 | |

**Waste Subcategories (Check all)**

| | Yes | No | | Yes | No | | Yes | No |
|---|---|---|---|---|---|---|---|---|
| Biological | | X | Construction Debris | | X | Classified | | X |
| PCB (any conc.) | | X | Medical | | X | Friable Asbestos | | X |
| Beryllium | | X | Sanitary / Industrial | X | | Non-Friable Asbestos | | X |
| Respiratory Hazard | | X | TDEC Special | | X | | | |

**Waste Description**

The waste includes 55-gallon poly bags with plastic sheeting used to stage drill cuttings, as well as paper wipes and rubber gloves generated on the EMDF Phase I Characterization project. The EMDF site is considered pristine and has no known radiological or chemical contamination. Drill cuttings are not included in this waste. Absorbent (i.e.,WasteLok) has been added for incidental condensation. The waste contents are radiological scanned and the results will accompany shipment.

Est. shipments 4 via van or pick-up truck

**Handling / Pickup Information**

| Pickup Site | Pickup Facility |
|---|---|
| Y-12 | EMWMF |

**Handling Instructions (please include applicable PPE instructions)**

No special handling instructions

**Waste Item / Container Information**

Item/Container: 1 of 1

| Container ID No. | | (Affix Barcode Label Here) |
|---|---|---|
| 20141217-001 | | |
| Origin Date | PCB Out-of-Service Date | |
| 12/18/2014 | | |

**Proper Shipping Description**

Non-Dot Regulated

| Est. Net Vol. | Net Vol. Units | Est. Gross Wt. | Gross Wt. Units | No. of Containers |
|---|---|---|---|---|
| 0.9479 | yd3 | 267 | kgs | 1 |

| Outer Container Type | Inner Container Type | Absorbent Mat'ls | | | HP Green Tag No. | Rad Survey Date | Rad Tech Badge No. |
|---|---|---|---|---|---|---|---|
| Unpackaged | Unpackaged | | X | Yes | Smears | 10/6/2014 | NA |
| | | | | No | | | |

**Signatures and Approvals**

| Generator | Badge | Date | Derivative Classifier | Badge | Date |
|---|---|---|---|---|---|
| Scott M Edmonds | 070687 | 12-17-14 | | | |
| **Verification Officer / EO** | **Badge** | **Date** | | | |
| | | | | | |

WTMS: 1/5/2015 4:36:37 PM

# ORR Landfill Shipping Form

**ALL FIELDS MUST BE COMPLETED. ENTER NO CLASSIFIED INFORMATION ON THIS FORM.**

| Project Shipment No | Date Shipped | Document ID No |
|---|---|---|
| EMDF-121614-002 | 12/18/2014 | EMDF-001 |

## Generation Process Information

| Generator's Name | Badge Number | Generator's Phone No. | Generator's Company |
|---|---|---|---|
| Scott Edmonds | 070687 | 865-803-6810 | UCOR LLC EMWMF on behalf of U.S. DOE |

| WBS Subproject | Origin Site and Facility | Radiological Area? | | |
|---|---|---|---|---|
| 1.12.02.03.03.01 - EMWMF Waste Ops | Y-12, EMWMF | | | Yes |
| | | | X | No |

| Physical Form | Master Profile No. / Rev. | TDEC Approval Letter No. |
|---|---|---|
| Solid | S-020 | |

## Waste Subcategories (Check all)

| | Yes | No | | Yes | No | | Yes | No |
|---|---|---|---|---|---|---|---|---|
| Biological | | X | Construction Debris | | X | Classified | | X |
| PCB (any conc.) | | X | Medical | | X | Friable Asbestos | | X |
| Beryllium | | X | Sanitary / Industrial | X | | Non-Friable Asbestos | | X |
| Respiratory Hazard | | X | TDEC Special | | X | | | |

## Waste Description

The waste includes 55-gallon poly bags with plastic sheeting used to stage drill cuttings, as well as paper wipes and rubber gloves generated on the EMDF Phase I Characterization project. The EMDF site is considered pristine and has no known radiological or chemical contamination. Drill cuttings are not included in this waste. Absorbent (i.e.,WasteLok) has been added for incidental condensation. The waste contents are radiological scanned and the results will accompany shipment.

Est. shipments 4 via van or pick-up truck

## Handling / Pickup Information

| Pickup Site | Pickup Facility |
|---|---|
| Y-12 | EMWMF |

**Handling Instructions (please include applicable PPE instructions)**

No special handling instructions

## Waste Item / Container Information

**Item/Container: 1 of 1**

| Container ID No. | | (Affix Barcode Label Here) |
|---|---|---|
| 20141218-001 | | |
| Origin Date | PCB Out-of-Service Date | |
| 12/18/2014 | | |

**Proper Shipping Description**

Non-Dot Regulated

| Est. Net Vol. | Net Vol. Units | Est. Gross Wt. | Gross Wt. Units | No. of Containers |
|---|---|---|---|---|
| 0.9479 | yd3 | 267 | kgs | 1 |

| Outer Container Type | Inner Container Type | Absorbent Mat'ls | | | HP Green Tag No. | Rad Survey Date | Rad Tech Badge No. |
|---|---|---|---|---|---|---|---|
| Unpackaged | Unpackaged | | X | Yes | Smears | 10/6/2014 | NA |
| | | | | No | | | |

## Signatures and Approvals

| Generator | Badge | Date | Derivative Classifier | Badge | Date |
|---|---|---|---|---|---|
| [signature] | 070687 | 12-18-14 | | | |
| **Verification Officer / EO** | **Badge** | **Date** | | | |
| | | | | | |

# ORR Landfill Shipping Form

**ALL FIELDS MUST BE COMPLETED. ENTER NO CLASSIFIED INFORMATION ON THIS FORM.**

| Project Shipment No | Date Shipped | Document ID No |
|---|---|---|
| EMDF-121614-003 | 12/18/2014 | EMDF-001 |

## Generation Process Information

| Generator's Name | Badge Number | Generator's Phone No. | Generator's Company |
|---|---|---|---|
| Scott Edmonds | 070687 | 865-803-6810 | UCOR LLC EMWMF on behalf of U.S. DOE |

| WBS Subproject | Origin Site and Facility | Radiological Area? | | |
|---|---|---|---|---|
| 1.12.02.03.03.01 - EMWMF Waste Ops | Y-12, EMWMF | | | Yes |
| | | | X | No |

| Physical Form | Master Profile No. / Rev. | TDEC Approval Letter No. |
|---|---|---|
| Solid | S-020 | |

## Waste Subcategories (Check all)

| | Yes | No | | Yes | No | | Yes | No |
|---|---|---|---|---|---|---|---|---|
| Biological | | X | Construction Debris | | X | Classified | | X |
| PCB (any conc.) | | X | Medical | | X | Friable Asbestos | | X |
| Beryllium | | X | Sanitary / Industrial | X | | Non-Friable Asbestos | | X |
| Respiratory Hazard | | X | TDEC Special | | X | | | |

## Waste Description

The waste includes 55-gallon poly bags with plastic sheeting used to stage drill cuttings, as well as paper wipes and rubber gloves generated on the EMDF Phase I Characterization project. The EMDF site is considered pristine and has no known radiological or chemical contamination. Drill cuttings are not included in this waste. Absorbent (i.e.,WasteLok) has been added for incidental condensation. The waste contents are radiological scanned and the results will accompany shipment.

Est. shipments 4 via van or pick-up truck

## Handling / Pickup Information

| Pickup Site | Pickup Facility |
|---|---|
| Y-12 | EMWMF |

**Handling Instructions (please include applicable PPE instructions)**

No special handling instructions

## Waste Item / Container Information

**Item/Container: 1 of 1**

| Container ID No. | | (Affix Barcode Label Here) |
|---|---|---|
| 20141218-001 | | |
| **Origin Date** | **PCB Out-of-Service Date** | |
| 12/18/2014 | | |

**Proper Shipping Description**

Non-Dot Regulated

| Est. Net Vol. | Net Vol. Units | Est. Gross Wt. | Gross Wt. Units | No. of Containers |
|---|---|---|---|---|
| 0.9479 | yd3 | 267 | kgs | 1 |

| Outer Container Type | Inner Container Type | Absorbent Mat'ls | | | HP Green Tag No. | Rad Survey Date | Rad Tech Badge No. |
|---|---|---|---|---|---|---|---|
| Unpackaged | Unpackaged | | X | Yes | Smears | 10/6/2014 | NA |
| | | | | No | | | |

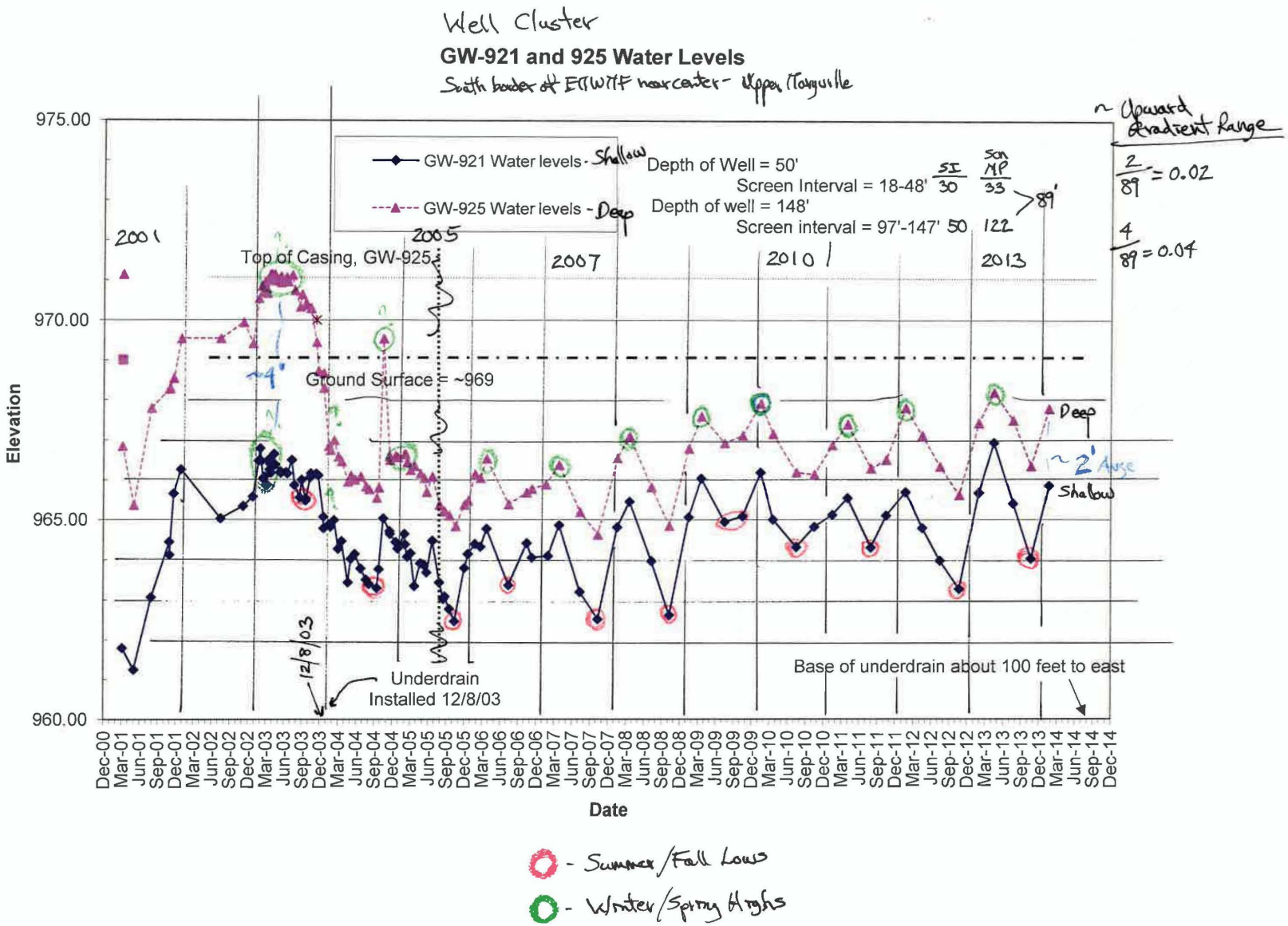
## Signatures and Approvals

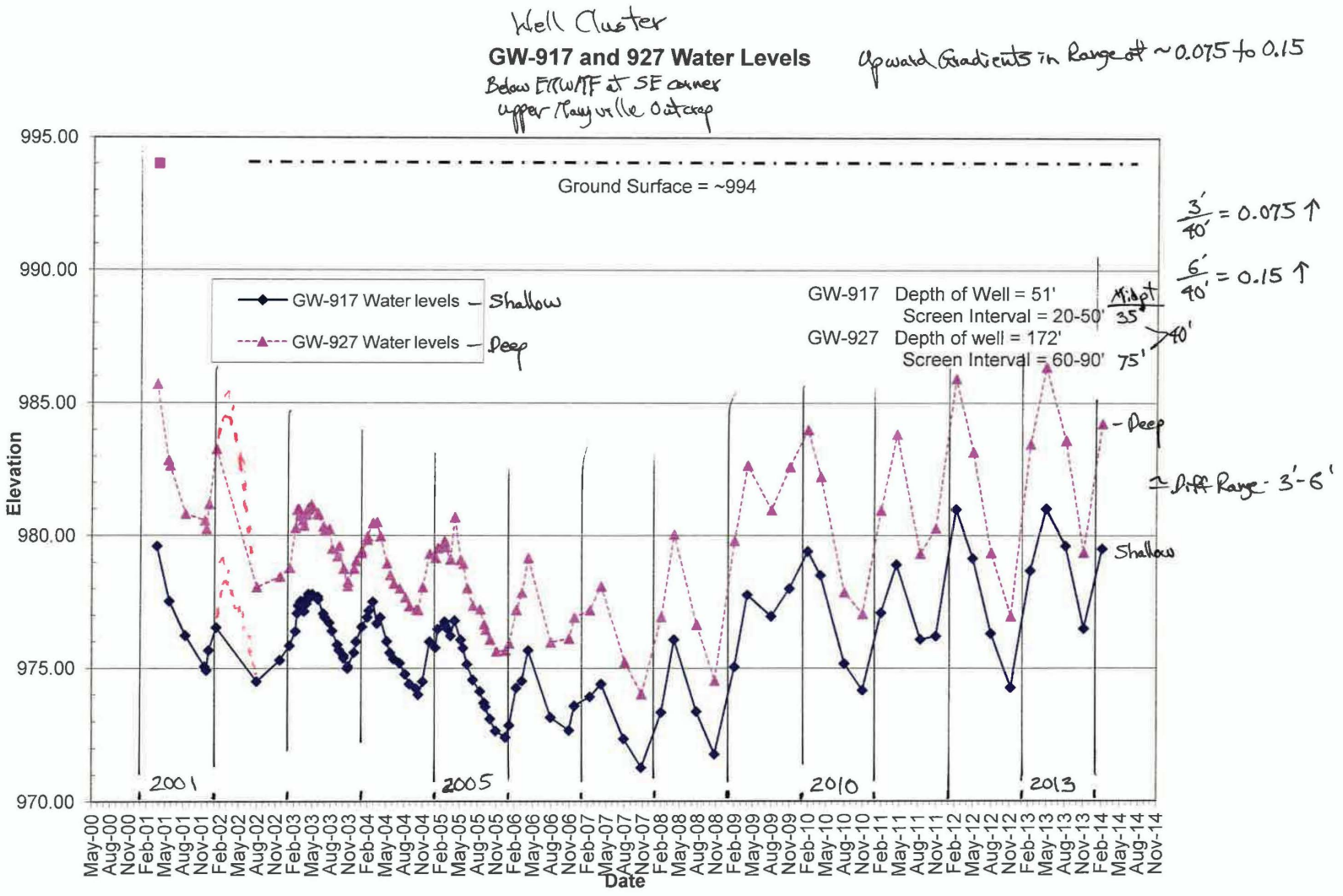
| Generator | Badge | Date | Derivative Classifier | Badge | Date |
|---|---|---|---|---|---|
| [signature] | 070687 | 12/18/14 | | | |
| **Verification Officer / EO** | **Badge** | **Date** | | | |
| | | | | | |

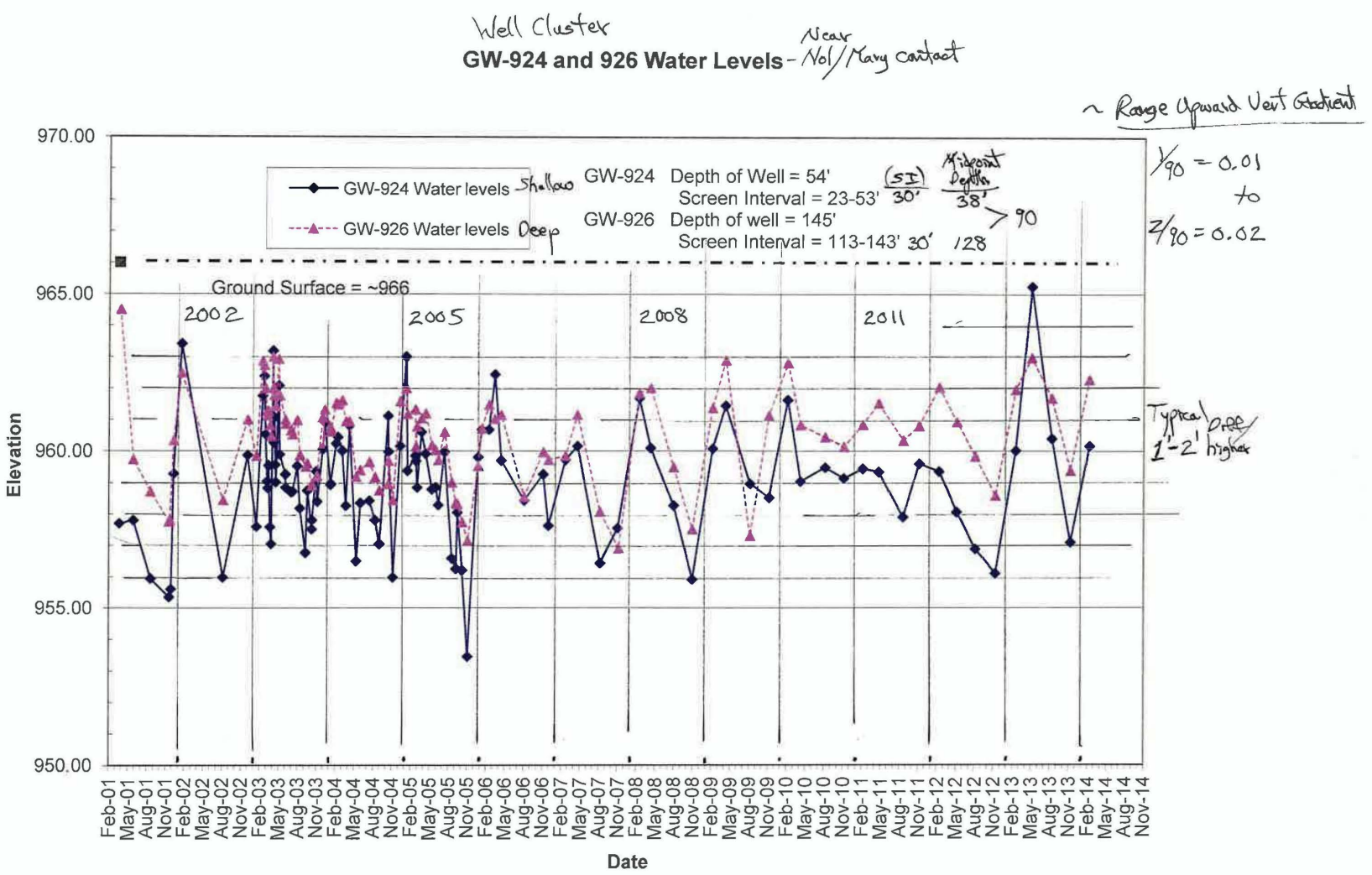
This page intentionally left blank.

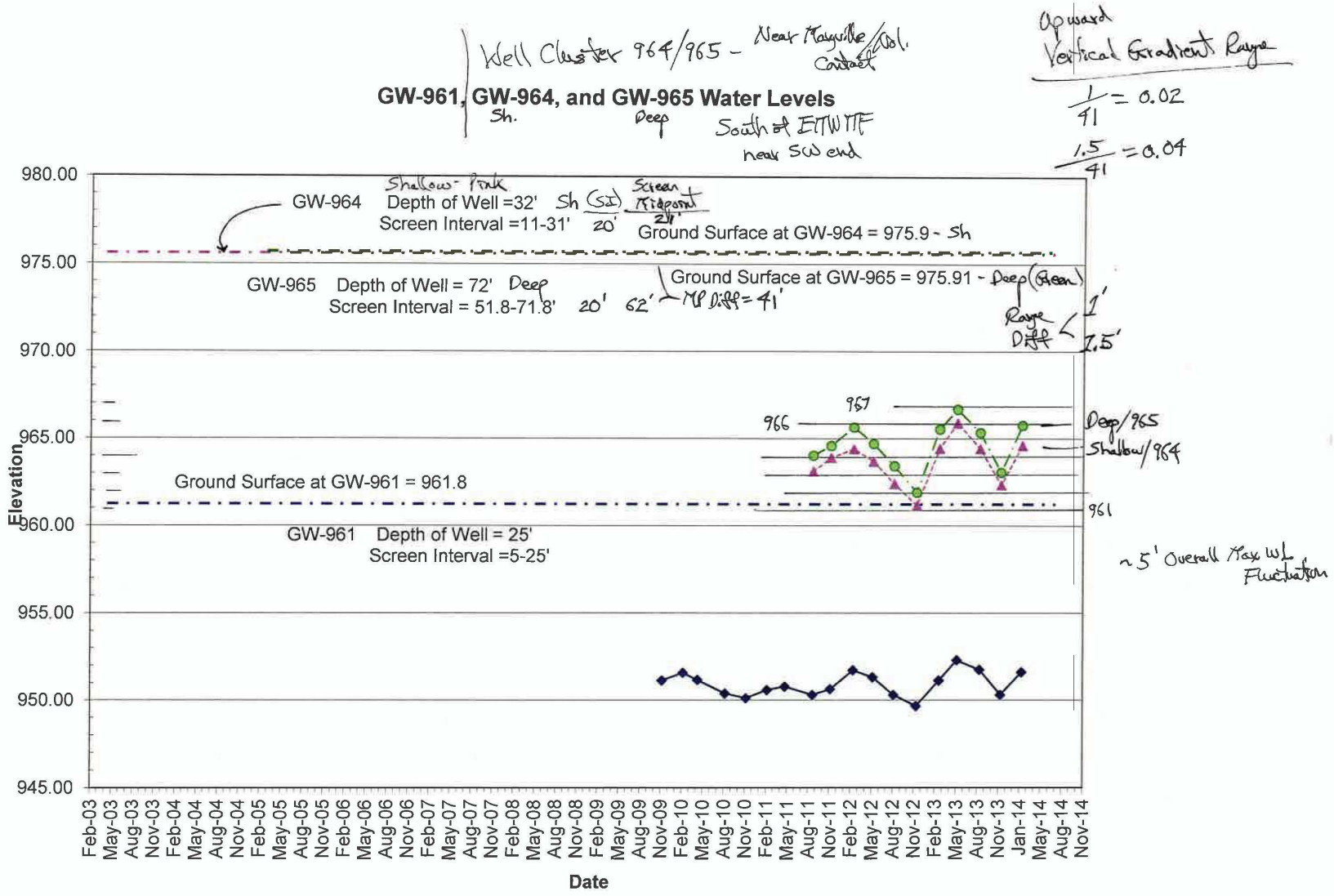
# EXHIBIT A.18:
# REPRESENTATIVE WATER LEVEL HYDROGRAPHS AND VERTICAL GRADIENTS FOR EMWMF MONITORING WELLS

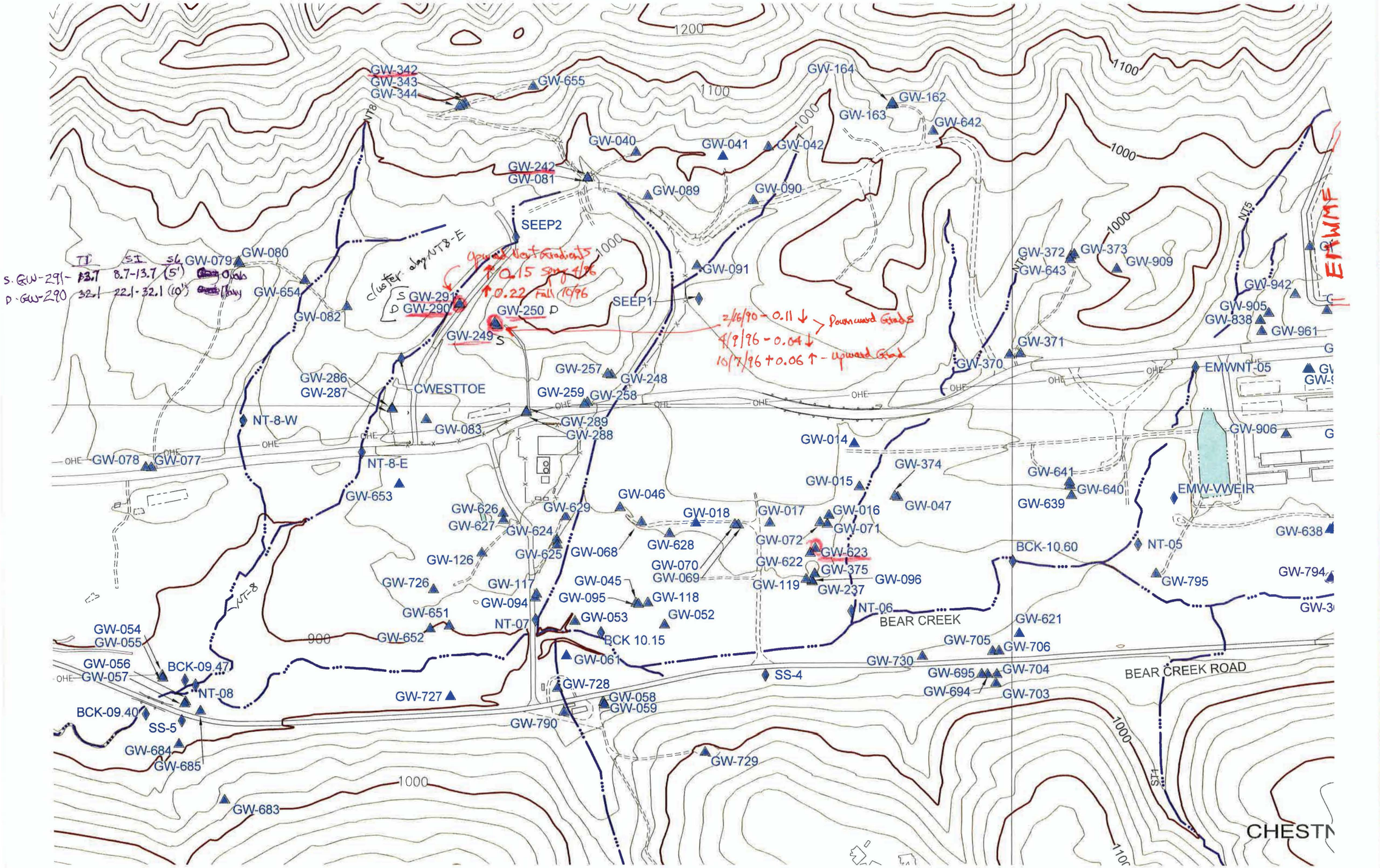
This page intentionally left blank.


Well Cluster
GW-921 and 925 Water Levels
South border of Ellwiff near center - Upper Marguerite
GW-921 Water levels - Shallow
GW-925 Water levels - Deep
Depth of Well = 50'
Screen Interval = 18-48'
Depth of well = 148'
Screen interval = 97'-147'
Top of Casing, GW-925
Ground Surface = ~969
Underdrain Installed 12/8/03
Base of underdrain about 100 feet to east
Elevation
Date
975.00
970.00
965.00
960.00
2001
2005
2007
2010
2013
~ Upward Gradient Range
2/89 = 0.02
4/89 = 0.04
~2' Avg
Deep
Shallow
- Summer/Fall Lows
- Winter/Spring Highs


Well Cluster
GW-917 and 927 Water Levels
Below EffWTF at SE corner
upper Tuscaloosa Outcrop
Upward Gradients in Range of ~0.075 to 0.15
Ground Surface = ~994
GW-917 Water levels – Shallow
GW-927 Water levels – Deep
GW-917 Depth of Well = 51'
Screen Interval = 20-50'
GW-927 Depth of well = 172'
Screen Interval = 60-90'
Midpt
35
75'
40'
3'/40' = 0.075 ↑
6'/40' = 0.15 ↑
Deep
Shallow
Diff Range - 3'-6'
Elevation
995.00
990.00
985.00
980.00
975.00
970.00
2001
2005
2010
2013
Date


Well Cluster
GW-924 and 926 Water Levels - Near Nol/Mary contact
~ Range Upward Vert Gradient
970.00
965.00
960.00
955.00
950.00
Elevation
GW-924 Water levels Shallow
GW-926 Water levels Deep
GW-924 Depth of Well = 54'
Screen Interval = 23-53'
GW-926 Depth of well = 145'
Screen Interval = 113-143'
(SI) 30'
Midpoint Depths 38' 128
> 90
1/90 = 0.01 to 2/90 = 0.02
Ground Surface = ~966
2002
2005
2008
2011
Typical Deep 1'-2' higher
Feb-01 May-01 Aug-01 Nov-01 Feb-02 May-02 Aug-02 Nov-02 Feb-03 May-03 Aug-03 Nov-03 Feb-04 May-04 Aug-04 Nov-04 Feb-05 May-05 Aug-05 Nov-05 Feb-06 May-06 Aug-06 Nov-06 Feb-07 May-07 Aug-07 Nov-07 Feb-08 May-08 Aug-08 Nov-08 Feb-09 May-09 Aug-09 Nov-09 Feb-10 May-10 Aug-10 Nov-10 Feb-11 May-11 Aug-11 Nov-11 Feb-12 May-12 Aug-12 Nov-12 Feb-13 May-13 Aug-13 Nov-13 Feb-14 May-14 Aug-14 Nov-14
Date


Well Cluster 964/965 - Near Maryville/Vol. Contact
GW-961, GW-964, and GW-965 Water Levels
Sh.
Deep
South of EITWTF near SW end
Upward Vertical Gradient Range
1/41 = 0.02
1.5/41 = 0.04
Shallow - Pink
GW-964 Depth of Well =32' Sh (SI) Screen Midpoint
Screen Interval =11-31' 20' 21'
Ground Surface at GW-964 = 975.9 - Sh
GW-965 Depth of Well = 72' Deep
Screen Interval = 51.8-71.8' 20' 62'
Ground Surface at GW-965 = 975.91 - Deep (Green)
MP Diff = 41'
Range Diff
1'
1.5'
967
966
Deep/965
Shallow/964
961
Ground Surface at GW-961 = 961.8
GW-961 Depth of Well = 25'
Screen Interval =5-25'
~5' Overall Max WL Fluctuation
Elevation
980.00
975.00
970.00
965.00
960.00
955.00
950.00
945.00
Date
Feb-03 May-03 Aug-03 Nov-03 Feb-04 May-04 Aug-04 Nov-04 Feb-05 May-05 Aug-05 Nov-05 Feb-06 May-06 Aug-06 Nov-06 Feb-07 May-07 Aug-07 Nov-07 Feb-08 May-08 Aug-08 Nov-08 Feb-09 May-09 Aug-09 Nov-09 Feb-10 May-10 Aug-10 Nov-10 Feb-11 May-11 Aug-11 Nov-11 Feb-12 May-12 Aug-12 Nov-12 Feb-13 May-13 Aug-13 Nov-13 Jan-14 May-14 Aug-14 Nov-14




APPENDIX E - ATTACHMENT A
EXHIBIT A.18
A.18-6

Wat Lev & Elev Tab - Well Info Burial Grds Excel file

| | | Date | DTW | Water Elev | TOC check | | (Not Labeled) | |
|---|---|---|---|---|---|---|---|---|
| | GW-290 | 2/21/1990 | 4.66 | 940.09 | 944.75 | max | 943.16 | |
| Deep | GW-290 | 4/9/1996 | 5.3 | 943.16 | 948.46 | min | 940.09 | Two Different TOCs listed in two different documents |
| | GW-290 | 10/7/1996 | 8.2 | 940.26 | 948.46 | | | Thus GS should be different also (cant find that documentation) ? |
| Sh | GW-291 | 4/9/1996 | 7.6 | 940.76 | 948.36 | max | 940.76 | |
| | GW-291 | 10/7/1996 | 11.6 | 936.76 | 948.36 | min | 934.86 | |
| | GW-291 | 4/4/1997 | 11.7 | 936.66 | 948.36 | | 15 | |
| | GW-291 | 10/10/1997 | 12.6 | 935.76 | 948.36 | | | |
| | GW-291 | 6/19/1998 | 11.59 | 936.77 | 948.36 | | | |
| | GW-291 | 7/28/1998 | 12.51 | 935.85 | 948.36 | | | |
| | GW-291 | 4/12/2000 | 10.3 | 938.26 | 948.56 | | | |
| | GW-291 | 9/21/2000 | 12.78 | 935.58 | 948.36 | | | |
| | GW-291 | 4/3/2001 | 10.84 | 937.72 | 948.56 | | | |
| | GW-291 | 9/26/2001 | 12.94 | 935.52 | 948.46 | | | |
| | GW-291 | 4/12/2002 | 11.85 | 936.71 | 948.56 | | | |
| | GW-291 | 9/30/2002 | 13.7 | 934.86 | 948.56 | | | |
| | GW-291 | 4/24/2003 | 11.23 | 937.43 | 948.66 | | | |
| | GW-291 | 9/8/2004 | 8.08 | 940.58 | 948.66 | | | |
| | GW-291 | 4/11/2005 | 11.14 | 937.52 | 948.66 | | | |

(D - S) upward Vert Grads

4/9/96 - $\frac{943.16 - 940.76}{27.1 - 11.2} = \frac{2.4}{15.9} = 0.15 \uparrow$ Spring

10/7/96 - $\frac{940.26 - 936.76}{15.9} = \frac{3.5}{15.9} = 0.22 \uparrow$ Fall

SI Fm

(S) GW-291 - 8.7-13.7 (5') - Overburden

(D) GW-290 - 22.1-32.1 - Maryville

| | | Date | DTW | Water Elev | TOC check | | | |
|---|---|---|---|---|---|---|---|---|
| Shallow | GW-249 | 2/16/1990 | 15.56 | 975.59 | 991.15 | max | 975.59 | |
| | GW-249 | 4/9/1996 | 29.1 | 962.05 | 991.15 | min | 953.25 | Dry |
| | GW-249 | 10/7/1996 | 37.1 | 954.05 | 991.15 | | | |
| | GW-249 | 4/4/1997 | 30.5 | 960.65 | 991.15 | | | |
| | GW-249 | 10/10/1997 | 37.8 | 953.35 | 991.15 | | | |
| | GW-249 | 4/12/2000 | 29.87 | 961.28 | 991.15 | | | |
| | GW-249 | 4/3/2001 | 34.05 | 957.1 | 991.15 | | | |
| | GW-249 | 9/26/2001 | 37.9 | 953.25 | 991.15 | | | |
| | GW-249 | 4/12/2002 | 31.71 | 959.44 | 991.15 | | | |
| | GW-249 | 4/24/2003 | 28.34 | 962.81 | 991.15 | | | |
| | GW-249 | 9/7/2004 | Dry | 953.52 | | | | |
| | GW-249 | 4/11/2005 | 32.93 | 958.22 | 991.15 | | | |
| Deep | GW-250 | 4/8/1988 | | 957.8 | | max | 972.9 | |
| | GW-250 | 6/30/1988 | | 957.3 | | min | 955.3 | |
| | GW-250 | 9/13/1988 | | 955.8 | | | | |
| | GW-250 | 11/17/1988 | | 955.3 | | | | |
| | GW-250 | 2/16/1990 | 18.35 | 972.9 | 991.25 | | | |
| | GW-250 | 4/9/1996 | 30.1 | 961.15 | 991.25 | | | |
| | GW-250 | 10/7/1996 | 35.7 | 955.55 | 991.25 | | | |

D - S

2/16/90 - $\frac{972.9 - 975.59}{56.5 - 32.5} = \frac{-2.69}{24} = -0.11$ Downward Grad ↓

4/9/96 - $\frac{961.15 - 962.05}{24} = \frac{-0.9}{24} = -0.04$ Downward Grad ↓

10/7/96 - $\frac{955.55 - 959.05}{24} = \frac{1.5}{24} = 0.06$ upward Grad ↑

S - GW-249 SI 29.9-35.1 (5') - Fm overburden

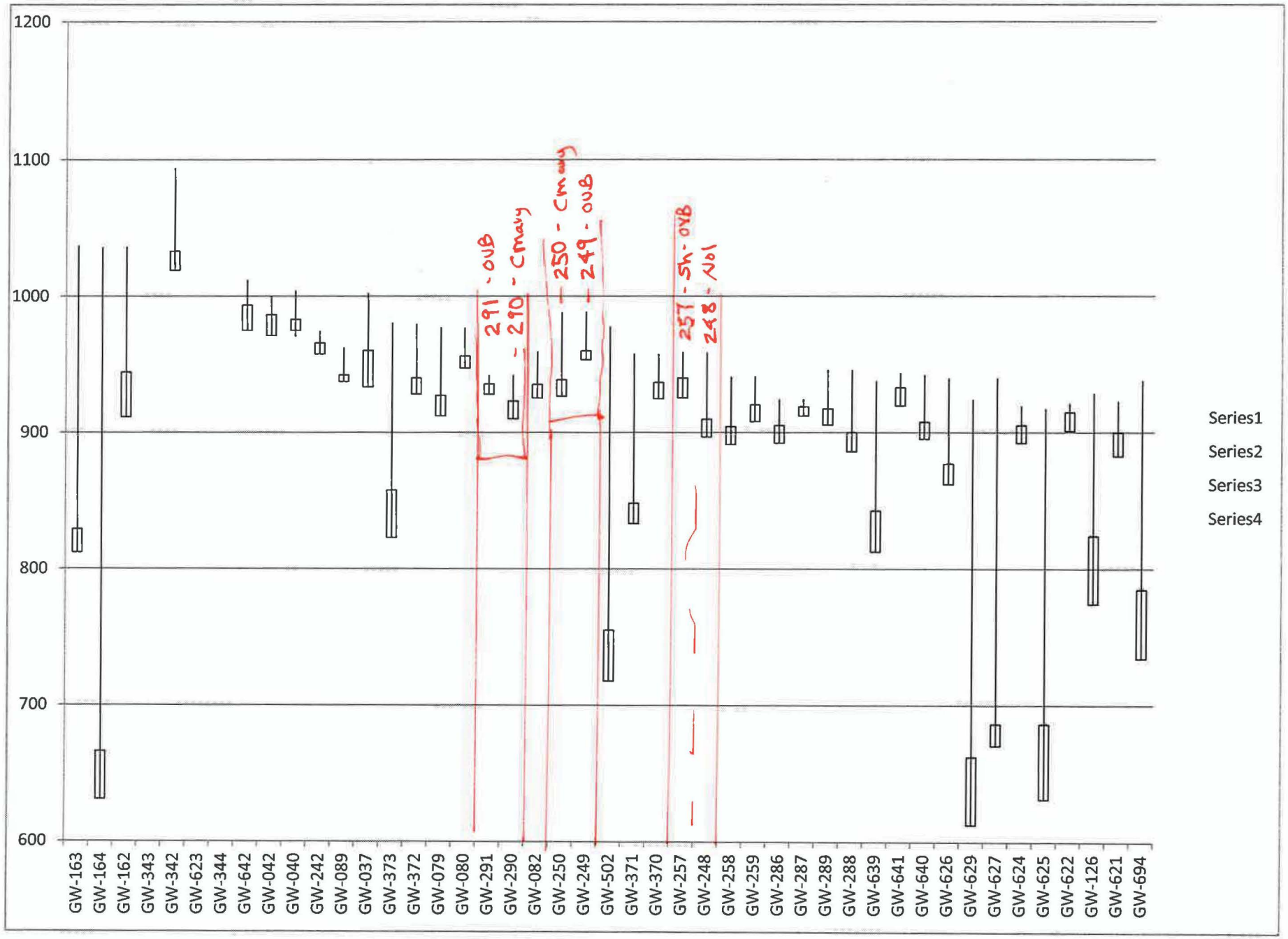
D - GW-250 51.3-61.7 (10') - Marysville

| Station | North | East | Surface Elevation | Measuring Point Elevation | Compendium Measuring Point Ele. (TOWW) | Formation Monitored | Top of Rock | Total Depth of Hole | Top of Screen | Bottom of Screen | Top of Filter Pack | Bottom of Filter Pack | Well Total Depth | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW-037 | 30685.33 | 43345.95 | 1002.32 | 1005.6 | | Crg | 39 | 70 | 64.5 | 66.5 | 42 | 68.7 | 67.8 | |
| GW-040 | 31111.21 | 43358.32 | 1004.11 | 1008.02 | | Cpv | 13 | 35 | 25.7 | 27.7 | 21 | 29 | 33.7 | |
| GW-042 | 31136.84 | 43938.32 | 999.95 | 1003.29 | | OVB | | 30 | 24.9 | 26.9 | 13.4 | 28.7 | 28.7 | |
| GW-079 | 30630 | 41616 | 977.2 | 980.5 | 981.2 | Crg | 26.5 | 65 | 59.9 | 64.9 | 49.9 | 64.9 | 65 | |
| GW-080 | 30624.04 | 41662.08 | 977.1 | 980.31 | 981 | Crg | 23.5 | 30 | 24.7 | 29.7 | 20.8 | 29.7 | 29.7 | |
| GW-082 | 30433.99 | 42090.24 | 960.52 | 962.49 | 964 | Cm | 23 | 35 | 29.4 | 34.4 | 24.1 | 34.1 | 34.4 | |
| GW-089 | 30924 | 43406 | 962.48 | 964.36 | | OVB | | 25 | 23 | 25 | 20 | 25 | 25 | |
| GW-126 | 29361.5 | 42678.7 | 929.02 | 932.06 | | Cn | 27 | 155 | 105 | 155 | - | - | 155 | open hole |
| GW-162 | 31328.05 | 44470.31 | 1036.4 | 1038.54 | | Cpv | 12 | 125 | 92 | 125 | - | - | 125 | open hole |
| GW-163 | 31334.18 | 44483.33 | 1037 | 1040 | | Cr | 12 | 225 | 208 | 225 | - | - | 225 | open hole |
| GW-164 | 31330.55 | 44480.86 | 1036 | 1038 | | Cr | 10 | 405 | 370 | 405 | - | - | 405 | open hole |
| GW-242 | 31004.38 | 43144.31 | 974.78 | 978.12 | 978.69 | Cl | | 17 | 10.6 | 17 | 9 | 17 | 17 | |
| GW-248 | 30142.73 | 43245.71 | 958.72 | 961.25 | | Cn | | 62 | 50.7 | 61.7 | 49.1 | 62 | 61.7 | |
| GW-249 | 30354.63 | 42747.63 | 988.62 | 991.15 | | OVB | | 35.1 | 29.9 | 35.1 | 28.5 | 35.1 | 35.1 | |
| GW-250 | 30367.81 | 42737.56 | 988.4 | 991.25 | | Cm | 33 | 61.7 | 51.3 | 61.7 | 49.5 | 61.7 | 61.7 | |
| GW-257 | 30147.6 | 43229.71 | 959.21 | 961.68 | 961.68 | OVB | | 33.7 | 23 | 33.7 | 19 | 33.7 | 33.7 | |
| GW-258 | 30021.98 | 43141.47 | 941.19 | 943.66 | | Cn | 32 | 50 | 38.6 | 49.3 | 37 | 50 | 49.3 | |
| GW-259 | 30014.68 | 43128.61 | 941.48 | 943.8 | 943.8 | OVB | | 33.5 | 22.3 | 33 | 21.1 | 33.5 | 33 | |
| GW-286 | 29993.36 | 42287.07 | 924.52 | 926.83 | 927.05 | Cn | 10 | 32.3 | 22 | 32 | 19.5 | 32.3 | 32 | |
| GW-287 | 29988.8 | 42288.43 | 924.6 | 926.87 | 927.04 | OVB | | 12.5 | 7.3 | 12.3 | 5.6 | 12.5 | 12.3 | |
| GW-288 | 29975.41 | 42874.4 | 946.07 | 948.36 | 948.36 | Cn | 42 | 60 | 49.1 | 59.1 | 46 | 60 | 59.1 | |
| GW-289 | 29981.56 | 42874.66 | 946.32 | 948.47 | 948.73 | Cl | | 40.6 | 30.6 | 40.6 | 28.9 | 40.8 | 40.6 | |
| GW-290 | 30444.92 | 42579.91 | 942.36 | 944.75 | | Cm | | 32.5 | 22.1 | 32.1 | 19.3 | 32.5 | 32.1 | |
| GW-291 | 30450.41 | 42582.81 | 944.53 | 948.36 | 948.66 | OVB | | 14.2 | 8.7 | 13.7 | 6.7 | 14.2 | 13.7 | |

| East | North | SE-Max WL | Max WL | Min WL | Number of Records | Surface Elevation (SE) | Station | Formation Monitored | |
|---|---|---|---|---|---|---|---|---|---|
| Bear Creek Burial Grounds | | | | | | | | | |
| 43345.95 | 30685.33 | | - | - | 0 | 1002.32 | GW-037 | Crg | Rogersville Shale |
| 43358.32 | 31111.21 | 7.64 | 996.47 | 984.9 | 14 | 1004.11 | GW-040 | Cpv | Pumpkin Valley |
| 43938.32 | 31136.84 | 14.95 | 985 | 977.1 | 10 | 999.95 | GW-042 | OVB | Overburden - shallow |
| 41616 | 30630 | 11.45 | 965.75 | 954.85 | 29 | 977.2 | GW-079 | Crg | Rogersville Shale |
| 41662.08 | 30624.4 | 14.69 | 962.41 | 954.46 | 35 | 977.1 | GW-080 | Crg | Rogersville Shale |
| 42090.24 | 30433.99 | 9.86 | 950.66 | 938.8 | 18 | 960.52 | GW-082 | Cm | Maryville Limestone |
| 43406 | 30924 | 0.42 | 962.06 | 957.26 | 2 | 962.48 | GW-089 | OVB | Overburden - shallow |
| 42678.7 | 29361.5 | 8.79 | 920.23 | 920.23 | 1 | 929.02 | GW-126 | Cn | Nolichucky Shale |
| 44470.31 | 31328.05 | 13.46 | 1022.94 | 1016.09 | 5 | 1036.4 | GW-162 | Cpv | Pumpkin Valley |
| 44483.33 | 31334.18 | | | | 0 | 1037 | GW-163 | Cr | Rome |
| 44480.86 | 31330.55 | | | | 0 | 1036 | GW-164 | Cr | Rome |
| 43144.31 | 31004.38 | -1.8 | 976.58 | 965.68 | 10 | 974.78 | GW-242 | Cl | Rutledge |
| 43245.71 | 30142.73 | 19.97 | 938.75 | 932.75 | 3 | 958.72 | GW-248 | Cn | Nolichucky Shale |
| 42747.63 | 30354.63 | 13.03 | 975.59 | 953.25 | 12 | 988.62 | GW-249 | OVB | Overburden - shallow |
| 42737.56 | 30367.81 | 15.5 | 972.9 | 955.3 | 7 | 988.4 | GW-250 | Cm | Maryville Limestone |
| 43229.71 | 30147.6 | 20.03 | 939.18 | 931.38 | 13 | 959.21 | GW-257 | OVB | Overburden - shallow |
| 43141.47 | 30021.98 | 2.7 | 938.49 | 938.49 | 1 | 941.19 | GW-258 | Cn | Nolichucky Shale |
| 43128.61 | 30014.68 | 5.08 | 936.4 | 936.4 | 1 | 941.48 | GW-259 | OVB | Overburden - shallow |
| 42287.07 | 29993.36 | 6.49 | 918.03 | 915.82 | 12 | 924.52 | GW-286 | Cn | Nolichucky Shale |
| 42288.43 | 29988.8 | 3.39 | 921.21 | 916.6 | 26 | 924.6 | GW-287 | OVB | Overburden - shallow |
| 42874.4 | 29975.41 | 5.88 | 940.19 | 926.47 | 8 | 946.07 | GW-288 | Cn | Nolichucky Shale |
| 42874.66 | 29981.56 | 1.9 | 944.42 | 926.22 | 21 | 946.32 | GW-289 | Cl | Rutledge |
| 42579.91 | 30444.92 | -0.8 | 943.16 | 940.09 | 3 | 942.36 | GW-290 | Cm | Maryville Limestone |
| 42582.81 | 30450.41 | 3.77 | 940.76 | 934.86 | 15 | 944.53 | GW-291 | OVB | Overburden - shallow |
| 42597.02 | 31320.37 | -0.49 | 1094.49 | 1069.2 | 3 | 1094 | GW-342 | Cpv | Pumpkin Valley |
| 44988.5 | 30240.77 | 4.3 | 953.64 | 941.14 | 19 | 957.94 | GW-370 | Cm | Maryville Limestone |
| 45035.53 | 30245.39 | 11.31 | 946.82 | 939.83 | 9 | 958.13 | GW-371 | Cm | Maryville Limestone |
| 45256.97 | 30672.53 | 5.59 | 974.28 | 943.99 | 20 | 979.87 | GW-372 | Cm | Maryville Limestone |
| 45271.21 | 30679.17 | 12.78 | 967.97 | 960.05 | 11 | 980.75 | GW-373 | Cm | Maryville Limestone |
| 43112.87 | 30269.49 | | | | 0 | 977.77 | GW-502 | Cm | Maryville Limestone |
| 45032.91 | 29023.3 | 6.19 | 916.88 | 904.44 | 19 | 923.07 | GW-621 | | |
| 44115.9 | 29367.74 | 3.98 | 917.56 | 908.06 | 14 | 921.54 | GW-622 | OVB | Overburden - shallow |
| 44137.84 | 29388.47 | -0.1 | 922.11 | 920.01 | 2 | 922.01 | GW-623 | Cn | Nolichucky Shale |
| 43007.38 | 29421.33 | 2.56 | 916.96 | 908.74 | 15 | 919.52 | GW-624 | OVB | Overburden - shallow |
| 43009.03 | 29398.45 | | | | 0 | 917.67 | GW-625 | | |
| 42772.01 | 29535.32 | 17.02 | 922.93 | 914.07 | 15 | 939.95 | GW-626 | | |
| 42774.1 | 29505.05 | 19.49 | 920.9 | 917.75 | 9 | 940.39 | GW-627 | | |
| 43046.5 | 29521.85 | 1.19 | 923.23 | 921.18 | 5 | 924.42 | GW-629 | Cn | Nolichucky Shale |
| 45259.76 | 29926.12 | 7.39 | 930.59 | 927.45 | 4 | 937.98 | GW-639 | Cn | Nolichucky Shale |
| 45252.92 | 29670.1 | 10.81 | 931.78 | 923.16 | 6 | 942.59 | GW-640 | Cn | Nolichucky Shale |
| 45250.72 | 29685.73 | 12.05 | 931.96 | 924.66 | 17 | 944.01 | GW-641 | OVB | Overburden - shallow |
| 44654.05 | 31215.27 | 14.41 | 997.52 | 991.4 | 19 | 1011.93 | GW-642 | Crg | Rogersville Shale |
| 44893.28 | 28844.77 | 18.7 | 919.88 | 892.7 | 8 | 938.58 | GW-694 | Cmn | Maynardville |
| 42907.49 | 31403.07 | | | | 0 | | GW-655 | | |
| 42597.28 | 31320.53 | | | | 0 | | GW-343 | | Rome |
| 42583.85 | 31313.16 | | | | 0 | | GW-344 | | Rome |
| EMWMF | | | | | | | | | |
| 46872 | 29961 | 0.45 | 954.95 | 948.69 | 77 | 955.4 | GW-363 | | Nolichucky |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 45260 | 29626 | 6.1 | 931.9 | 928.04 | 23 | 938 | GW-639 | | Nolichucky |
| 48276 | 31186 | 1.06 | 998.94 | 993.41 | 79 | 1000 | GW-916 | | Rogersville Shale |
| 47914 | 30463 | 13 | 981 | 971.27 | 82 | 994 | GW-917 | | Maryville |
| 47549 | 31672 | -1.64 | 1066.64 | 1058.96 | 76 | 1065 | GW-918 | | Pumpkin Valley |
| 47375 | 30193 | 2.69 | 962.31 | 956.5 | 80 | 965 | GW-920 | | Nolichucky |
| 47139 | 30350 | 1.07 | 966.93 | 960.49 | 79 | 968 | GW-921 | | Maryville |
| 47147 | 30024 | 2.36 | 952.64 | 950.99 | 79 | 955 | GW-922 | | Nolichucky |
| 48184 | 30822 | 16.21 | 996.79 | 982.4 | 60 | 1013 | GW-923 | | |
| 46300 | 30185 | 0.76 | 965.24 | 953.45 | 78 | 966 | GW-924 | | Nolichucky |
| 47128 | 30349 | -3.04 | 971.04 | 954.78 | 78 | 968 | GW-925 | | Maryville |
| 46290 | 30185 | 3.03 | 962.97 | 956.9 | 78 | 966 | GW-926 | | Nolichucky |
| 47906 | 30463 | 7.66 | 986.34 | 974.02 | 78 | 994 | GW-927 | | Maryville |
| 47426 | 31374 | 0.88 | 1048.82 | 1043.02 | 15 | 1049.7 | GW-935 | | |
| 46663 | 31075 | 20.91 | 982.09 | 981.35 | 2 | 1003 | GW-938 | | |
| 46941 | 30726 | 14.01 | 985.29 | 982.96 | 2 | 999.3 | GW-940 | | |
| 46610 | 30458 | 11.39 | 975.41 | 973.09 | 2 | 986.8 | GW-941 | | |
| 46235 | 30509 | 10.32 | 961.08 | 958.7 | 2 | 971.4 | GW-942 | | |
| 46300 | 30719 | 7.41 | 970.29 | 968.46 | 2 | 977.7 | GW-943 | | |
| 47431 | 31374 | 0.1 | 1050 | 1039.7 | 15 | 1050.1 | GW-946 | | |
| 47694 | 31406 | 0.66 | 1053.74 | 1038.24 | 15 | 1054.4 | GW-947 | | |
| 47911 | 31431 | -0.78 | 1059.68 | 1046.82 | 15 | 1058.9 | GW-948 | | |
| 48089 | 31194 | 48.39 | 1002.81 | 1001.2 | 14 | 1051.2 | GW-949 | | |
| 47561 | 31395 | -0.51 | 1051.41 | 1037.09 | 15 | 1050.9 | GW-950 | | |
| 47577 | 30585 | 42.08 | 972.82 | 968.91 | 15 | 1014.9 | GW-951 | | |
| 47775 | 30604 | 31.11 | 988.59 | 981.43 | 15 | 1019.7 | GW-952 | | |
| 46613 | 30649 | 11.01 | 983.69 | 982.56 | 2 | 994.7 | GW-953 | | |
| 46092 | 30347 | 8.81 | 952.27 | 949.65 | 21 | 961.08 | GW-961 | | |
| 46606 | 30282 | 9.92 | 965.88 | 961.15 | 12 | 975.8 | GW-964 | | |
| 46612 | 30282 | 9.23 | 966.68 | 961.91 | 12 | 975.91 | GW-965 | | |

Red numbers denotes ~~above~~ Groundwater above Surface Elevation
Blue numbers denotes Groundwater within 5 feet of Surface Elevation
Green Shading - Identified by Andy Binford to monitor the east side of EMWMF
Orange Shading - Identified by Andy Binford as possible targets to look west of EMWMF


1200
1100
1000
900
800
700
600
291 - OUB
290 - Cmary
250 - Cmary
249 - OUB
257 - SH-OYB
248 - NOI
GW-163
GW-164
GW-162
GW-343
GW-342
GW-623
GW-344
GW-642
GW-042
GW-040
GW-242
GW-089
GW-037
GW-373
GW-372
GW-079
GW-080
GW-291
GW-290
GW-082
GW-250
GW-249
GW-502
GW-371
GW-370
GW-257
GW-248
GW-258
GW-259
GW-286
GW-287
GW-289
GW-288
GW-639
GW-641
GW-640
GW-626
GW-629
GW-627
GW-624
GW-625
GW-622
GW-126
GW-621
GW-694
Series1
Series2
Series3
Series4

This page intentionally left blank.

# EXHIBIT A.19:
# SUMMARY DESCRIPTIONS AND GEOTECHNICAL LABORATORY TEST RESULTS FOR OGDEN SITES B AND C AND THE EMWMF

This page intentionally left blank.

**Pro2Serve Summary of Results of Geotechnical Laboratory Tests from Sites Adjacent to the EMDF**

A considerable amount of geotechnical test data is available from sites directly adjacent to the EMDF footprint. Because the data were collected from boring locations and test pits directly along geologic strike with the same formations outcropping across the EMDF footprint, they are directly relevant to current and future planning and investigations at the EMDF. These results are summarized below along with data summary tables of geotechnical laboratory results and relevant maps and cross sections. The results from these investigations are reviewed in the following two subsections for their relevance to the EMDF site. The data were collected from boring locations and test pits directly along geologic strike with the same formations outcropping across the EMDF footprint. Among other investigation locations near the EMDF, Figure 7 in the Phase I EMDF Report shows the locations of the 79 Ogden Site B and C soil borings designated as B-1 through B-27, and C-1 through C-52, respectively, and ten test pit locations TP-11A through TP-20 at the EMWMF footprint. Results of the investigations, including detailed boring/test pit logs, cross sections, results of extensive laboratory testing, interpretations, conclusions, and recommendations are provided in reports by Ogden and CH2MHill (Ogden 1993a/b, and CH2MHill 2000). A detailed review of the original source documents is encouraged for planning Phase II investigations at the proposed EMDF site. The Site C investigation results were in fact used in the detailed design of the EMWMF and Site C and Site B results are applicable to the EMDF design. Review of these documents is encouraged for details that are relevant to subsurface conditions anticipated at the proposed EMDF site. The geotechnical engineering data are particularly relevant to properly planning for future more detailed investigations at the EMDF site, for potential use in a more detailed EMDF design, and to avoid unnecessary duplication of effort and costs.

**Geotechnical Data - Ogden Sites B and C Investigations**

The following bullets summarize noteworthy components of the Ogden investigations relevant to the EMDF Phase I investigation and possible future EMDF investigations. The Odgen investigations and reports included:

- A total of 79 soil borings on a 200 ft grid spacing located within the outrcrop belts of the same geologic formations at the EMDF [Site B - 27 soil borings (6 with rock coring and 4 piezometers), plus 15 pre-existing monitoring wells; Site C - 52 soil borings (11 with rock coring and 9 piezometers) – See locations and geologic formation contacts shown in Figure 7]
- Detailed boring logs and log profiles with Northwest/southeast trending cross sections to illustrate subsurface conditions at all boring locations
- Borings located mostly in upland areas – none targeted specifically in NT valleys for characterization of alluvial/floodplain materials & depths
- Standard penetration test (SPT) sampling at 5ft intervals to auger refusal or ~20 ft bgs
- Selected boring locations with rock coring up to 50-60 ft into bedrock to total boring depths of 100-110 feet bgs [Most deeper borings and rock coring were higher up on site slopes - mostly in the outcrop belts of the Rome and Pumpkin Valley]
- Geotechnical log descriptions (per ASTM/Unified Soil Classification system (USCS), N values/blow counts, etc.)

Ogden collected disturbed SPT drive samples, undisturbed Shelby Tube samples, and bulk (bag) samples from auger cuttings (collected from 10 ft subsurface intervals). Laboratory analysis was conducted on mostly clay soils and highly weathered shales (with minor sand/sandstone). The testing was conducted according to conventional ASTM methods for geotechnical engineering index properties and included:

- Natural Moisture Content
- Unit Weight
- Specific Gravity
- Atterberg Limits [Liquid limit/plastic limit, and plasticity index]
- Visual classification (per USCS)
- Grain Size/Particle Size Analysis

Additional laboratory testing on a more limited set of samples included:

- Consolidation Tests
- Proctor Tests (compaction tests)
- Shear Strength Tests
  - Unconfined compressive strength tests
  - Unconsolidated-undrained triaxial compression tests
  - For Site C only – Unconfined compressive strength tests on 5 rock core samples (4in), from shale (3), siltstone (1), and sandstone (1)
  - Slake-durability Tests (on four bedrock cores – to evaluate weathering of shales used for engineering fill)

In-place density tests (two at Site B and one at Site C) were also conducted from weathered bedrock bulldozer trenches on exposed material. The results of the laboratory testing for Ogden Sites B and C are provided in Exhibit A.17. The reports by Ogden should be referenced for additional details, interpretations, and conclusions (Ogden 1993 a/b), particularly with regard to EMDF Phase II planning.

**Geotechnical Data - Other EMWMF Subsurface Investigations**

As noted above, the Ogden Site C investigation inadvertently provided data for the EMWMF design even though it was originally intended to support design for a planned above-ground waste storage facility. Other investigations completed in support of the EMWMF are summarized below with relevance to likely subsurface conditions at the EMDF site.

In addition to the Site B and Site C data, geotechnical laboratory testing was conducted on vadose zone soils and saprolite samples from test pits to provide design data for the EMWMF (CH2MHill 2000). The samples were collected from ten test pits located across the EMWMF footprint excavated to depths of 15-17 ft bgs. The pits were located within the outcrop belts of the Rutledge, Rogersville, and Maryville formations (see locations on Figure 7). Other than one location that encountered hard limestone at bottom (TP-19), the subsurface materials from these test pits were all logged as clayey residuum and weathered/fractured shale (saprolite). Geotechnical laboratory testing included:

- Visual classification (per USCS)
- Natural Moisture Content
- Grain Size/Particle Size Analysis
- Atterberg Limits
- Moisture-Density
- Specific Gravity
- Permeability
- Triaxial Strength
- Consolidation

Laboratory testing also included determination of distribution coefficients ($K_d$) for Uranium and Lead (per EPA 530-SW-87-006-F batch equilibrium method) based on samples of weathered shale (saprolite) at four locations across the EMWMF footprint. The results of the permeability tests at 5 psi (per ASTM method D5084) using soils from two of the tests pits were within the same order of magnitude as the Phase I permeability tests ($K = 2.9 \times 10^{-6}$ and $1.8 \times 10^{-7}$ cm/sec from TP-12 and TP-16, respectively). Results of the lab testing of test pit samples are summarized in the tables in Exhibit A.17. The original report (CH2MHill 2000) should be referenced for additional details.

Most other subsurface investigations at the EMWMF were primarily focused on monitoring well/piezometer installations and ground water data and did not involve geotechnical laboratory testing. Results from those investigations provide additional data on subsurface conditions at the EMWMF along strike with the EMDF, but the data vary depending on the drilling methods and subsurface sampling practices employed (e.g. – whether split tube sampling and hollow stem auger drilling were used, or air rotary drilling with logging of fine cuttings, vs rock coring).

# APPENDIX III

# LABORATORY TEST DATA
# SUMMARY SHEETS AND TEST RESULTS

Geotechnical Study
ORR Storage Facility - Site "B"
Y-12 Plant
Oak Ridge, Tennessee
Ogden File No. 0-4267-0056-0200

OGDEN

# SUMMARY OF LABORATORY TEST RESULTS

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site B<br>Project Number: 0-4267-0056-0200<br>Date: March 9, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| B1 | 2 | SS | 5.0 - 6.5 | 28.2 | | | 2.69 | 45 | 31 | CL | S | SHALE, weathered tan to reddish-brown |
| B2 | 1 | ST | 2.0 - 3.0 | 21.1 | 118.7 | 98.0 | 2.72 | 45 | 32 | CL | S,U,C | CLAY, sandy, tan mottled reddish-brown and gray |
| B2 | 2 | ST | 8.0 - 9.5 | 25.7 | 113.6 | 90.4 | 2.69 | 37 | 25 | CL | S,U | CLAY, silty, brown mottled reddish-brown |
| B4 | 1 | ST | 2.0 - 4.0 | 22.4 | 125.5 | 102.5 | 2.65 | 53 | 34 | CH | S,T | CLAY, silty, tan to reddish-brown |
| B5 | 1 | SS | 0.0 - 1.5 | 21.0 | | | 2.68 | 43 | 25 | SC | S | SHALE, weathered, tan mottled black |
| B6 | 1 | B | 0.0 - 10.0 | 8.5 | | | 2.66 | 37 | 23 | SC | S,P | SHALE, weathered tan |
| B7 | 1 | ST | 2.0 - 3.7 | 23.2 | 117.6 | 95.5 | 2.69 | 49 | 30 | CL | S,T | CLAY, silty, reddish-brown mottled tan with weathered shale |
| B8 | 2 | SS | 5.0 - 6.5 | 18.6 | | | 2.66 | 38 | 24 | SC | S | SHALE, weathered, brown |
| B9 | 1 | ST | 2.0 - 3.5 | 17.6 | 122.6 | 104.3 | 2.69 | 55 | 34 | SC | S,U | SHALE, weathered, brown to gray mottled reddish-brown |
| B10 | 1 | SS | 0.0 - 1.5 | 18.6 | | | 2.66 | 30 | 20 | SC | S | CLAY, silty, sandy, brown with rock fragments and roots |
| B11 | 2 | SS | 5.0 - 6.5 | 26.2 | | | 2.65 | 48 | 31 | CL | S | CLAY, silty, brown with weathered shale |
| B12 | 2 | SS | 5.0 - 6.5 | 15.6 | | | 2.69 | 43 | 24 | SC | S | SHALE, weathered, tan, gray and reddish-brown |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
P-PROCTOR TEST
S-SIEVE OR GRAIN SIZE ANALYSIS
D-DIRECT SHEAR TEST
U-UNCONFINED COMPRESSION TEST
T-TRIAXIAL TEST
CBR-CALIFORNIA BEARING RATIO

DATA CHECKED BY DR

GA Technical Services

# SUMMARY OF LABORATORY TEST RESULTS

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site B<br>Project Number: 0-4267-0056-0200<br>Date: March 9, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| B13 | 1 | ST | 2.0 - 4.0 | 17.0 | 133.5 | 114.1 | 2.66 | 27 | 17 | SC | S | CLAY, silty, sandy, brown mottled reddish-brown with weathered shale |
| B14 | 3 | SS | 10.0 - 11.5 | 21.0 | | | 2.72 | 33 | 24 | CL | S | CLAY, sandy, reddish-brown to brown mottled gray with sandstone fragment |
| B15 | 1 | ST | 2.0 - 4.0 | 20.6 | 135.6 | 112.4 | 2.70 | 41 | 26 | CL | S,U,C | CLAY, silty, brown with small rock fragments |
| B16 | 1 | B | 10.0 - 20.0 | 14.1 | | | 2.68 | 43 | 29 | CL | S | SHALE, weathered, brown |
| B17 | 1 | SS | 0.0 - 1.5 | 18.1 | | | 2.70 | | | SC - SM | S | CLAY, silty, brown with rock fragments |
| B18 | 1 | SS | 0.0 - 1.5 | 22.3 | | | 2.67 | 38 | 25 | CL | S | CLAY, silty, brown with small rock fragments |
| B19 | 1 | ST | 3.0 - 4.0 | 19.3 | 128.6 | 107.8 | 2.69 | 31 | 16 | SC | S,U | CLAY, sandy, reddish-brown mottled yellow with weathered shale and sandstone fragment |
| B19 | 1 | B | 20.0 - 30.0 | 10.2 | | | 2.72 | 33 | 24 | SC | S,P,C,T,CBR | SHALE, weathered tan to gray |
| B20 | 2 | SS | 5.0 - 6.5 | 18.4 | | | 2.72 | 36 | 22 | SC | S | CLAY, silty, brown with sandstone fragments and weathered shale |
| B21 | 1 | ST | 2.0 - 4.0 | 27.2 | 123.4 | 97.0 | 2.66 | 58 | 39 | CH | S,U | CLAY, silty, reddish-brown with weathered shale |
| B22 | 1 | ST | 1.5 - 3.0 | 17.8 | | | 2.67 | 28 | 18 | SC | S | SHALE, and sandstone, weathered brown mottled tan |
| B23 | 2 | SS | 5.0 - 6.5 | 15.5 | | | 2.66 | 35 | 19 | SC | S | SAND, clayey, tan mottled reddish-brown with weathered sandstone |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
S-SIEVE OR GRAIN SIZE ANALYSIS
U-UNCONFINED COMPRESSION TEST
CBR-CALIFORNIA BEARING RATIO
P-PROCTOR TEST
D-DIRECT SHEAR TEST
T-TRIAXIAL TEST

DATA CHECKED BY

GA Technical Services

# SUMMARY OF LABORATORY TEST RESULTS

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site B<br>Project Number: 0-4267-0056-0200<br>Date: March 9, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| B24 | 1 | ST | 2.0 - 4.0 | 21.5 | 107.8 | 88.7 | | | | | | SHALE, weathered, clayey brown |
| B24 | 1 | B | 10.0 - 20.0 | 15.7 | | | 2.66 | 49 | 34 | GC | S,P,C,CBR | SHALE, weathered brown |
| B25 | 1 | B | 20.0 - 30.0 | 10.0 | | | 2.72 | 31 | 22 | SC | S | SHALE, weathered, tan to gray |
| B26 | 2 | SS | 5.3 - 6.8 | 12.7 | | | 2.62 | 27 | 16 | GC | S | SANDSTONE, weathered, tan to reddish-brown |
| B27 | 1 | ST | 2.0 - 4.0 | 16.8 | 121.2 | 103.8 | 2.69 | | | | T | CLAY, sandy, reddish-brown with sandstone fragments |
| B27 | 2 | ST | 15.0 - 16.5 | 18.0 | 120.8 | 102.3 | 2.68 | 47 | 31 | SC | S | CLAY, sandy, reddish-brown with sandstone fragments |
| B27 | 1 | B | 10.0 - 20.0 | 11.6 | | | 2.65 | 37 | 25 | CL | S,P,C,CBR | CLAY, sandy, reddish-brown with sandstone fragments |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
P-PROCTOR TEST
S-SIEVE OR GRAIN SIZE ANALYSIS
D-DIRECT SHEAR TEST
U-UNCONFINED COMPRESSION TEST
T-TRIAXIAL TEST
CBR-CALIFORNIA BEARING RATIO

DATA CHECKED BY

GA Technical Services

# APPENDIX III

## LABORATORY TEST DATA
## SUMMARY SHEETS AND TEST RESULTS

Geotechnical Study
ORR Storage Facility, Site "C"
Y-12 Plant
Oak Ridge, Tennessee
Ogden File No. 0-4267-0056-0100

OGDEN

# SUMMARY OF LABORATORY TEST RESULTS

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site C<br>Project Number: 0-4267-0056-0100<br>Date: March 3, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| C-1 | 3 | SS | 10.0 - 11.5 | 25.1 | | | 2.67 | 57 | 34 | CH | S | SHALE, weathered, reddish-brown mottled tan |
| C-1 | 1 | B | 0.0 - 10.0 | 17.0 | | | 2.70 | 68 | 49 | CH | S | CLAY, silty, brown and reddish-brown |
| C-3 | 3 | SS | 10.0 - 10.8 | 16.0 | | | 2.69 | 39 | 19 | SC | S | SHALE, weathered, tan mottled gray |
| C-4 | 2 | SS | 5.0 - 6.5 | 23.5 | | | 2.69 | 44 | 22 | SC | S | SHALE, weathered, tan, gray and brown |
| C-9 | 1 | B | 0.0 - 10.0 | 19.8 | | | 2.69 | 64 | 33 | CH | S,P | CLAY, silty, reddish-brown |
| C-9 | 1 | ST | 2.0 - 4.0 | 22.0 | 124.6 | 102.1 | | | | | | CLAY, silty, brown and reddish-brown with weathered shale fragments |
| C-10 | 1 | ST | 5.0 - 7.0 | 14.9 | | | 2.66 | 35 | 21 | SC | S,C,U | CLAY, silty, reddish-brown with weathered shale fragments |
| C-13 | 1 | ST | 2.0 - 4.0 | 18.5 | | | 2.68 | 38 | 22 | CL | S,C,U | CLAY, silty, reddish-brown with weathered shale fragments |
| C-17 | 1 | B | 5.0 - 15.0 | 15.8 | | | 2.69 | 37 | 21 | CL | S | CLAY, silty, dark brown |
| C-17 | 3 | SS | 10.0 - 11.5 | 13.9 | | | 2.68 | 37 | 21 | SC | S | SANDSTONE, clayey, tan to gray |
| C-19 | 1 | B | 0.0 - 10.0 | 18.2 | | | 2.71 | 47 | 28 | CL | S,P | CLAY, silty, light tan |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
P-PROCTOR TEST
S-SIEVE OR GRAIN SIZE ANALYSIS
D-DIRECT SHEAR TEST
U-UNCONFINED COMPRESSION TEST
T-TRIAXIAL TEST
CBR-CALIFORNIA BEARING RATIO

DATA CHECKED BY

GA Technical Services

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site C<br>Project Number: 0-4267-0056-0100<br>Date: March 3, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| C-20 | 1 | ST | 2.0 - 3.5 | 26.1 | 115.0 | 91.2 | 2.70 | 45 | 28 | CL | S,U | CLAY, silty, brown and reddish-brown with weathered shale fragments |
| C-21 | 3 | SS | 10.0 - 11.5 | 19.8 | | | 2.65 | 38 | 26 | CL | S | CLAY, silty, reddish-brown, mottled gray with sandstone fragments |
| C-22 | 1 | ST | 1.5 - 3.5 | 20.5 | 109.8 | 91.1 | | | | | | CLAY, silty, brown and dark brown with weathered shale fragments and roots |
| C-22 | 2 | SS | 5.0 - 6.5 | 19.2 | | | 2.65 | 38 | 16 | CL | S | SHALE, weathered, tan mottled black and reddish-brown |
| C-23 | 3 | SS | 10.0 - 11.5 | 15.5 | | | 2.70 | 45 | 23 | CL | S | SHALE, weathered, tan to gray |
| C-25 | 1 | B | 0.0 - 15.0 | 20.2 | | | 2.69 | 48 | 27 | CL | S | CLAY, silty, dark brown |
| C-28 | 2 | SS | 5.0 - 6.5 | 20.1 | | | 2.70 | 54 | 31 | CH | S | CLAY, very sandy, gray and tan with sandstone fragments |
| C-29 | 2 | SS | 4.0 - 5.5 | 17.5 | | | 2.68 | 42 | 29 | SC | S | CLAY, silty, tan to reddish-brown with chert fragments |
| C-30 | 2 | SS | 5.0 - 6.5 | 23.0 | | | 2.67 | 44 | 31 | CL | S | CLAY, silty, tan |
| C-32 | 1 | SS | 0.0 - 1.5 | 29.4 | | | 2.69 | 36 | 13 | CL | S | CLAY, silty, brown with small rock fragments |
| C-32 | 2 | ST | 5.0 - 6.6 | 16.1 | 126.5 | 109.0 | | | | | | SHALE, weathered, brown, gray and black |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
P-PROCTOR TEST
S-SIEVE OR GRAIN SIZE ANALYSIS
D-DIRECT SHEAR TEST
U-UNCONFINED COMPRESSION TEST
T-TRIAXIAL TEST
CBR-CALIFORNIA BEARING RATIO

DATA CHECKED BY

GA Technical Services

# SUMMARY OF LABORATORY TEST RESULTS

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site C<br>Project Number: 0-4267-0056-0100<br>Date: March 3, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| C-33 | 1 | B | 10.0 - 20.0 | 9.6 | | | 2.66 | 39 | 26 | CL | S | CLAY, silty, dark brown and reddish-brown |
| C-33 | 2 | SS | 5.0 - 5.8 | 16.7 | | | 2.68 | 39 | 23 | CL | S | SHALE, weathered, sandy, tan to reddish-brown |
| C-36 | 1 | ST | 2.0 - 4.0 | ~~26.3~~ 23.6 | 112.6 | 89.0 | 2.70 | 54 | 31 | CH | S,C,U | CLAY, brown and reddish-brown mottled dark brown with weathered shale fragments |
| C-37 | 1 | ST | 0.0 - 2.0 | 14.8 | 115.0 | 100.2 | | | | | | CLAY, silty, brown and reddish-brown with weathered shale fragments |
| C-37 | 1 | SS | 5.0 - 6.5 | 17.3 | | | 2.71 | 30 | 20 | CL | S | CLAY, silty, sandy, tan to reddish-brown mottled gray with sandstone fragments |
| C-40 | 2 | SS | 5.5 - 7.0 | 16.5 | | | 2.71 | 37 | 25 | SC | S | SHALE, weathered tan mottled gray |
| C-40 | 1 | B | 10.0 - 25.0 | 10.2 | | | 2.68 | 33 | 21 | CL | S,P, CBR | CLAY, silty, brown and dark brown |
| C-40 | 6 | SS | 25.0 - 26.5 | 11.2 | | | 2.70 | 33 | 15 | GC | S | SHALE, weathered, tan mottled brown |
| C-41 | 1 | ST | 0.0 - 2.0 | 22.3 | 113.6 | 92.9 | | | | | | CLAY, silty, reddish-brown mottled tan and gray with weathered sandstone |
| C-41 | 1 | SS | 2.0 - 3.5 | 15.1 | | | 2.69 | 36 | 26 | CL | S | CLAY, silty, reddish-brown mottled tan |
| C-42 | 1 | ST | 0.0 - 2.0 | 15.2 | 116.8 | 101.4 | | | | | | CLAY, silty, brown and reddish-brown with roots and weathered shale fragments |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
S-SIEVE OR GRAIN SIZE ANALYSIS
U-UNCONFINED COMPRESSION TEST
CBR-CALIFORNIA BEARING RATIO
P-PROCTOR TEST
D-DIRECT SHEAR TEST
T-TRIAXIAL TEST

DATA CHECKED BY

GA Technical Services

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site C<br>Project Number: 0-4267-0056-0100<br>Date: March 3, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| C-42 | 2 | SS | 7.0 - 8.5 | 17.6 | | | 2.68 | 39 | 26 | SC | S | CLAY, very sandy, brown with sandstone fragments |
| C-42 | 1 | B | 20.0 - 30.0 | 12.6 | | | 2.65 | 36 | 24 | SC | S | SHALE, weathered, brown and reddish-brown |
| C-42 | 2 | ST | 5.0 - 7.0 | 20.2 | 120.2 | 100.0 | | | | | | CLAY, silty, brown and reddish-brown with weathered shale fragments |
| C-43 | 2 | SS | 5.0 - 6.3 | 23.4 | | | 2.69 | 28 | 17 | SC | S | SANDSTONE, weathered tan to dark brown |
| C-43 | 4 | SS | 15.0 - 16.2 | 14.1 | | | 2.67 | 30 | 15 | SC | S | SHALE, weathered maroon |
| C-44 | 1 | B | 10.0 - 20.0 | 19.2 | | | 2.68 | 35 | 21 | CL | S | CLAY, silty, dark brown |
| C-44 | 5 | SS | 20.0 - 21.3 | 17.8 | | | 2.69 | 32 | 21 | SC | S | SHALE, weathered, clayey, brown mottled reddish-brown |
| C-45 | 1 | ST | 0.0 - 2.0 | 24.1 | 118.3 | 95.7 | 2.68 | 49 | 32 | SC | S,T | CLAY, silty, brown and reddish-brown with weathered shale fragments |
| C-45 | 1 | B | 10.0 - 20.0 | 18.7 | | | 2.70 | 46 | 32 | CL | S | CLAY, silty, brown |
| C-45 | 4 | SS | 15.0 - 16.5 | 11.0 | | | 2.67 | 32 | 20 | SC | S | SHALE, weathered, tan to brown mottled gray |
| C-45 | 5 | SS | 20.0 - 20.9 | 11.4 | | | 2.65 | 27 | 18 | SC | S | SHALE, weathered, clayey, tan to brown |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
P-PROCTOR TEST
S-SIEVE OR GRAIN SIZE ANALYSIS
D-DIRECT SHEAR TEST
U-UNCONFINED COMPRESSION TEST
T-TRIAXIAL TEST
CBR-CALIFORNIA BEARING RATIO

DATA CHECKED BY

GA Technical Services

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site C<br>Project Number: 0-4267-0056-0100<br>Date: March 3, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| C-46 | 2 | SS | 5.0 - 6.5 | 15.2 | | | 2.69 | 21 | 14 | SC | S | SANDSTONE, weathered, clayey, tan |
| C-46 | 4 | SS | 15.0 - 16.5 | 19.9 | | | 2.69 | 34 | 13 | CL | S | SANDSTONE, weathered, dark brown to reddish-brown |
| C-47 | 2 | SS | 5.0 - 6.5 | 12.9 | | | 2.72 | 33 | 16 | SC | S | SANDSTONE, weathered, reddish-brown mottled white |
| C-47 | 1 | B | 20.0 - 30.0 | 18.2 | | | 2.67 | 44 | 26 | CL | S,P | CLAY, silty, brown |
| C-47 | 10 | SS | 45.0 - 45.8 | 13.8 | | | 2.66 | 29 | 14 | CL | S | SANDSTONE, weathered, tan to gray |
| C-47 | 2 | B | 60.0 - 65.0 | 16.0 | | | 2.67 | 39 | 22 | CL | S | CLAY, silty, dark brown |
| C-48 | 4 | SS | 15.0 - 16.5 | 12.1 | | | 2.66 | 30 | 15 | SC | S | SHALE, weathered, sandy, brown |
| C-48 | 1 | B | 30.0 - 35.0 | 7.3 | | | 2.70 | 38 | 23 | SC | S | SHALE, weathered, sandy brown |
| C-48 | 9 | SS | 40.0 - 41.5 | 16.9 | | | 2.72 | 39 | 19 | SC | S | SHALE, weathered, gray and brown |
| C-48 | 2 | B | 50.0 - 60.0 | 9.5 | | | 2.72 | 38 | 23 | SC | S | SHALE, weathered, brown and gray |
| C-49 | 1 | B | 0.0 - 10.0 | 12.3 | | | 2.66 | 27 | 11 | CL | C,S,P,T | CLAY, silty, brown |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
P-PROCTOR TEST
S-SIEVE OR GRAIN SIZE ANALYSIS
D-DIRECT SHEAR TEST
U-UNCONFINED COMPRESSION TEST
T-TRIAXIAL TEST
CBR-CALIFORNIA BEARING RATIO

DATA CHECKED BY

GA Technical Services

| | | | | | UNIT WEIGHT (PCF) | | SPECIFIC GRAVITY | ATTERBERG LIMITS | | | Other Tests ** | Project: ORR Storage Facility, K-25 Site, Site C<br>Project Number: 0-4267-0056-0100<br>Date: March 3, 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole No. | Sample No. | Sample Type* | Depth (ft) | Natural Moisture (%) | Wet | Dry | $G_s$ | Liquid Limit (%) | Plasticity Index (%) | Unified Soil Classification | | Soil Description |
| C-50 | 6 | SS | 25.0 - 25.8 | 11.6 | | | 2.69 | 27 | 18 | SC | S | SANDSTONE, weathered, and shale weathered, reddish-brown to tan |
| C-51 | 1 | B | 20.0 - 30.0 | 14.6 | | | 2.67 | 36 | 22 | CL | S,P,T,C, CBR | CLAY, silty, tan |
| C-52 | 2 | SS | 6.5 - 8.0 | 15.4 | | | 2.71 | 40 | 26 | SC | S | SHALE, weathered, tan, mottled white |
| C-52 | 6 | SS | 25.0 - 26.5 | 16.3 | | | 2.65 | 38 | 25 | SC | S | SHALE, weathered, brown tan, gray and white |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

*ST-SHELBY TUBE SAMPLE, SS-SPLIT SPOON SAMPLE, B-BAG SAMPLE
**TEST RESULTS REPORTED ON OTHER SHEETS:

C-CONSOLIDATION
S-SIEVE OR GRAIN SIZE ANALYSIS
U-UNCONFINED COMPRESSION TEST
CBR-CALIFORNIA BEARING RATIO
P-PROCTOR TEST
D-DIRECT SHEAR TEST
T-TRIAXIAL TEST

DATA CHECKED BY _____

GA Technical Services

WASTE MANAGEMENT
FEDERAL SERVICES, INC.

CH2MHILL
Constructors, Inc.

Golder Associates

ATI
American Technologies, Inc.

ORIGINAL

ENVIRONMENTAL MANAGEMENT
WASTE MANGEMENT FACILITY (EMWMF)

WASTE MANAGEMENT FEDERAL SERVICES (WMFS),
Subcontract No. BC009F-L001 in fulfillment of Bechtel-Jacobs Company, LLC,
Contract No. 23900-SC-BC009F

# SSRS Item No. 3.3 Rev.1,
# Phase IV
# FINAL SITE INVESTIGATION REPORT

Prepared for

Bechtel Jacobs Company LLC
2010 Highway 58
Oak Ridge, TN 37830

Waste Management Federal Services
704 South Illinois Ave.
Suite C203
Oak Ridge, TN 37830

March 2000

# TABLE 3-4
# SUMMARY OF SOIL TESTING DATA
# EMWMF AREA

| Sample Identification | Sample Type | Sample Depth | Soil Classification | Natural Moisture % | Atterberg Limits | | | | Grain Size Distribution | | | Compaction | | Gs | Unit Weight | | Permeability (cm/sec) | Additional Tests Conducted (See Notes) | Triaxial Strength (Effective) | | Coefficient of Consolidation $C_v$ ($ft^2$/day) | Distribution Coefficient $K_{d\ (ml/g)}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | L.L. | P.L. | P.I. | L.I. | % Finer No. 4 Sieve | % Finer No. 200 Sieve | % Finer .005 mm | Maximum Dry Density (lb/cuft) | Optimum Moisture % | | Moisture % | Dry (lb/cuft) | | | c' (psf) | phi' (degrees) | | U | Pb |
| GTP - 11A | Jar | 10.0' | | 19.6 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 10.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| GTP - 12 | Bulk | 4.0' | ML | 23.6 | 44 | 28 | 16 | -0.48 | 100.0 | 51.5 | 22.0 | 112.8 | 16.0 | 2.78 | 19.6 | 105.5 | 2.9E-06 | 5 psi | | | 1.0 | | |
| | Bulk | 4.0' | | | | | | | | | | | | | 19.6 | 105.5 | 1.2E-06 | 30 psi | | | | | |
| | Jar | 4.0' | | 23.5 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 9.0' | ML | 18.5 | 47 | 28 | 19 | -0.05 | 100.0 | 77.1 | 31.7 | 112.0 | 15.0 | | | | | | 159 | 31 | | | |
| | Jar | 9.0' | | 18.5 | | | | | | | | | | | | | | | | | | | |
| GTP - 13 | Bulk | 4.0' | CL | 13.9 | 39 | 19 | 20 | -0.27 | 96.7 | 69.1 | 35.7 | | | | | | | | | | | | |
| | Jar | 12.0' | | 15.0 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 12.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| GTP - 15 | Jar | 3.0' | | 10.4 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 3.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| | Jar | 8.0' | | 12.5 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 8.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| GTP - 16 | Bulk | 8.0' | CH | | 53 | 25 | 28 | -0.10 | 100.0 | 87.4 | 41.3 | 111.0 | 16.5 | 2.75 | 19.2 | 105.3 | 1.8E-07 | 5 psi | | | | | |
| | Bulk | 8.0' | | | | | | | | | | | | | 19.2 | 105.3 | 5.8E-08 | 30 psi | | | | | |
| | Jar | 8.0' | | 22.5 | | | | | | | | | | | | | | | | | | | |
| | Bag | 11.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| GTP - 17 | Jar | 10.0' | | 18.4 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 10.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| | Bag | 10.0' | | | | | | | | | | | | | | | | | | | | 26,900 | 38,900 |
| GTP - 18 | Jar | 6.0' | | 14.1 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 6.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| | Bag | 6.0' | | | | | | | | | | | | | | | | | | | | 26,400 | 38,900 |
| GTP - 19 | Jar | 7.0' | | 15.0 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 7.0' | Shale | | | | | | | | | | | | | | | | | | | | |
| | Bag | 7.0' | | | | | | | | | | | | | | | | | | | | 22,300 | 38,900 |

# TABLE 3-4
# SUMMARY OF SOIL TESTING DATA
# EMWMF AREA

| Sample Identification | Sample Type | Sample Depth | Soil Classification | Natural Moisture % | Atterberg Limits | | | | Grain Size Distribution | | | Compaction | | Gs | Unit Weight | | Permeability (cm/sec) | Additional Tests Conducted (See Notes) | Triaxial Strength (Effective) | | Coefficient of Consolidation $C_v$ ($ft^2$/day) | Distribution Coefficient $K_{d\ (ml/g)}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | L.L. | P.L. | P.I. | L.I. | % Finer No. 4 Sieve | % Finer No. 200 Sieve | % Finer .005 mm | Maximum Dry Density (lb/cuft) | Optimum Moisture % | | Moisture % | Dry (lb/cuft) | | | c' (psf) | phi' (degrees) | | U | Pb |
| GTP - 20 | Bulk | 3.0' | SM | | 42 | 28 | 14 | -0.82 | 100.0 | 49.5 | 24.4 | 106.0 | 17.0 | | | | | | | | | | |
| | Jar | 3.0' | | 16.2 | | | | | | | | | | | | | | | | | | | |
| | Bag | 3.0' | | | | | | | | | | | | | | | | | | | | 28,600 | 38,900 |
| | Jar | 9.0' | | 23.6 | | | | | | | | | | | | | | | | | | | |
| | Bulk | 9.0' | Shale | | | | | | | | | | | | | | | | | | | | |

ABBREVIATIONS: LIQUID LIMIT (LL)
PLASTIC LIMIT (PL)
PLASTICITY INDEX (PI)
LIQUIDITY INDEX (LI)
SPECIFIC GRAVITY (Gs)

Note: No samples collected from Test Pit 14. Material nearly identical to soil from GTP-18.

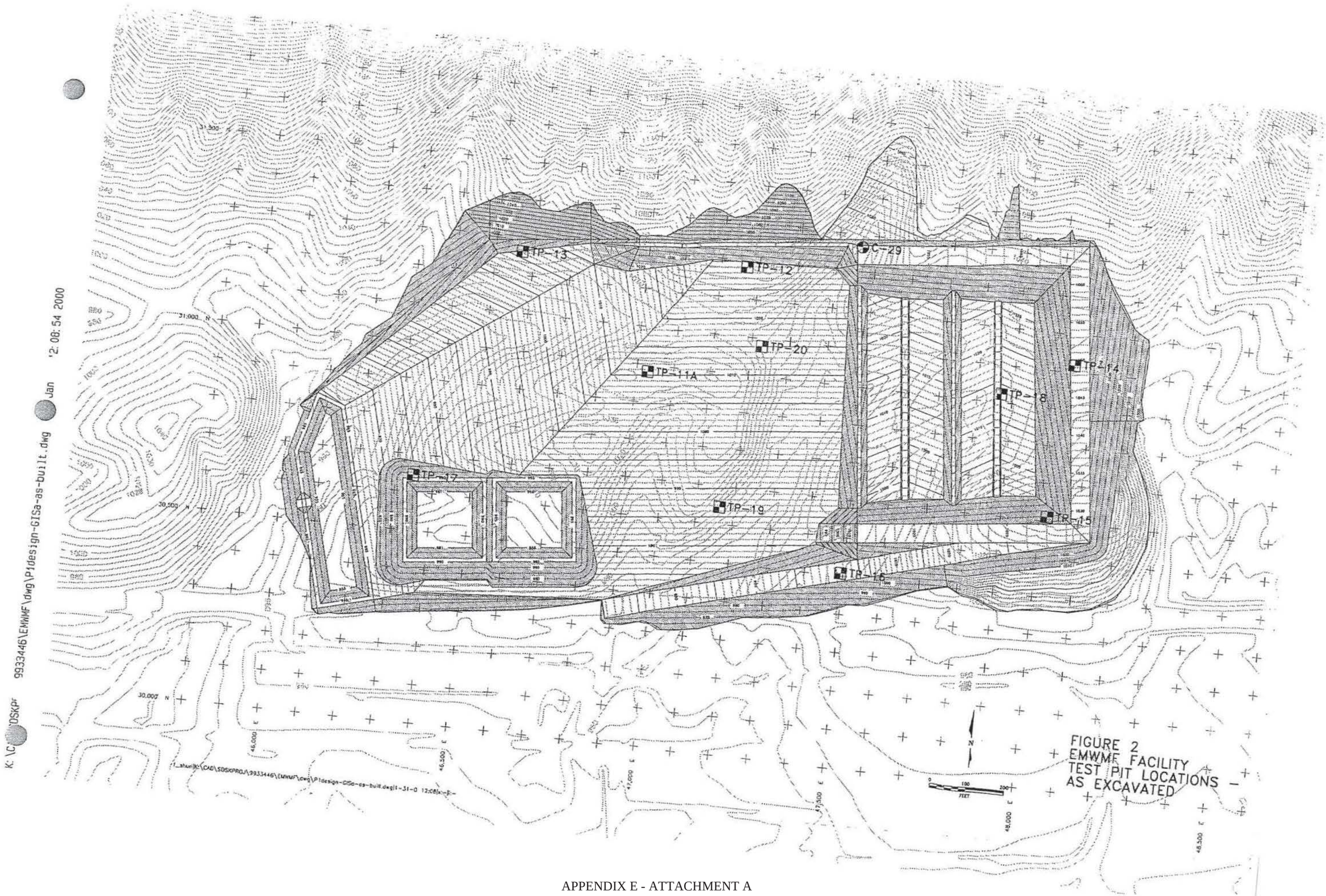
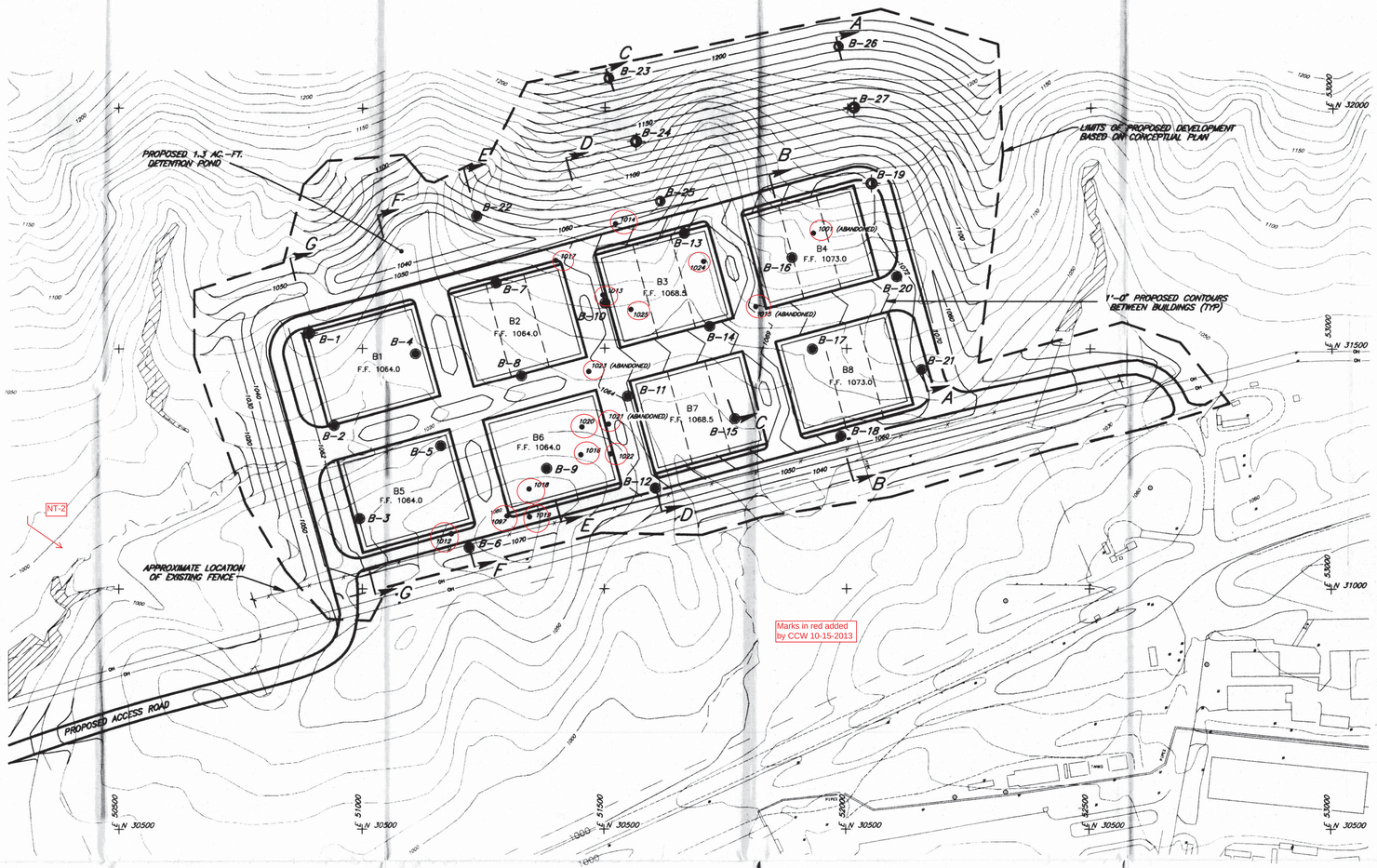



FIGURE 2
EMWMF FACILITY
TEST PIT LOCATIONS -
AS EXCAVATED



## VICINITY MAP
SCALE: 1" = 2000'

ADAPTED FROM OAK RIDGE AREA 1987 EDITION (DRAWING NO 16A) TVA TOPOGRAPHIC MAP

### SUMMARY OF BORING COORDINATES AND GROUND ELEVATIONS

| HOLE | NORTH | EAST | ELEVATION |
|---|---|---|---|
| B-1 | 31532 | 50891 | 1046.1 |
| B-2 | 31339 | 50943 | 1013.4 |
| B-3 | 31146 | 50994 | 1048.1 |
| B-4 | 31489 | 51111 | 1026.8 |
| B-5 | 31297 | 51163 | 1038.9 |
| B-6 | 31085 | 51222 | 1078.8 |
| B-7 | 31636 | 51277 | 1056.6 |
| B-8 | 31443 | 51329 | 1035.6 |
| B-9 | 31250 | 51381 | 1068.1 |
| B-10 | 31594 | 51500 | 1062.2 |
| B-11 | 31400 | 51547 | 1034.7 |
| B-12 | 31209 | 51604 | 1042.6 |
| B-13 | 31739 | 51664 | 1069.2 |
| B-14 | 31546 | 51715 | 1050.2 |
| B-15 | 31353 | 51767 | 1032.5 |
| B-16 | 31690 | 51886 | 1098.6 |
| B-17 | 31499 | 51928 | 1054.3 |
| B-18 | 31317 | 51988 | 1037.7 |
| B-19 | 31843 | 52050 | 1146.3 |
| B-20 | 31650 | 52102 | 1081.4 |
| B-21 | 31457 | 52154 | 1062.0 |
| B-22 | 31775 | 51237 | 1095.7 |
| B-23 | 32061 | 51508 | 1225.9 |
| B-24 | 31930 | 51564 | 1165.5 |
| B-25 | 31806 | 51614 | 1109.9 |
| B-26 | 32128 | 51981 | 1234.9 |
| B-27 | 32001 | 52013 | 1187.8 |

## PLAN SYMBOLS

- OGDEN SAMPLED BORING LOCATION
- OGDEN SAMPLED & CORED BORING LOCATION
- OGDEN BORING CONVERTED TO PIEZOMETER
- 1019 MMES MONITORING WELL LOCATIONS
- PROFILE LIMITS
- EXISTING CONTOUR, 10' INTERVAL
- 900 EXISTING INDEX CONTOUR
- PROPOSED CONTOUR, 10' INTERVALS UNLESS NOTED
- LOCATION OF WETLANDS (TAKEN FROM BWSC DRAWING)
- LIMITS OF PROPOSED ROADS
- B9 F.F. 1064.0 OUTLINE OF PROPOSED BUILDING WITH IDENTIFIER AND FINISHED FLOOR ELEVATION
- OH EXISTING OVERHEAD POWERLINES

GRAPHIC SCALE
100' 0 100' 200'

## NOTES

1. PLAN ADAPTED FROM COMPUTER DISKETTE SUPPLIED BY BARGE, WAGGONER, SUMNER AND CANNON. (THE TOPOGRAPHIC MAP HAS BEEN COMPILED FROM SEVERAL SOURCES AND SHOULD BE VERIFIED FOR ACCURACY).
2. BORING LOCATIONS AND ELEVATIONS PROVIDED BY BARGE, WAGGONER, SUMNER AND CANNON. ALL ELEVATIONS REFER TO MEAN SEA LEVEL.
3. OGDEN EXPLORATION CONDUCTED FROM 2-1-93 THRU 2-18-93.
4. THIS DRAWING PRODUCED BY AutoCAD RELEASE 11.
5. FOR PROFILES, SEE SHEETS 2 THRU 4.
6. FOR LOGS OF BORINGS, SEE SHEET 5 AND APPENDIX II.

GARY T. BRILL REGISTERED ENGINEER 18,478 STATE OF TENNESSEE

THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|
| | | |

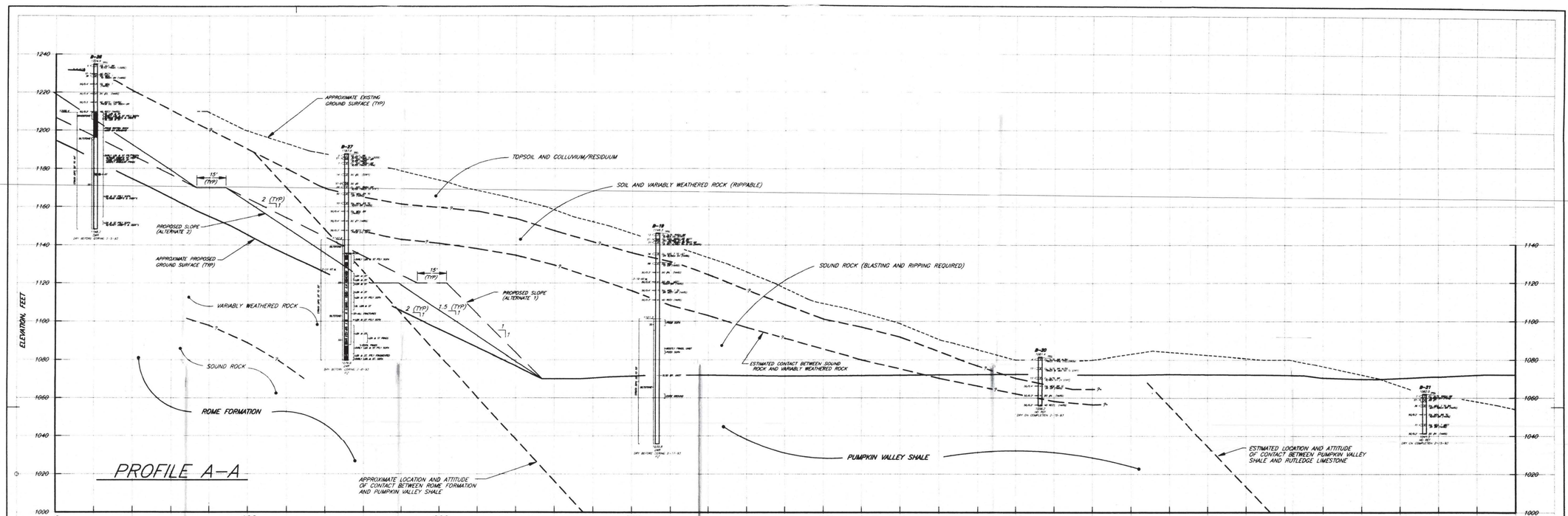
# PLAN
## GEOTECHNICAL STUDY ORR STORAGE FACILITY, K-25 SITE SITE "B"
OAK RIDGE, TENNESSEE

SCALE: 1" = 100' | DR: jpms | CHK: MWF | REV: GTB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 042870058B200 | DATE: J-23-93 | SHEET 1 OF 5




NOTES:
1. FOR PLAN, SEE SHEET 1.
2. FOR BORING SYMBOLS & ABBREVIATIONS, SEE SHEET 5.

GARY T. BRILL REGISTERED ENGINEER STATE OF TENNESSEE

THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|

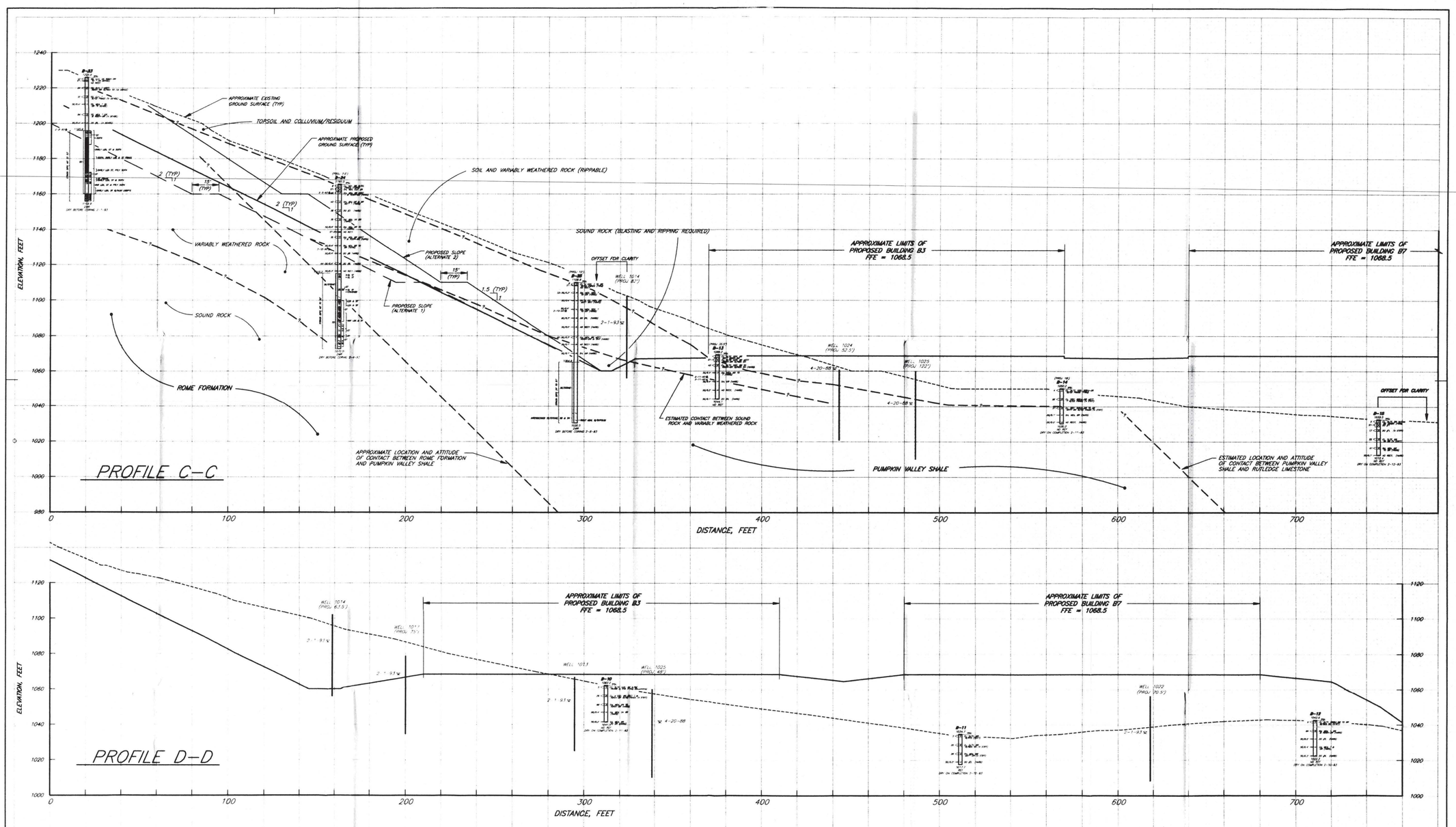
**PROFILES A-A & B-B**
**GEOTECHNICAL STUDY**
**ORR STORAGE FACILITY, K-25 SITE**
**SITE "B"**
**OAK RIDGE, TENNESSEE**

SCALE: 1" = 20' | DR jone | CHK MAR | REV GTB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 0426700580200 | DATE: 3-23-93 | SHEET 2 OF 5




NOTES
1. FOR PLAN, SEE SHEET 1.
2. FOR BORING SYMBOLS & ABBREVIATIONS, SEE SHEET 5.

GARY T. BALL REGISTERED ENGINEER STATE OF TENNESSEE

THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|

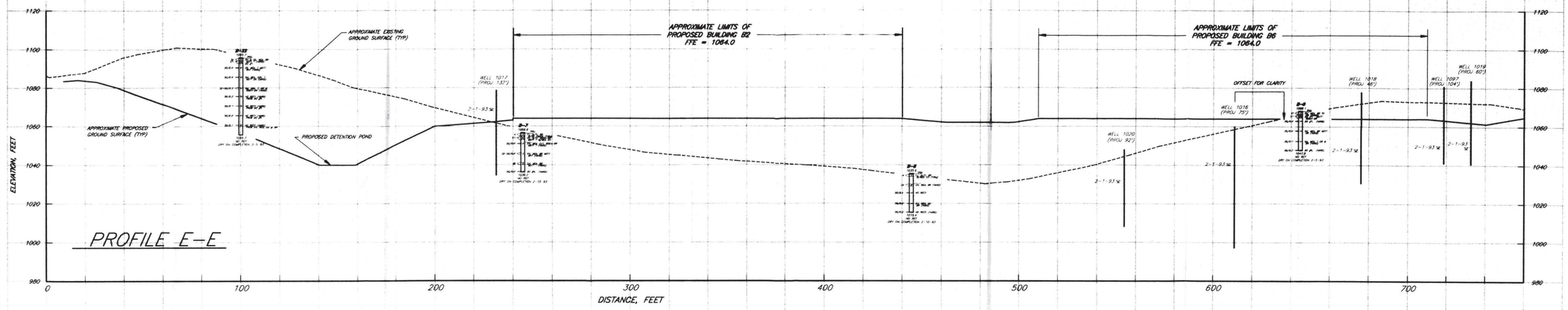
**PROFILES C-C & D-D**
**GEOTECHNICAL STUDY**
**ORR STORAGE FACILITY, K-25 SITE**
**SITE "B"**
**OAK RIDGE, TENNESSEE**

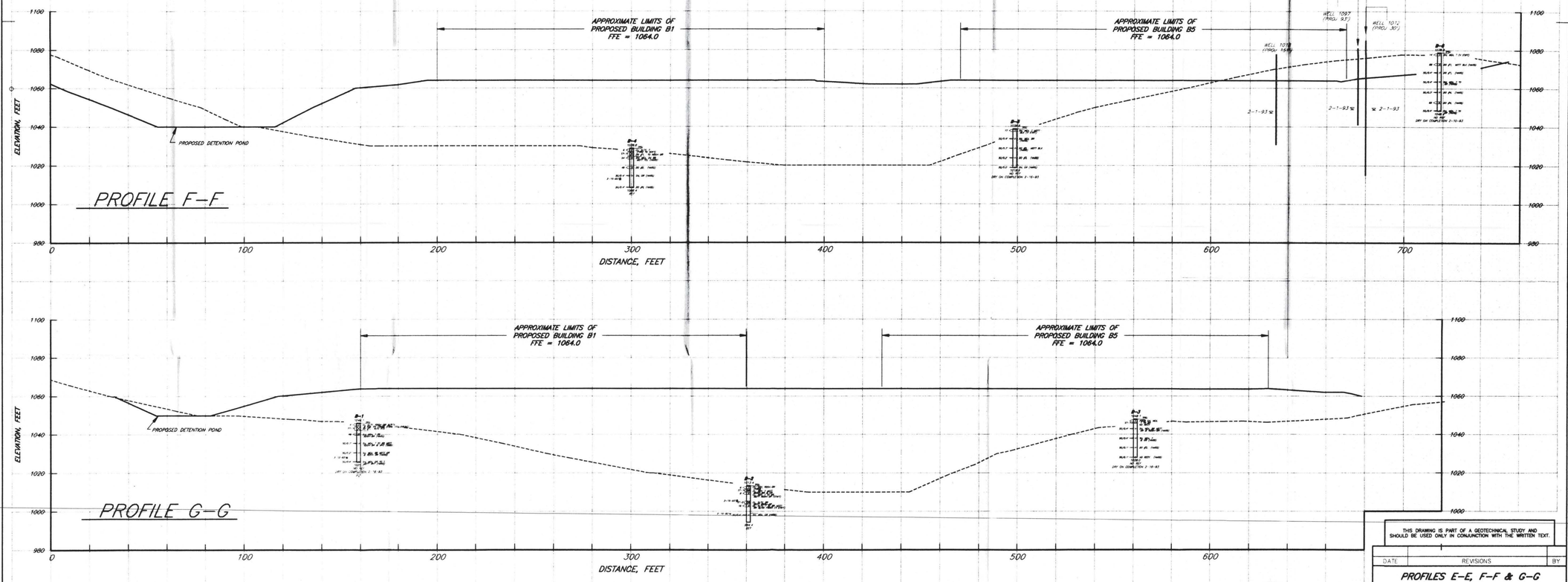
SCALE: 1" = 20' | DR: JDW | CHK: MMR | REV: GTB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 042467005802000 | DATE: 3-23-93 | SHEET 3 OF 5







THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|
| | | |

**PROFILES E-E, F-F & G-G**
**GEOTECHNICAL STUDY**
**ORR STORAGE FACILITY, K-25 SITE**
**SITE "B"**
**OAK RIDGE, TENNESSEE**

SCALE: 1" = 20' | DR: JONE | CHK: MMF | REV: GTB

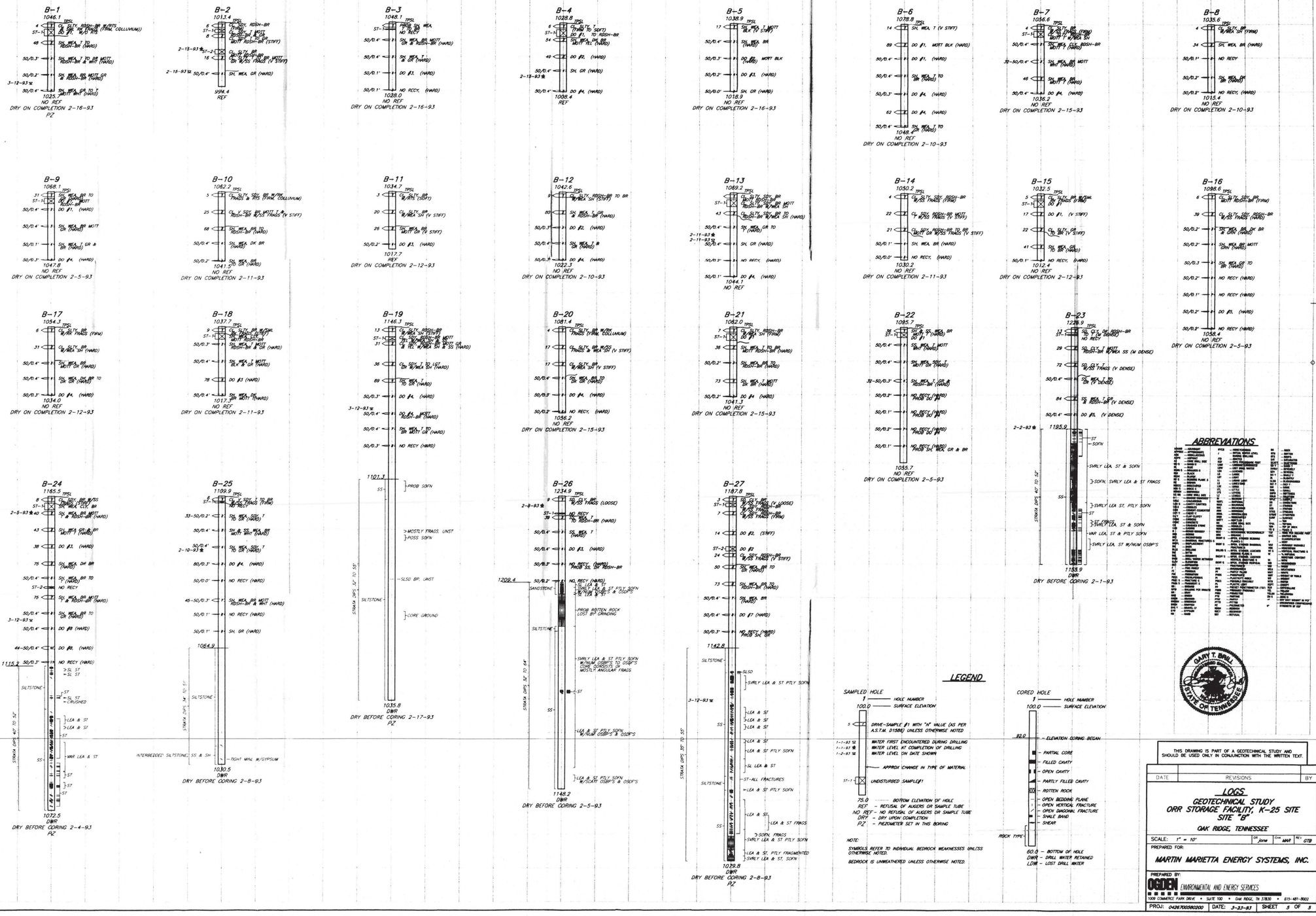
PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

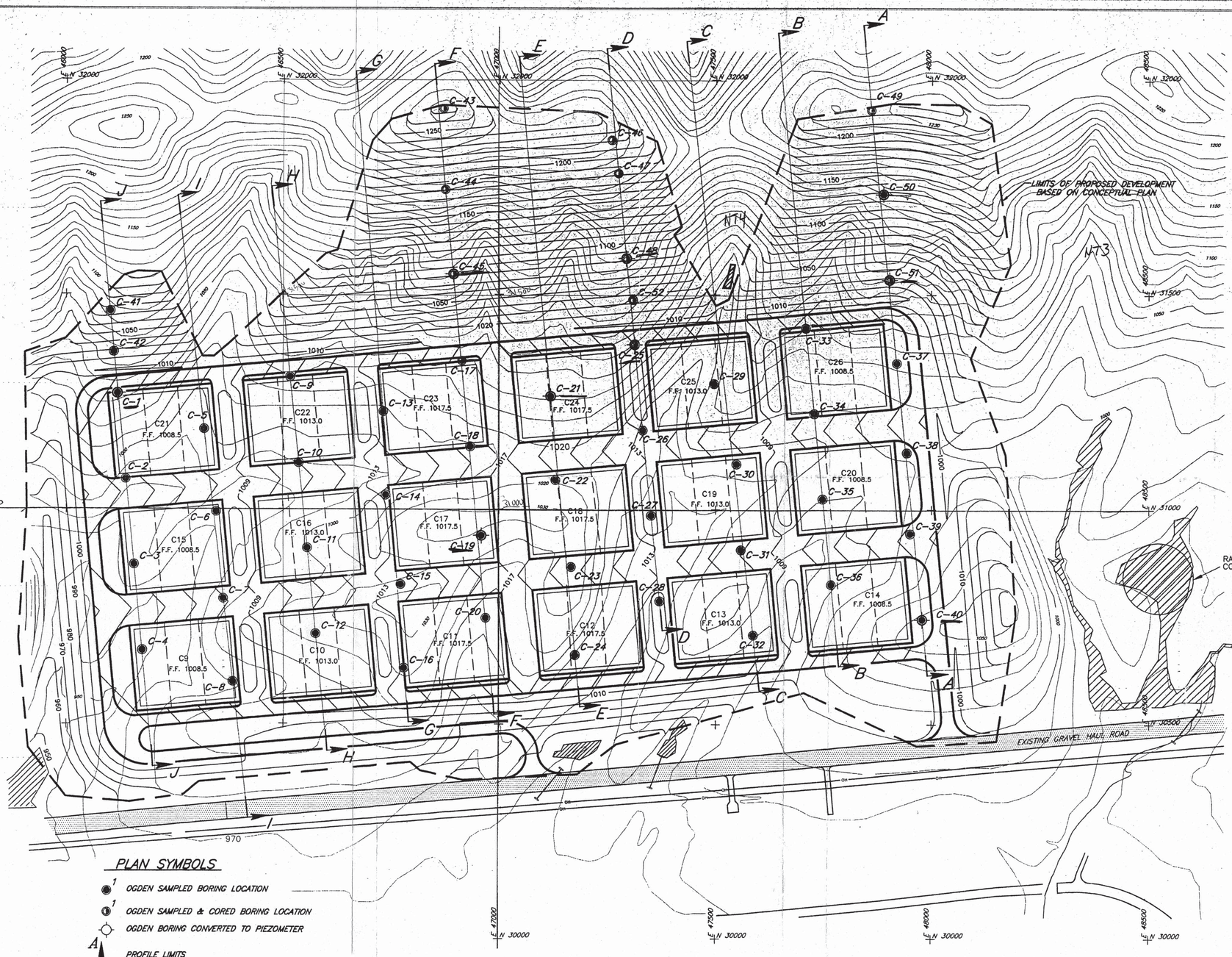
PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1509 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 0438700580200 | DATE: 3-23-93 | SHEET 4 OF 5

**NOTES**
1. FOR PLAN, SEE SHEET 1.
2. FOR BORING SYMBOLS & ABBREVIATIONS, SEE SHEET 5.

GARY T. BAILEY — REGISTERED GEOLOGIST — STATE OF TENNESSEE


B-1
1046.1
1025.
NO REF.
DRY ON COMPLETION 2-16-93
PZ
B-2
1013.4
994.4
REF
B-3
1048.1
1028.0
NO REF.
DRY ON COMPLETION 2-16-93
B-4
1028.8
1008.4
REF
B-5
1038.9
1018.9
NO REF.
DRY ON COMPLETION 2-16-93
B-6
1078.8
1048.2
NO REF.
DRY ON COMPLETION 2-10-93
B-7
1056.6
1036.2
NO REF.
DRY ON COMPLETION 2-15-93
B-8
1035.6
1015.4
NO REF.
DRY ON COMPLETION 2-10-93
B-9
1068.1
1047.8
NO REF.
DRY ON COMPLETION 2-5-93
B-10
1062.2
1041.5
NO REF.
DRY ON COMPLETION 2-11-93
B-11
1034.7
1017.7
REF.
DRY ON COMPLETION 2-12-93
B-12
1042.6
1022.3
NO REF.
DRY ON COMPLETION 2-10-93
B-13
1069.2
1044.1
NO REF.
B-14
1050.2
1030.2
NO REF.
DRY ON COMPLETION 2-11-93
B-15
1032.5
1012.4
NO REF.
DRY ON COMPLETION 2-12-93
B-16
1098.6
1058.4
NO REF.
DRY ON COMPLETION 2-5-93
B-17
1054.3
1034.0
NO REF.
DRY ON COMPLETION 2-12-93
B-18
1037.7
1017.3
NO REF.
DRY ON COMPLETION 2-11-93
B-19
1146.3
1101.3
PROB SOFN
MOSTLY FRAGS, UNST
POSS SOFN
SLSD, BP, UNST
CORE GROUND
1035.8
DWR
DRY BEFORE CORING 2-17-93
PZ
B-20
1081.4
1056.2
NO REF.
DRY ON COMPLETION 2-15-93
B-21
1062.0
1041.3
NO REF.
DRY ON COMPLETION 2-15-93
B-22
1095.7
1055.7
NO REF.
DRY ON COMPLETION 2-5-93
B-23
1228.9
1195.9
1155.9
DWR
DRY BEFORE CORING 2-1-93
B-24
1165.5
1115.2
1072.5
DWR
DRY BEFORE CORING 2-4-93
PZ
B-25
1109.9
1064.9
1030.5
DWR
DRY BEFORE CORING 2-8-93
B-26
1234.9
1209.4
1148.2
DWR
DRY BEFORE CORING 2-5-93
B-27
1187.8
1142.8
1079.8
DWR
DRY BEFORE CORING 2-8-93
PZ
STRATA DIPS 42° TO 52°
STRATA DIPS 14° TO 51°
STRATA DIPS 12° TO 64°
STRATA DIPS 35° TO 55°
STRATA DIPS 40° TO 52°
SILTSTONE
SANDSTONE
INTERBEDDED SILTSTONE, SS & SH
LEGEND
SAMPLED HOLE
1 — HOLE NUMBER
100.0 — SURFACE ELEVATION
5 — DRIVE-SAMPLE #1 WITH "N" VALUE (AS PER A.S.T.M. D1586) UNLESS OTHERWISE NOTED
WATER FIRST ENCOUNTERED DURING DRILLING
WATER LEVEL AT COMPLETION OF DRILLING
WATER LEVEL ON DATE SHOWN
APPROX. CHANGE IN TYPE OF MATERIAL
ST-1 — UNDISTURBED SAMPLE #1
75.0 — BOTTOM ELEVATION OF HOLE
REF - REFUSAL OF AUGERS OR SAMPLE TUBE
NO REF - NO REFUSAL OF AUGERS OR SAMPLE TUBE
DRY - DRY UPON COMPLETION
PZ - PIEZOMETER SET IN THIS BORING
NOTE:
SYMBOLS REFER TO INDIVIDUAL BEDROCK WEAKNESSES UNLESS OTHERWISE NOTED.
BEDROCK IS UNWEATHERED UNLESS OTHERWISE NOTED.
CORED HOLE
1 — HOLE NUMBER
100.0 — SURFACE ELEVATION
92.0 — ELEVATION CORING BEGAN
PARTIAL CORE
FILLED CAVITY
OPEN CAVITY
PARTLY FILLED CAVITY
ROTTEN ROCK
OPEN BEDDING PLANE
OPEN VERTICAL FRACTURE
OPEN DIAGONAL FRACTURE
SHALE BAND
SHEAR
ROCK TYPE
60.0 — BOTTOM OF HOLE
DWR - DRILL WATER RETAINED
LDW - LOST DRILL WATER
ABBREVIATIONS
GARY T. BALL
REGISTERED GEOLOGIST
STATE OF TENNESSEE
THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.
DATE
REVISIONS
BY
LOGS
GEOTECHNICAL STUDY
ORR STORAGE FACILITY, K-25 SITE
SITE "B"
OAK RIDGE, TENNESSEE
SCALE: 1" = 10'
DR: jbm
CHK: MAR
REV: GTB
PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.
PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002
PROJ: 0426700580200
DATE: 3-23-93
SHEET 5 OF 5




## PLAN SYMBOLS

- OGDEN SAMPLED BORING LOCATION
- OGDEN SAMPLED & CORED BORING LOCATION
- OGDEN BORING CONVERTED TO PIEZOMETER
- PROFILE LIMITS
- EXISTING CONTOUR, 10' INTERVAL
- EXISTING INDEX CONTOUR
- PROPOSED CONTOUR, INTERVALS VARY
- LOCATION OF WETLANDS
- LIMITS OF PROPOSED ROADS
- OUTLINE OF PROPOSED BUILDING WITH IDENTIFIER AND FINISHED FLOOR ELEVATION
- CUT/FILL LIMITS
- OVERHEAD POWERLINES
- CULVERT

GRAPHIC SCALE
100' 0 100' 200'

## NOTES

1. PLAN ADAPTED FROM COMPUTER DISKETTE SUPPLIED BY BARGE, WAGGONER, SUMNER AND CANNON. (THE TOPOGRAPHIC MAP HAS BEEN COMPILED FROM SEVERAL SOURCES AND SHOULD BE VERIFIED FOR ACCURACY).
2. BORING LOCATIONS AND ELEVATIONS PROVIDED BY BARGE, WAGGONER, SUMNER AND CANNON. ALL ELEVATIONS REFER TO MEAN SEA LEVEL.
3. OGDEN EXPLORATION CONDUCTED FROM 12-28-92 THRU 2-1-93.
4. THIS DRAWING PRODUCED BY AutoCAD RELEASE 11.
5. FOR PROFILES, SEE SHEETS 2 THRU 7.
6. FOR LOGS OF BORINGS, SEE SHEETS 8 AND 9 AND APPENDIX II.

## VICINITY MAP
SCALE: 1" = 2000'
ADAPTED FROM OAK RIDGE AREA 1987 EDITION (DRAWING NO 16A) TVA TOPOGRAPHIC MAP

### SUMMARY OF BORING COORDINATES AND GROUND ELEVATIONS

| HOLE | NORTH | EAST | ELEVATION |
|---|---|---|---|
| C-1 | 31269 | 46118 | 1036.2 |
| C-2 | 31070 | 46137 | 983.7 |
| C-3 | 30871 | 46156 | 977.7 |
| C-4 | 30672 | 46176 | 958.5 |
| C-5 | 31186 | 46318 | 999.6 |
| C-6 | 30994 | 46346 | 976.3 |
| C-7 | 30792 | 46362 | 985.5 |
| C-8 | 30599 | 46384 | 983.1 |
| C-9 | 31307 | 46516 | 1031.3 |
| C-10 | 31108 | 46535 | 992.0 |
| C-11 | 30909 | 46554 | 1005.1 |
| C-12 | 30710 | 46574 | 1016.7 |
| C-13 | 31228 | 46730 | 1009.0 |
| C-14 | 31032 | 46736 | 1006.2 |
| C-15 | 30825 | 46772 | 1026.5 |
| C-16 | 30631 | 46780 | 1023.2 |
| C-17 | 31346 | 46914 | 1037.5 |
| C-18 | 31147 | 46933 | 1009.6 |
| C-19 | 30839 | 46959 | 1030.8 |
| C-20 | 30747 | 46969 | 995.5 |
| C-21 | 31263 | 47119 | 1040.9 |
| C-22 | 31068 | 47131 | 1020.3 |
| C-23 | 30866 | 47167 | 1025.6 |
| C-24 | 30662 | 47176 | 991.4 |
| C-25 | 31384 | 47312 | 1061.8 |
| C-26 | 31185 | 47332 | 1000.2 |
| C-27 | 30986 | 47351 | 987.2 |
| C-28 | 30787 | 47370 | 978.0 |
| C-29 | 31293 | 47497 | 1021.8 |
| C-30 | 31106 | 47548 | 996.2 |
| C-31 | 30906 | 47559 | 996.6 |
| C-32 | 30708 | 47587 | 982.2 |
| C-33 | 31422 | 47711 | 1042.5 |
| C-34 | 31223 | 47730 | 1009.9 |
| C-35 | 31024 | 47749 | 1002.8 |
| C-36 | 30825 | 47768 | 1001.8 |
| C-37 | 31341 | 47920 | 1038.5 |
| C-38 | 31133 | 47943 | 1013.4 |
| C-39 | 30944 | 47950 | 1014.4 |
| C-40 | 30744 | 47978 | 1045.8 |
| C-41 | 31461 | 46102 | 1084.2 |
| C-42 | 31366 | 46110 | 1060.0 |
| C-43 | 31932 | 46871 | 1274.7 |
| C-44 | 31744 | 46876 | 1204.0 |
| C-45 | 31545 | 46895 | 1119.9 |
| C-46 | 31859 | 47259 | 1239.3 |
| C-47 | 31790 | 47229 | 1219.3 |
| C-48 | 31583 | 47293 | 1136.9 |
| C-49 | 31929 | 47861 | 1229.3 |
| C-50 | 31734 | 47890 | 1146.7 |
| C-51 | 31601 | 47874 | 1092.5 |
| C-52 | 31488 | 47308 | 1097.6 |

GARY T. BRILL REGISTERED ENGINEER No. 078858 STATE OF TENNESSEE

THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|
| | | |

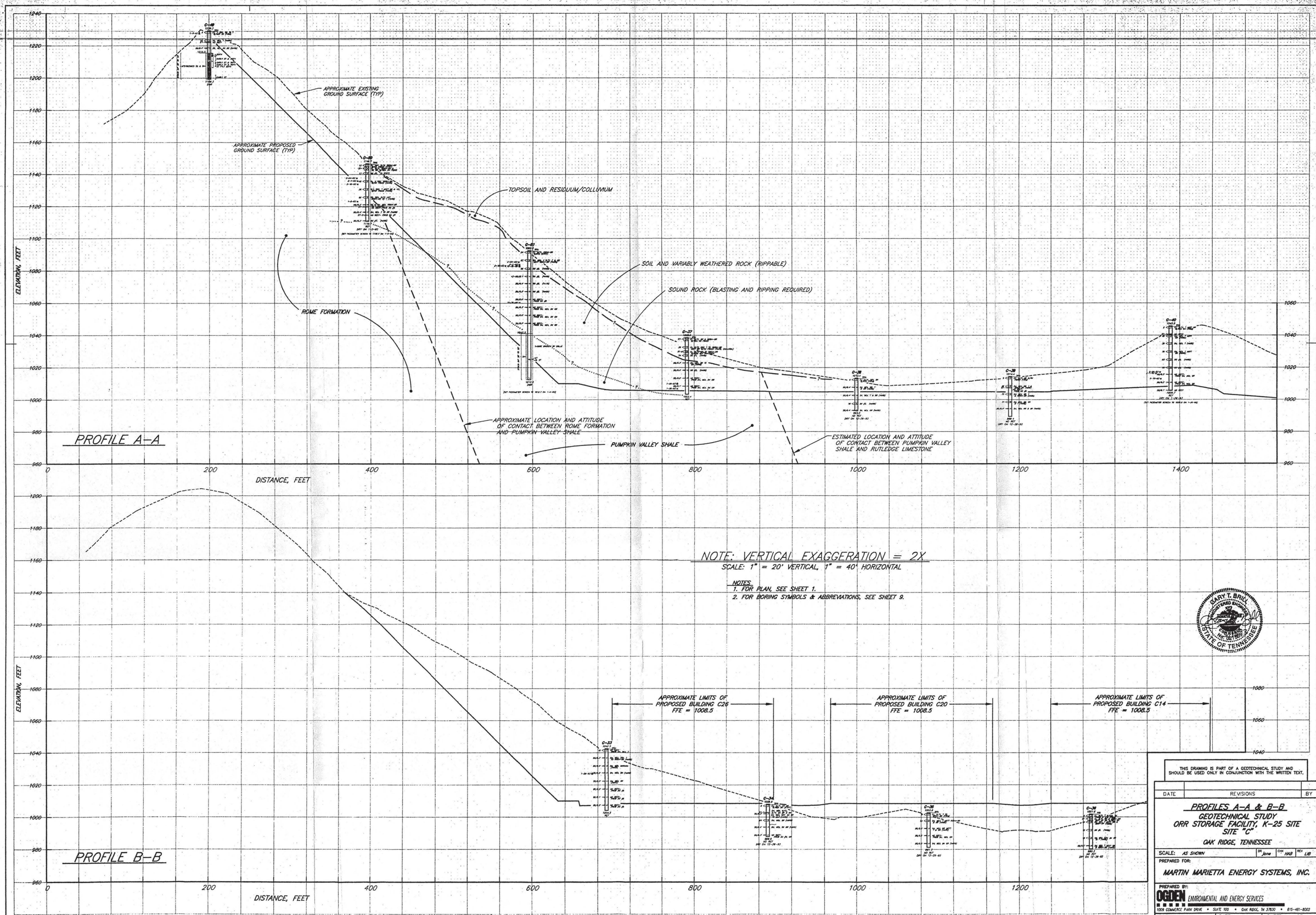
# PLAN
## GEOTECHNICAL STUDY
## ORR STORAGE FACILITY, K-25 SITE
## SITE "C"
OAK RIDGE, TENNESSEE

SCALE: AS SHOWN | DR jone | CHK HAB | REV LIB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: [illegible] DATE: [illegible] SHEET 1 OF 9




THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|

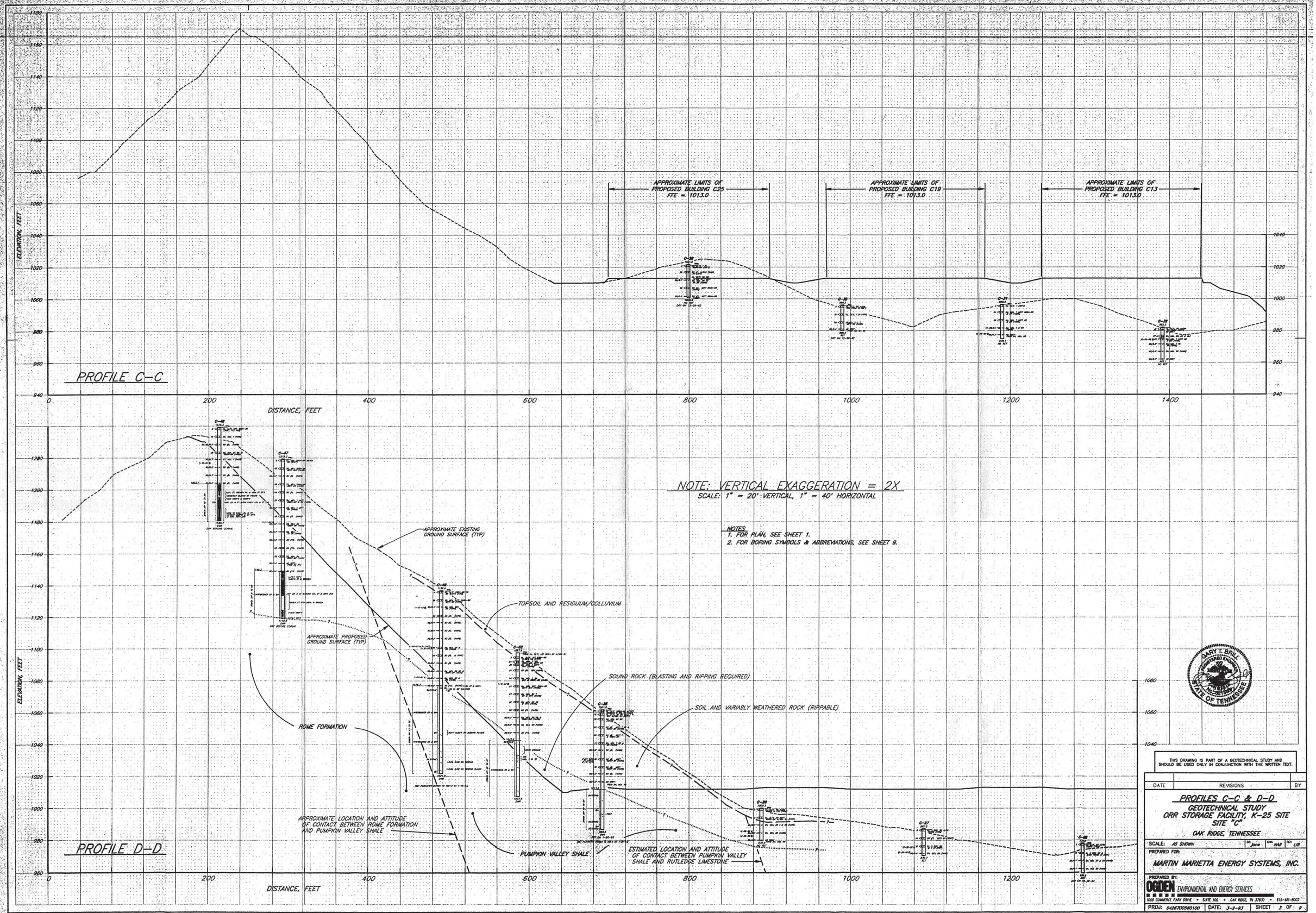
**PROFILES A-A & B-B**
GEOTECHNICAL STUDY
ORR STORAGE FACILITY, K-25 SITE
SITE "C"
OAK RIDGE, TENNESSEE

SCALE: AS SHOWN | DR Jane | CHK HAB | REV LIB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 0426700580100 | DATE: 3-9-93 | SHEET 2 OF 9




NOTE: VERTICAL EXAGGERATION = 2X

SCALE: 1" = 20' VERTICAL, 1" = 40' HORIZONTAL

NOTES

1. FOR PLAN, SEE SHEET 1.
2. FOR BORING SYMBOLS & ABBREVIATIONS, SEE SHEET 9.

GARY T. BRILL — REGISTERED ENGINEER — STATE OF TENNESSEE

THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|

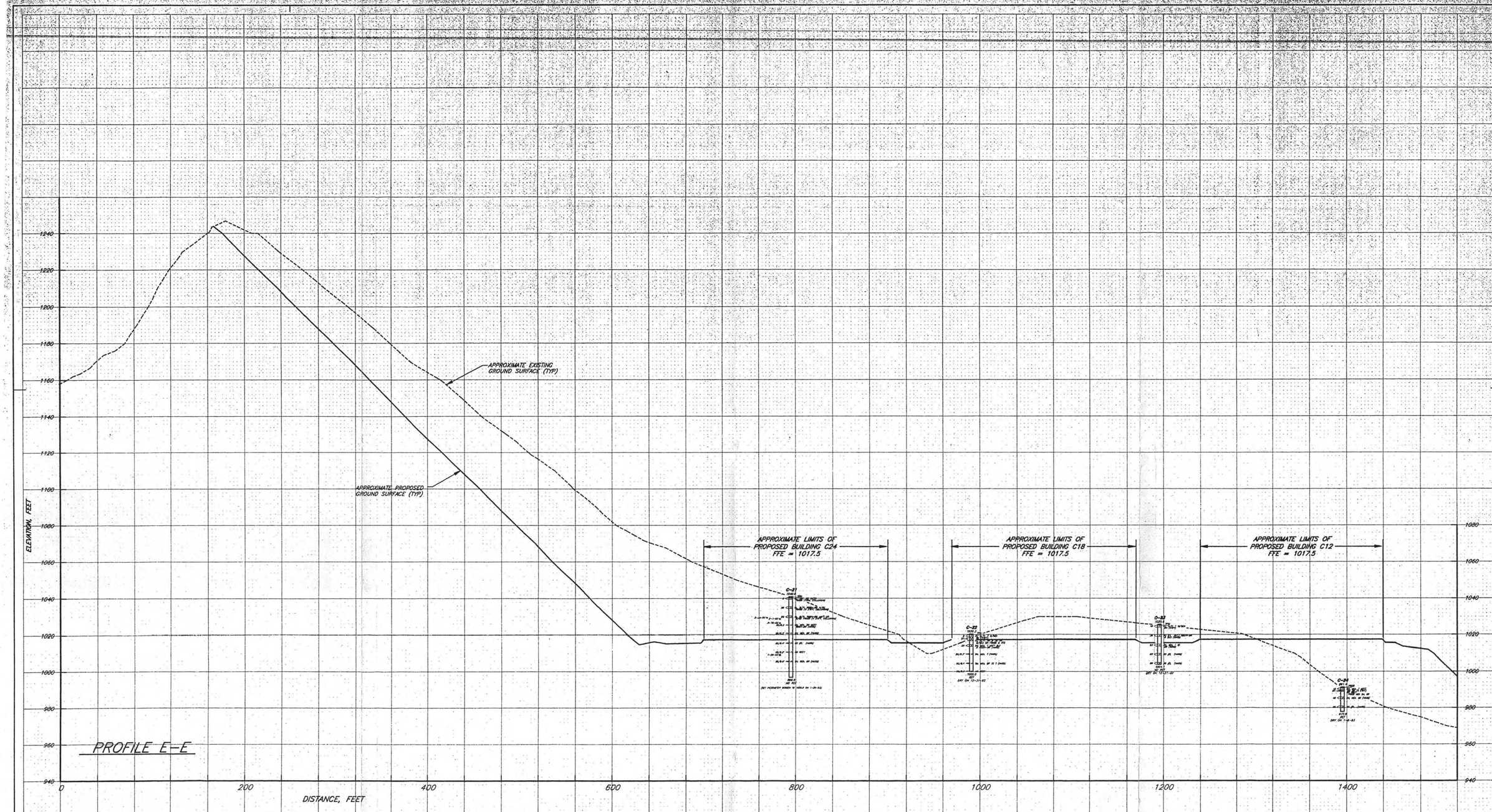
**PROFILES C–C & D–D**
GEOTECHNICAL STUDY
ORR STORAGE FACILITY, K-25 SITE
SITE "C"
OAK RIDGE, TENNESSEE

SCALE: AS SHOWN | DR: Jone | CHK: HAB | REV: LJB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1008 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 042870058D100 | DATE: 3-9-93 | SHEET 3 OF 9




NOTE: VERTICAL EXAGGERATION = 2X

SCALE: 1" = 20' VERTICAL, 1" = 40' HORIZONTAL

NOTES
1. FOR PLAN, SEE SHEET 1.
2. FOR BORING SYMBOLS & ABBREVIATIONS, SEE SHEET 9.

GARY T. BRILL REGISTERED ENGINEER STATE OF TENNESSEE

THIS DRAWING IS PART OF A GEOTECHNICAL STUDY AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE WRITTEN TEXT.

| DATE | REVISIONS | BY |
|---|---|---|

PROFILE E-E
GEOTECHNICAL STUDY
ORR STORAGE FACILITY, K-25 SITE
SITE "C"
OAK RIDGE, TENNESSEE

SCALE: AS SHOWN | DR jone | CHK HAB | REV LIB

PREPARED FOR:
MARTIN MARIETTA ENERGY SYSTEMS, INC.

PREPARED BY:
OGDEN ENVIRONMENTAL AND ENERGY SERVICES
1009 COMMERCE PARK DRIVE • SUITE 100 • OAK RIDGE, TN 37830 • 615-481-8002

PROJ: 0426700580100 | DATE: 3-9-93 | SHEET 4 OF 9

# APPENDIX F:
# ALTERNATIVES RISK ASSESSMENT
# AND
# FUGITIVE EMISSION MODELING

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... F-4
1. INTRODUCTION ..... F-5
2. TRANSPORTATION OF WASTE ..... F-5
2.1 SCENARIO DEVELOPMENT ..... F-6
2.1.1 On-Site Disposal Alternative ..... F-6
2.1.2 Off-Site Disposal Alternative ..... F-6
2.1.3 Scenario Routes ..... F-6
2.1.4 Waste Parameters ..... F-8
2.1.5 Receptors ..... F-8
2.2 TRANSPORTATION RISK MODELING ..... F-8
2.2.1 Radiological Risk ..... F-9
2.2.1.1 RADTRAN Code ..... F-10
2.2.1.2 RISKIND Code ..... F-10
2.2.2 Vehicle-Related Risk ..... F-10
2.3 ASSUMPTIONS AND INPUTS ..... F-10
2.4 RISK RESULTS ..... F-14
2.5 RAIL VERSUS TRUCK COMPARISON ..... F-17
3. NATURAL PHENOMENA HAZARDS ..... F-19
3.1 TORNADO RISKS ..... F-19
3.1.1 Model Inputs and Assumptions ..... F-19
3.1.2 Tornado Probability ..... F-20
3.1.3 Modeling Results ..... F-20
3.2 SEISMIC RISKS ..... F-20
3.2.1 Historical Seismicity ..... F-21
3.2.2 Future Seismicity ..... F-22
4. FUGITIVE DUST EMISSIONS ..... F-23
4.1 METHOD ..... F-23
4.2 RESULTS ..... F-25
5. REFERENCES ..... F-27

# FIGURES

Figure F-1. Transportation Routes Assessed in On-site and Off-site Disposal Alternatives ..... F-7
Figure F-2. Approach to Determining Transportation Risk ..... F-9
Figure F-3. Modified Mercalli Intensity Scale (from U.S. Geological Survey) ..... F-21
Figure F-4. Uniform Hazard Response Spectrum for 90% Probability of Non-Exceedance in 250 years ..... F-22

# TABLES

Table F-1. Mass-weighted, Average Radionuclide Concentrations Used in Risk Assessment Modeling ..... F-13
Table F-2. Summary of Selected Input Parameters for RADTRAN ..... F-14
Table F-3. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Single Shipment ..... F-15
Table F-4. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Multiple (All) Shipments ..... F-16
Table F-5. Transportation Risk Assessment, Injury and Fatality Risk from Vehicle-related Incidents ..... F-17
Table F-6. Comparison of Radiological Risk for Trucking Waste versus Trucking and Rail Transport of Waste to Destination NNSS for All Shipments ..... F-18
Table F-7. Comparison of Vehicle-related Risk for Trucking Waste Versus Trucking and Rail Transport of Waste to Destination NNSS ..... F-18
Table F-8. Summary of Inputs for Calculation of Emission Rates ..... F-24
Table F-9. East Bear Creek Valley Particulate Matter Calculations Summary ..... F-26

# ACRONYMS

| | |
|---|---|
| ABC | articulated bulk containers |
| ANL | Argonne National Laboratory |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| DOE | U.S. Department of Energy |
| EBCV | East Bear Creek Valley |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| ETSZ | East Tennessee Seismic Zone |
| ETTP | East Tennessee Technology Park |
| FEMA | Federal Emergency Management Agency |
| ILCR | Incremental Lifetime Cancer Risk |
| LLW | low-level waste |
| M | moment magnitude |
| MEI | maximally exposed individual |
| MMI | Modified Mercalli Intensity |
| NAAQS | National Ambient Air Quality Standard |
| NNSS | Nevada National Security Site |
| NOAA | National Oceanic and Atmospheric Administration |
| ORNL | Oak Ridge National Laboratory |
| ORR | Oak Ridge Reservation |
| PGA | peak ground acceleration |
| PM | particulate matter |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RI/FS | Remedial Investigation/Feasibility Study |
| SOF | sum of fraction |
| TEDE | total effective dose equivalent |
| TSCA | Toxic Substances Control Act of 1976 |
| U.S. | United States |
| USGS | U.S. Geological Survey |
| WAC | waste acceptance criteria |
| Y-12 | Y-12 National Security Complex |

This page intentionally left blank.

# 1. INTRODUCTION

This Appendix presents the methodology and results of risk assessments for the on-site and off-site disposal of waste expected to be generated by future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) actions on the United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR) after Environmental Management Waste Management Facility (EMWMF) capacity is reached. Risks were estimated based on transportation of wastes assumed to occur in the On-site and Off-site Disposal Alternatives, and based on natural phenomena and fugitive dust emissions associated with the On-site Disposal Alternative. Risk assessments were completed using computer codes developed at Argonne and Sandia National Laboratories: RADTRAN, RESRAD, and RISKIND.

RADTRAN code was developed at Sandia National Laboratories. RADTRAN combines user-determined demographic, routing, transportation, packaging, and materials data with meteorological data (partly user-determined) and health physics data to calculate expected radiological consequences of incident-free radioactive materials transportation and associated accident risks (Sandia 2009).

RESRAD is a family of codes developed at Argonne National Laboratory (ANL) for evaluating human health risk at sites contaminated with radioactive residues. RESRAD is a pathway analysis computer code that calculates radiation doses and cancer risks to a specified population group (ANL 2001).

RISKIND was developed at ANL for analyzing the potential radiological health consequences to individuals or specific population subgroups exposed to radiation materials through routine and accident transportation scenarios (ANL 1995).

Combining the use of RISKIND and RADTRAN models allowed a thorough assessment of the risk due to transporting the waste (on-site and off-site). This analysis is presented in Chapter 2 below. Chapter 3 presents the assessment of risk associated with natural phenomena scenarios (for the On-site Disposal Alternative) using the RESRAD code, while Chapter 4 presents an assessment of the fugitive dust exposures expected during construction of an on-site facility.

Risk due to seismicity were evaluated using U.S. Geological Survey probability and spectral acceleration calculators available at the following publicly accessible websites:

- https://geohazards.usgs.gov/eqprob/2009/index.php
- http://eqint.cr.usgs.gov/deaggint/2008/index.php,
- http://geohazards.usgs.gov/designmaps/us/application.php

As noted in Section 3.2.2, a more detailed seismic evaluation will be carried out as part of the design process.

# 2. TRANSPORTATION OF WASTE

The assessment of risk posed by transportation of CERCLA waste (on-site and off-site) was completed based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). As noted in this guidance, the primary end point for typical transportation risk assessments is the potential human health effect from exposure to low doses of radiation (cancer) or exposure to chemicals (toxic effects and cancer). As described in Chapter 2 of the Remedial Investigation/Feasibility Study (RI/FS), chemical contaminants for future waste streams to be disposed in the Environmental Management Disposal Facility (EMDF) are assumed to be similar to those of waste disposed at the EMWMF and contribute relatively minimal transportation risk. Because the risks to human health due to transportation are primarily from radioactive constituents in waste expected to be generated by future

CERCLA actions, this assessment is limited to scenarios based on radioactive waste characterizations. The risk assessment process for transportation is developed in Section 2.1 through Section 2.3. Section 2.4 presents the results of the assessment.

## 2.1 SCENARIO DEVELOPMENT

Transportation risk is associated with both the On-site and Off-site Disposal Alternatives. Parameters for evaluating transportation risk in the two cases, on-site transportation and off-site transportation, are discussed in the following sections. These include parameters associated with the alternatives: waste transported, routes traveled, vehicles used, and receptors (public and individuals) along the route. These parameters are the inputs to computer models used to ultimately determine the risks associated with transporting the waste.

### 2.1.1 On-Site Disposal Alternative

The proposed EMDF site that is evaluated in the On-site Disposal Alternative is located immediately east of the EMWMF in East Bear Creek Valley (EBCV). Cleanup actions at all three ORR sites, Oak Ridge National Laboratory (ORNL), Y-12 National Security Site (Y-12), and the East Tennessee Technology Park (ETTP) will generate CERCLA waste which will be transported to the on-site disposal facility. A single route was modeled that represented on-site transport for both the On-site Disposal Alternative and Off-site Disposal Alternative. Although there will be shorter and longer routes during the life of the project, a distance of 11 miles was assumed to be a representative distance for risk modeling from any of the three sites to EMDF for the On-site Disposal Alternative or from any of the three sites to the ETTP rail yard for the Off-site Disposal Alternative. This distance was selected after examining various travel distances from locations within ORNL, Y-12, and ETTP to the new EBCV site and various travel distances to the ETTP rail yard from locations within ORNL, Y-12, and ETTP. All wastes were considered (total number of shipments, all types of waste) to travel this route by truck for on-site transport risk analyses.

### 2.1.2 Off-Site Disposal Alternative

The scenario involving transportation of waste to an off-site disposal facility must first be analyzed according to the type of waste generated, in order to evaluate the routes the waste must travel. For purposes of mapping routes, the waste may be broken into three categories. Classified waste travels from the site of origin to the Nevada Nuclear Security Site (NNSS) for disposal. Low-level waste (LLW) and waste with LLW and Toxic Substances Control Act of 1976 (TSCA) components (LLW/TSCA) will travel by truck from the site of origin to ETTP rail yard, be transferred to rail where it will travel to Kingman, Arizona, be unloaded and then trucked from there to the NNSS disposal facility outside of Las Vegas, Nevada. The third route will be followed for waste with LLW and Resource Conservation and Recovery Act of 1980 (RCRA) hazardous components (LLW/RCRA) and will involve transfer by truck from the site of origin to ETTP, where it will be transferred to rail and transported directly to Clive, Utah, for disposal at Energy*Solutions* disposal facility.

### 2.1.3 Scenario Routes

To summarize, there are essentially six full or partial routes to be traveled for the on-site and off-site scenarios:

- Truck from waste origin to disposal at EMDF (transported on-site).
- Truck from waste origin to ETTP rail yard (transported on-site, but initial leg of off-site routes involving rail transport).
- Rail from ETTP rail yard to Kingman, Arizona, rail yard (off-site).

- Truck from Kingman, Arizona, rail yard to disposal at NNSS (off-site).
- Rail from ETTP rail yard to disposal at Energy*Solutions* site in Clive, Utah (off-site).
- Truck from waste origin to disposal at NNSS in Nevada (off-site).

The two on-site scenario routes listed above (waste origin to EMDF and waste origin to ETTP rail yard) were condensed into a single route "input" for modeling purposes, since the distance traveled is very similar and the mode of transport is the same. Combinations of partial routes make up the total off-site routes.

Figure F-1 is a schematic of all transportation routes used in modeling the risk.

Routes assumed to be followed in transporting the waste off-site were determined, and then input into the TRAGIS model developed at ORNL (ORNL 2000). Where possible, this model was used to determine population densities along the routes, miles traveled by state, and number of stops and locations, all of which provides input into dose calculation models RADTRAN and RISKIND. Additionally, TRAGIS output data were used in determining vehicle-related risks associated with transportation.

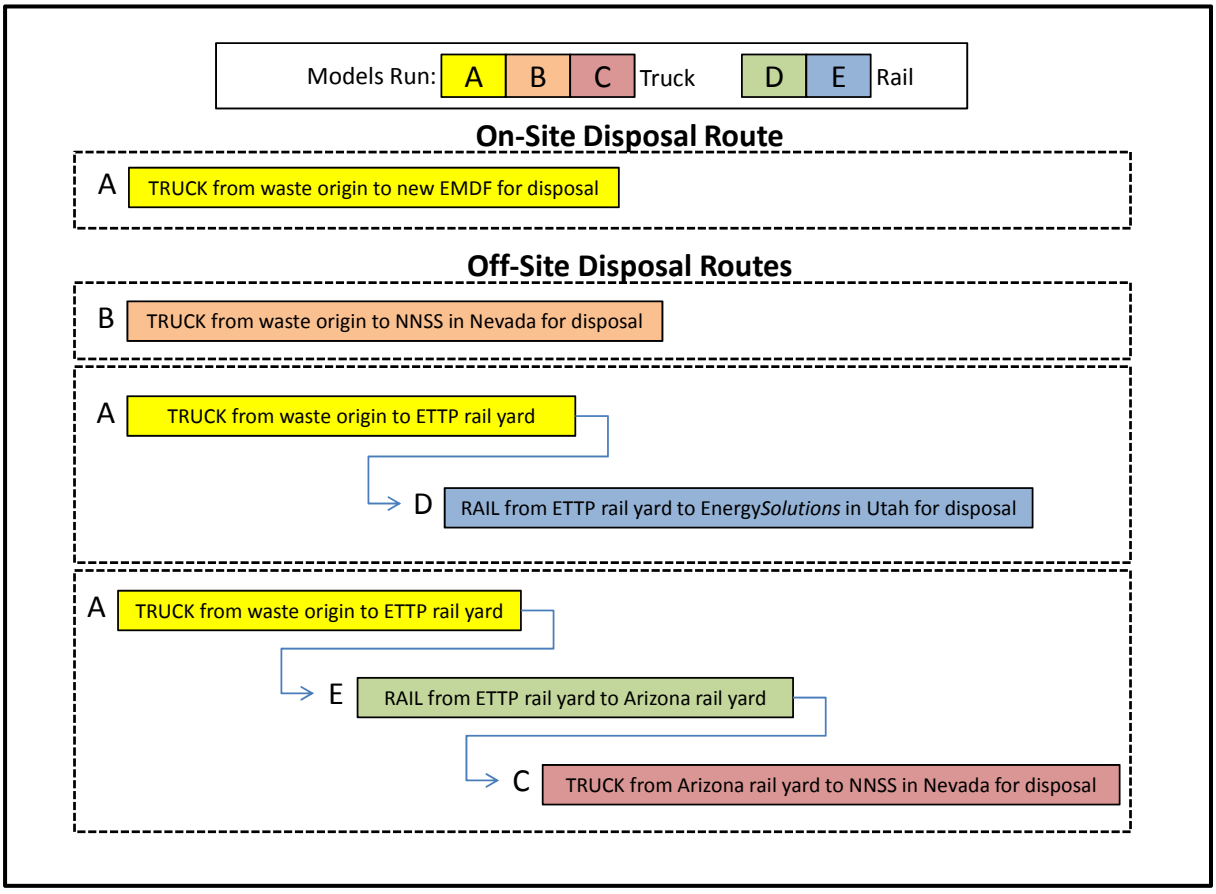



**Figure F-1. Transportation Routes Assessed in On-site and Off-site Disposal Alternatives**

### 2.1.4 Waste Parameters

Waste parameters are required in order to model the dose rates needed to ultimately determine the risk in transporting the waste for both on- and off-site disposal scenarios. The waste characterization data used were developed in Chapter 2 and Appendix A of this RI/FS; the mass-weighted average concentrations of nuclides are used in the models RISKIND and RADTRAN. Predicted waste generation rates and volumes are provided in Chapter 2 and Appendix A of this RI/FS. Chapter 6 of this RI/FS provides information about packaging and number of shipments which were determined for each of the routes described in Section 2.1.3 of this Appendix. Intermodal containers are assumed to be used, both for trucking and rail transport. These data also provide input to the dose calculation models. Section 2.3 contains a summary of inputs and assumptions to the models.

### 2.1.5 Receptors

Receptors are the collective groups or individuals exposed to the radioactive waste during transport. Dose models calculate exposures for multiple receptors under specific scenarios; the user must identify the receptors. For purposes of on-site transportation, the receptors were identified as the driver and a resident along the route. These individuals are referred to as maximally exposed individuals (MEIs). A collective population was evaluated as well, and in the case of on-site travel, the collective population includes the crew (only the driver in this case), off-link (resident along the route) populations, and handlers. For trucks traveling off-site individual receptors or MEIs identified for the truck routes in this assessment include the truck driver(s), a passenger in a car sharing the road, a person living or working along the transport route, a truck inspector at a weigh station, and a person at a service station. Collective populations evaluated include the crew (driver and passenger), on-link (i.e., persons sharing the road), and off-link (i.e., persons living/working on the route).

Rail transport MEIs included a resident along the route, rail inspector at the rail yard, rail yard crew member, person stuck in traffic near a rail line, and a resident near a rail stop. Collective populations evaluated for rail transport included: crew (engineer, conductor, brakeman), on-link, and off-link populations.

## 2.2 TRANSPORTATION RISK MODELING

Assessing risk encountered through the transportation of waste involves multiple pathways and multiple receptors. Figure F-2 illustrates transportation risk exposure through two primary modes – “cargo-related” (radiological risk), having to do with the waste itself and “vehicle-related” risk, risk independent of the cargo and having to do with the emissions, rate of speed, vehicle, and route/route-related parameters.

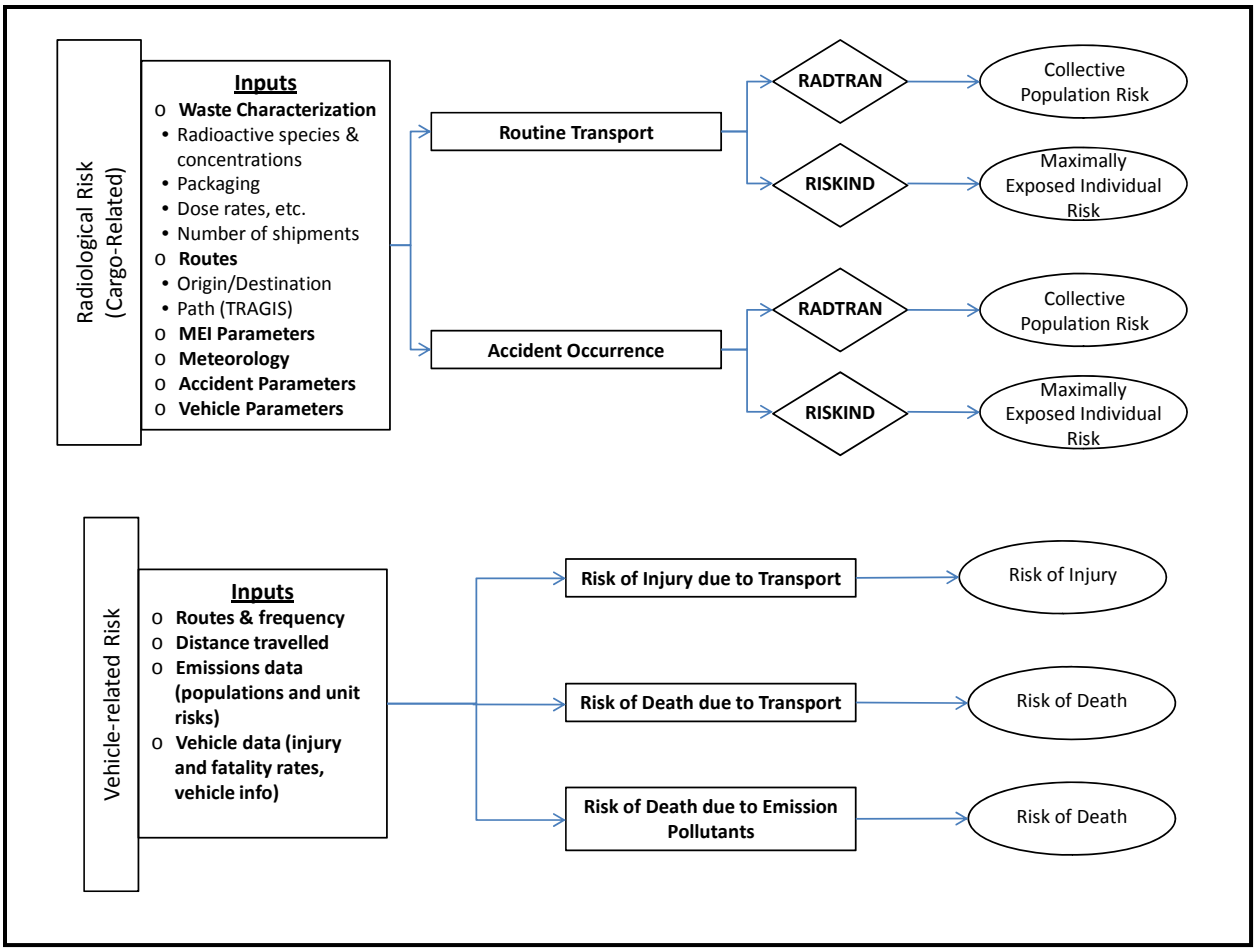



**Figure F-2. Approach to Determining Transportation Risk**

### 2.2.1 Radiological Risk

Radiological risk, presented by the cargo itself, is the primary concern when assessing transportation risk. Estimates of exposure to low levels of ionizing radiation during transportation are made through the use of computer models which estimate the dose levels received by various receptors. This exposure occurs in one of two ways (see Figure F-2), through routine travel or through accidents. In both cases, receptors of concern include the general public and individuals, MEIs. *A Resource Handbook on DOE Transportation Risk Assessment* recommends using two separate codes to estimate the doses that could potentially occur to various people or groups of people along the transportation routes in order to perform a uniform and comprehensive assessment. The handbook suggests that the RADTRAN code be used to evaluate doses to collective populations and the RISKIND code be used to predict the doses for MEIs. This assessment follows these recommendations and uses the inputs as described in Sections 2.1 and 2.3 and Figure F-2 to obtain estimated doses (in rem or person-rem) for various individuals or groups. In order to translate these doses to a unit of risk, the dose rates were converted into expected cancer incidents based on conversion factors derived from decades of studying radiation exposed populations (DOE 2003).

#### 2.2.1.1 RADTRAN Code

The RADTRAN code was used to predict radiological exposures as total effective dose equivalent (TEDE) in person-rem to collective populations in routine and accident transportation scenarios. These exposures are converted to terms reported for risk assessments (i.e., morbidity and mortality rates), using health risk conversion factors. For this RI/FS, RADTRAN was run for the five different routes (A through E) as shown in Figure F-1. For those routes that are made up of several partial routes, summing the output from the model is necessary to obtain information for the whole route.

#### 2.2.1.2 RISKIND Code

Like RADTRAN, RISKIND calculates exposures as TEDE during transportation of radioactive materials under routine and accident scenarios. RISKIND, however, was used to calculate the exposures to MEIs. RISKIND determines the dose rates that MEIs are exposed to independent of the route traveled. Therefore, it was only necessary to run the model for three scenarios which were dependent on the identified MEIs:

- Truck travel from waste origin to the proposed EMDF (drivers, resident along route).
- Truck travel from waste origin to NNSS or from Kingman, Arizona to NNSS (drivers, person in traffic, resident along route, truck inspector, and person at service station).
- Rail travel from ETTP rail to either Clive, Utah, or Kingman, Arizona (resident along the route, rail inspector at the rail yard, rail yard crew member, person stuck in traffic near a rail line, and a resident near a rail stop).

For those routes made up of more than one partial route, summing the output from the model is necessary to obtain information for the whole route. Exposure to individuals during routine travel is modeled as in-transit and stationary (e.g., traveling and stopped). For example, a truck may stop at a rest stop/restaurant for a short period of time, or stop overnight. Model inputs may be tailored to take into account all these situations. Again, summing the results for the different situations is required for a complete picture.

### 2.2.2 Vehicle-Related Risk

Vehicle-related risk is associated with travel; vehicle accidents occur, sometimes causing injuries and fatalities. In addition, risk due to emissions from vehicles must be considered, since extended exposure to fumes can cause illness and fatalities. These risk factors are functions of the inputs shown in Figure F-2: routes and frequencies traveled (related to amount of waste transported), routes dictate population densities and distances that must be accounted for; and vehicle data (truck and type of truck versus railcars) corresponds to tabulated injury and fatality rates. The processes followed and truck/rail injury and fatality rates used to calculate non-radiological (vehicle-related) risks were taken from *The DOE Risk Assessment Handbook* (DOE 2002).

## 2.3 ASSUMPTIONS AND INPUTS

The development of transportation risk scenarios and input to the modeling codes required multiple assumptions and minor calculations. The following assumptions and calculated inputs were assembled to complete the risk analysis.

**On-Site Disposal Alternative Assumptions and Inputs**

- All waste generated is considered to be disposed at the on-site facility. As described in Chapter 2 of the RI/FS, the small percentage of waste that does not meet the disposal facility waste acceptance criteria (WAC) or is shipped off-site due to other project-specific factors is not a differentiator in the alternatives and is not included in the RI/FS waste volume estimate.

- A single route is used for all on-site travel to the proposed EMDF, and this is sufficiently representative whether the waste is generated at ORNL, ETTP, or Y-12.
- It is estimated that 162,380 shipments of waste will be made.
- The MEIs include the driver of the truck and a resident/worker within the defined radial contamination range that the program evaluates. Travel is assumed to occur on a non-public road, and; therefore, the MEIs exposure analysis does not include a typical MEI in traffic with vehicle.
- Collective population considered includes the crew (essentially the driver), the off-link population (on route [i.e., resident/worker within the defined radial contamination range]), and handlers. On-link population specifically refers to a location on the road with the truck. Because the Haul Road is a private DOE road, no population is considered to be traveling with the vehicle on the road; therefore, no on-link population is considered for the collective population evaluation.
- Truck is considered to be a Class VIIIA, 16 ½ tons.
- Shielding is assumed to be provided for higher activity waste; therefore, a shielding factor of 0.5 is assumed.
- Shipping container is assumed to be an intermodal cask with dimensions 6 ft × 8 ft × 20 ft. The shipping container is assumed to hold 12 $yd^3$ of waste. Waste is assumed to have a density of 1.5 $g/cm^3$.
- Waste characterization is as determined in Appendix A of this RI/FS. Radionuclide mass-weighted average concentrations were converted from pCi/g to Ci/waste package and are summarized in Table F-1.
- Dose rate is assumed to be 1 mrem/hr at 1 m after verification of dose rate based on MICROSHIELD software calculations using the waste data discussed above in Section 2.1.4 and given in Table F-1. Gamma radiation is assumed.
- Dose measurement offset is 0 (i.e., edge of the intermodal container is the edge of the truck).
- During an accident scenario, MEIs will shelter in a nearby structure at a distance of 30 m.
- Minor accidents do not result in a release of material. Severe accidents do result in a release of material. A breathing rate of 9,200 $m^3$/year is assumed. This is the average breathing rate based on the default breathing rate of 8,000 $m^3$/year ($2.9\times10^{-4}$ $m^3$/sec) for RISKIND and the $3.3\times10^{4}$ $m^3$/sec default rate for RADTRAN.
- Automobile shielding is assumed for driver; house shielding for resident/worker.
- A summary of some pertinent input values for RADTRAN is given in Table F-2.
- Routine and accident scenarios are evaluated for MEIs and collective populations.

**Off-Site Disposal Alternative Assumptions and Inputs**

- See routes as defined in Figure F-1.
- Mixed waste (LLW/RCRA) is transferred to Energy*Solutions* in Clive, Utah for disposal.
- LLW and LLW/TSCA waste is transferred to NNSS for disposal.
- Classified waste is trucked to NNSS for disposal.
- Rail cars used are articulated bulk container (ABC) flat cars that hold eight intermodals. Weight limit is 354,000 lb maximum, allowing 36,000 lb per intermodal.
- For the off-site routes defined in which waste is *trucked*, the number of shipments made were calculated:
  - On-site transport (intermodals) to ETTP rail yard (and further transporting to Kingman, Arizona): -106,016

  - On-site transport (intermodals) to ETTP rail yard (and further transporting to Clive, Utah): 8,302
  - Off-site transport (transload from rail to truck, 1 intermodal = 1 shipment or same as on-site transport of intermodals to rail yard) from Kingman, Arizona, to NNSS: 106,016
  - Off-site transport of classified waste (intermodals) from ETTP to NNSS: 1,898
- For the off-site routes defined in which waste is transferred by *rail*, the number of shipments made were calculated as follows:
  - Off-site rail transport (eight intermodals per rail car ) from ETTP rail yard to Clive, Utah: 1,037
  - Off-site rail transport (eight intermodals per rail car) from ETTP rail yard to Kingman, Arizona: 13,252
- An ABC rail car is assumed to hold eight intermodals, stacked two high. This makes the rail car dimension 12 ft × 8 ft × 80 ft long.
- Waste characterization is as determined in Appendix A of this RI/FS. Radionuclide mass-weighted average concentrations were converted from pCi/g to Ci/waste package. The values (pCi/g) are given in Table F-1.
- The MEIs for off-site trucking included two drivers, a person in traffic, a resident/worker along the route, a truck inspector, and a person at a service station.
- Shielding is assumed to be provided for higher activity waste for off-site truck transport; therefore, a shielding factor of 0.5 is assumed.
- The MEIs for off-site rail transport included a person living/working along rail route, rail inspector at a rail yard, rail yard crew members, person stuck in traffic near a rail line, and a resident hear a rail stop.
- The collective population considered included the crew, on-link population (on road with truck/rail), off-link population (living/working on route), and handlers.
- All stops along the routes were as determined by TRAGIS model, plus one additional stop to account for traffic jams.
- A portion of the route for trucking waste from the ETTP rail yard to Palo Verde (the portion through Arizona only) was estimated because of the unavailability of the TRAGIS model.
- Population densities for travel along truck and rail routes were obtained from TRAGIS modeling. These population densities were based on 2000 census data. Census data from 2010 were obtained, and a weighted average increase from 2000–2010 was calculated to escalate the population densities input to the RADTRAN model.
- Numbers of persons during stops were assumed as: 10 (5–20 m) at rest/refuel stops, 10 (5–100 m) in traffic jams, and 1 (1–5 m) at inspections.
- Waste handled is soil-like, with a deposition rate of 3 m/sec.
- TRAGIS output was used for applicable routes, stops, and population densities.
- Vehicle speeds, accident rates, and fatality/injury rates were taken from a DOE Handbook (DOE 2002).
- Vehicle densities were taken from RADTRAN user manual (Sandia 2009).
- Accident probability was assumed to be 90% minor accidents, 10% severe accidents for trucking; and 98% minor accidents, 2% severe accidents for rail transport.
- Minor accidents do not result in a release of material. Severe accidents do result in a release of material.

- Dose rate is assumed to be 1 mrem/hr at 1 meter for an intermodal. Gamma radiation is assumed. Rail transport exposures involving multiple intermodals are taken into account by the models.
- Dose measurement offset is 0 (i.e., edge of the intermodal container is the edge of the truck).
- During an accident scenario, MEIs will shelter in a nearby structure at a distance of 30 m.
- A breathing rate of $2.9\times10^{-4}$ $m^3$/sec is assumed.
- For truck transport, automobile shielding is assumed for driver; house shielding for resident/worker.
- For non-radiological incidents, travel by truck was assumed to be round-trip distances. Travel by rail was assumed to be one-way; return trips would be made with other cargo.
- For rail transport, crew is assumed to not be exposed during transit. Driver is considered a crew member during stops. Rail inspectors are assumed to be unshielded.
- For MEI exposures, routine stops are assumed to produce a 10 to 15-minute exposure duration; short-term accidents a 2-hour exposure duration; and long-term accidents result in an assumed 50-year exposure duration due to contamination of land and therefore food sources.
- A summary of selected pertinent input values is given in Table F-2.
- Routine and accident scenarios are evaluated for MEIs and collective populations.

**Table F-1. Mass-weighted, Average Radionuclide Concentrations Used in Risk Assessment Modeling**

| Radionuclide | Average Concentration (pCi/g) | Radionuclide | Average Concentration (pCi/g) | Radionuclide | Average Concentration (pCi/g) |
|---|---|---|---|---|---|
| Ag-110m | 4.76E-01 | Fe-59 | 1.49E+00 | Pu-244 | 3.22E-02 |
| Am-241 | 9.18E+00 | H-3 | 1.91E+02 | Ra-226 | 9.10E-01 |
| Am-243 | 5.77E-01 | I-129 | 1.79E+00 | Ra-228 | 7.95E-01 |
| C-14 | 2.91E+01 | K-40 | 4.21E+00 | Ru-106 | 6.27E+04 |
| Cm-242 | 1.63E-01 | Kr-85 | 1.04E+02 | Sr-90 | 9.73E+03 |
| Cm-243 | 6.69E+00 | Mn-54 | 8.47E-01 | Tc-99 | 3.67E+01 |
| Cm-244 | 1.14E+04 | Nb-94 | 7.93E-02 | Th-228 | 4.27E-01 |
| Cm-245 | 1.39E-01 | Ni-59 | 4.04E+01 | Th-229 | 4.00E-03 |
| Cm-246 | 5.41E+00 | Ni-63 | 1.05E+02 | Th-230 | 1.55E+00 |
| Cm-247 | 9.55E-03 | Np-237 | 2.91E-01 | Th-232 | 1.69E+00 |
| Co-57 | 1.48E-01 | Pb-210 | 2.50E+00 | U-232 | 1.65E+00 |
| Co-60 | 5.05E+02 | Pm-147 | 1.00E+01 | U-233 | 8.13E+01 |
| Cs-134 | 2.48E+04 | Pu-238 | 5.69E+01 | U-234 | 2.69E+02 |
| Cs-137 | 5.83E+03 | Pu-239 | 1.17E+01 | U-235 | 1.63E+01 |
| Eu-152 | 6.43E+03 | Pu-240 | 1.74E+02 | U-236 | 1.14E+01 |
| Eu-154 | 4.85E+03 | Pu-241 | 2.01E+02 | U-238 | 1.60E+02 |
| Eu-155 | 1.41E+03 | Pu-242 | 3.79E-01 | Zn-65 | 1.46E+00 |

**Table F-2. Summary of Selected Input Parameters for RADTRAN**

| Parameter | Units | Truck Transport | Rail Transport |
|---|---|---|---|
| Dose at 1m from container | mrem/hr | 1.0 | 1.0 |
| Traveling speed | km/hr | 89 Rural<br>41 Suburban | 64.4 Rural<br>40.2 Suburban<br>24.2 Urban |
| Population density | people/km$^2$ | Varies by location on route (per TRAGIS) | Varies by location on route (per TRAGIS) |
| Persons per vehicle | Number of people | 1.5 | 3 |
| Accident exposure duration | hr or yr | Short-term 2 hour<br>Long-term 50 year | Short-term 2 hour<br>Long-term 50 year |
| Ratio minor accidents to major accidents | NA | 9:1 | 9.8:0.2 |
| Release fraction | (fraction of material released from package) | 0.1 | 0.1 |
| Aerosol fraction | (fraction of *release fraction* that is aerosolized) | 0.05 | 0.05 |
| Respirable fraction | (fraction of *aerosolized fraction* that can be inhaled) | 0.1 | 0.1 |

## 2.4 RISK RESULTS

The risk models require inputs as described in the sections above. Results from the models are typically given as dose rates, TEDEs, in units of person-rems. These values must then be multiplied by dose-to-risk conversion factors, also called health risk conversion factors, to result in the risk factors typically reported in assessments. For comparative purposes, such as this RI/FS, the DOE recommends using $6\times10^{-4}$ fatal cancers/TEDE and $8\times10^{-4}$ cancer illnesses/TEDE to convert to mortality and morbidity rates, respectively, for both collective populations and MEIs (DOE 2003). Table F-3 and F-4 summarize the results for this assessment, for the two alternatives: on-site and off-site disposal of CERCLA waste. Results are given for MEIs and collective populations, for both routine and accident situations. These numbers are reported for single shipments (see Table F-3) and multiplied by the number of shipments to calculate risk based on all shipments of all waste for each given alternative for the lifecycle of the project and; therefore, account for cumulative exposures over thousands or hundreds of thousands of shipments (see Table F-4). As expected, on-site transport of waste carries a significantly lower risk of cancer illnesses and fatalities than off-site transport of waste. Off-site Option 1 (majority of waste traveling to NNSS for disposal) is analyzed as the bounding option. Option 2, where the majority of waste is disposed at Energy*Solutions* would have lower risk due to a shorter distance traveled, and rail is used for the entire transport.

Table F-5 summarizes the risk rates for injuries and fatalities expected from vehicular operation due to exposure to emissions and expected traffic accidents for both alternatives. Again, as expected, travel required for on-site disposal results in far fewer fatalities and injuries due to vehicle-related incidents than does off-site travel and transport to disposal sites. Logically, this is because of the much reduced travel time/miles and avoidance of public roadways in the case of on-site transportation. As noted in Table F-5, for the off-site disposal, if all waste (with the exception of classified waste) were to be shipped to Energy*Solutions* in Clive Utah, the risks of injuries and fatalities would decrease by about a factor of 3 compared to the Off-site Disposal Alternative. However, the risks would still remain several orders of magnitude above the On-site Disposal Alternative risks.

**Table F-3. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Single Shipment**

| Receptor/Scenario | On-site Disposal Alternative | | Off-site Disposal Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Truck to EMDF | | Truck to NNSS | | Truck to ETTP Rail to Kingman Truck Kingman to NNSS | | Truck to ETTP Rail to Clive, UT | | Off-Site Total | |
| | Fatal | Non-fatal | Fatal | Non-fatal | Fatal | Non-fatal | Fatal | Non-fatal | Fatal | Non-fatal |
| **MEIs** | | | | | | | | | | |
| ***Routine Travel*** | | | | | | | | | | |
| Driver (Truck) or Crew Member (Rail) | 4.99E-08 | 6.65E-08 | 9.00E-06 | 1.20E-05 | 4.49E-07 | 5.99E-07 | 5.34E-08 | 7.12E-08 | 9.50E-06 | 1.27E-05 |
| Resident Along Route | 2.40E-08 | 3.20E-08 | 2.40E-08 | 3.20E-08 | 7.20E-08 | 9.60E-08 | 4.80E-08 | 6.40E-08 | 1.44E-07 | 1.92E-07 |
| ***Accidents*** | | | | | | | | | | |
| Driver (Truck) or Crew Member (Rail) | 7.68E-09 | 1.02E-08 | 7.68E-09 | 1.02E-08 | 2.17E-08 | 2.90E-08 | 1.40E-08 | 1.87E-08 | 4.34E-08 | 5.79E-08 |
| Resident Along Route | 3.06E-09 | 4.08E-09 | 3.06E-09 | 4.08E-09 | 1.28E-08 | 1.70E-08 | 9.72E-09 | 1.30E-08 | 2.56E-08 | 3.41E-08 |
| **Collective Population** | | | | | | | | | | |
| ***Routine Travel*** | | | | | | | | | | |
| Crew | 4.25E-08 | 5.66E-08 | 1.91E-05 | 2.54E-05 | 1.43E-07 | 1.91E-07 | 4.25E-08 | 5.66E-08 | 1.93E-05 | 2.57E-05 |
| On-Link | a | a | 1.06E-05 | 1.42E-05 | 8.79E-07 | 1.17E-06 | 3.27E-07 | 4.36E-07 | 1.18E-05 | 1.58E-05 |
| Off-Link | 3.91E-10 | 5.22E-10 | 7.74E-07 | 1.03E-06 | 4.66E-06 | 6.21E-06 | 3.61E-06 | 4.81E-06 | 9.04E-06 | 1.21E-05 |
| Handlers | 5.90E-07 | 7.87E-07 | 5.90E-07 | 7.87E-07 | 3.30E-06 | 4.40E-06 | 2.71E-06 | 3.61E-06 | 6.60E-06 | 8.80E-06 |
| ***Accidents*** | | | | | | | | | | |
| Societal Accident Exposure | 1.60E-13 | 2.13E-13 | 2.03E-09 | 2.71E-09 | 4.11E-09 | 5.48E-09 | 1.11E-09 | 1.48E-09 | 7.25E-09 | 9.67E-09 |

[a] No on-link analysis for on-site; all travel is on non-public road.

**Table F-4. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Multiple (All) Shipments**

| Receptor/Scenario | On-site Disposal Alternative | | Off-site Disposal Alternative (Option 1) (see assumptions Section 2.3 for explanation of number of shipments) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Truck to EMDF | | Truck to NNSS | | Truck to ETTP Rail to Kingman, AZ Truck Kingman to NNSS | | Truck to ETTP Rail to Clive, UT | | Off-Site Total | |
| | Number of shipments = 162,380 | | Number of shipments = 1,898 | | Number of shipments = 106,016 (to ETTP rail) 13,252 (rail to Kingman) 106,016 (Kingman to NNSS) | | Number of shipments = 8,302 (to ETTP rail) 1,037 (rail to Clive) | | | |
| | Fatal | Non-fatal | Fatal | Non-fatal | Fatal | Non-fatal | Fatal | Non-fatal | Fatal | Non-fatal |
| **MEIs** | | | | | | | | | | |
| ***Routine Travel*** | | | | | | | | | | |
| Driver (Truck) or Crew Member (Rail) | 8.10E-03 | 1.08E-02 | 1.71E-02 | 2.28E-02 | 4.73E-02 | 6.31E-02 | 4.18E-04 | 5.57E-04 | 6.48E-02 | 8.64E-02 |
| Resident Along Route | 3.90E-03 | 5.20E-03 | 4.56E-05 | 6.07E-05 | 5.41E-03 | 7.21E-03 | 2.24E-04 | 2.99E-04 | 5.68E-03 | 7.57E-03 |
| ***Accidents*** | | | | | | | | | | |
| Driver (Truck) or Crew Member (Rail) | 1.25E-03 | 1.66E-03 | 1.46E-05 | 1.94E-05 | 1.71E-03 | 2.28E-03 | 7.04E-05 | 9.38E-05 | 1.80E-03 | 2.40E-03 |
| Resident Along Route | 4.97E-04 | 6.63E-04 | 5.81E-06 | 7.74E-06 | 7.37E-04 | 9.83E-04 | 3.23E-05 | 4.31E-05 | 7.75E-04 | 1.03E-03 |
| **Collective Population** | | | | | | | | | | |
| ***Routine Travel*** | | | | | | | | | | |
| Crew | 6.90E-03 | 9.20E-03 | 3.62E-02 | 4.83E-02 | 1.52E-02 | 2.03E-02 | 3.53E-04 | 4.70E-04 | 5.18E-02 | 6.90E-02 |
| On-Link | a | a | 2.02E-02 | 2.69E-02 | 6.26E-02 | 8.35E-02 | 4.97E-04 | 6.62E-04 | 8.32E-02 | 1.11E-01 |
| Off-Link | 6.35E-05 | 8.47E-05 | 1.47E-03 | 1.96E-03 | 6.84E-02 | 9.13E-02 | 3.74E-03 | 4.99E-03 | 7.37E-02 | 9.82E-02 |
| Handlers | 9.59E-02 | 1.28E-01 | 1.12E-03 | 1.49E-03 | 1.53E-01 | 2.04E-01 | 7.10E-03 | 9.46E-03 | 1.62E-01 | 2.15E-01 |
| ***Accidents*** | | | | | | | | | | |
| Societal Accident Exposure | 2.59E-08 | 3.46E-08 | 3.86E-06 | 5.15E-06 | 1.16E-04 | 1.54E-04 | 1.15E-06 | 1.54E-06 | 1.21E-04 | 1.61E-04 |

[a] No on-link analysis for on-site; all travel is on non-public road.

**Table F-5. Transportation Risk Assessment, Injury and Fatality Risk from Vehicle-related Incidents**

| Scenario | Emissions | Vehicle Travel | |
|---|---|---|---|
| | Fatal | Fatal | Non-Fatal |
| **On-site Disposal Alternative** | | | |
| Truck to EMDF | 1.02E-02 | 2.29E-02 | 7.94E-01 |
| **Off-site Disposal Alternative Option 1** | | | |
| Truck to NNSS | 4.65E-01 | 1.28E-01 | 2.22E+00 |
| Truck to ETTP;<br>Rail to Clive, UT | 9.13E-02 | 4.36E-02 | 1.43E-01 |
| Truck to ETTP;<br>Rail to Kingman, AZ;<br>Truck to NNSS | 6.91E+00 | 1.07E+00 | 1.27E+01 |
| **Off-site Disposal Alternative Total*** | **7.47E+00** | **1.24E+00** | **1.51E+01** |
| **All waste shipped for disposal by rail to Energy*Solutions* in Clive, Utah (Option 2)** | **1.73E+00** | **7.3E-01** | **4.19E+00** |

## 2.5 RAIL VERSUS TRUCK COMPARISON

A comparison using only the NNSS disposal site destination was performed to analyze the risk posed by transporting all waste by truck to the western disposal sites, as opposed to a majority of the waste being transported to these sites by rail. LLW and LLW/TSCA waste transported by truck to the ETTP rail yard, then by rail from the ETTP rail yard to Kingman, Arizona, and finally by truck from Kingman to the NNSS site for disposal was analyzed as part of the off-site disposal option. Additionally, classified waste transport by truck only from the ORR to NNSS was analyzed. Thus, this same truck route (ORR to NNSS) was modified to include the increased shipments of the LLW and LLW/TSCA waste streams in order to make a side-by-side comparison of truck versus rail transport. Outputs from RADTRAN runs, for the collective population risk, and RISKIND runs, for the MEI risk, for single shipments, were used and number of shipments modified to allow this comparison.

Table F-6 summarizes the comparison of radiological risk for the original shipment route using rail transportation (all shipments) versus the truck route to NNSS, for the same number of shipments. There is actually little difference for accident scenarios since the rail route also has a trucking leg from Kingman to NNSS. However, large differences are seen in the risk to drivers, crew, and on-link populations during routine travel due to the much larger number of shipments by truck.

Table F-7 summarizes the same comparison, in terms of vehicular risk. As expected, vehicle-related risks are significantly higher when all the waste is trucked versus when rail transport is used where possible.

**Table F-6. Comparison of Radiological Risk for Trucking Waste versus Trucking and Rail Transport of Waste to Destination NNSS for All Shipments**

| Receptor/Scenario | Truck Transport Only | | Truck and Rail Transport | |
|---|---|---|---|---|
| | Truck to NNSS | | Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS | |
| | Fatal | Non-Fatal | Fatal | Non-Fatal |
| **MEIs** | | | | |
| ***Routine Travel*** | | | | |
| Driver (Truck) or Crew Member (Rail) | 9.54E-01 | 1.27E+00 | 4.73E-02 | 6.31E-02 |
| Resident Along Route | 2.54E-03 | 3.39E-03 | 5.41E-03 | 7.21E-03 |
| ***Accident*** | | | | |
| Driver (Truck) or Crew Member (Rail) | 8.14E-04 | 1.09E-03 | 1.71E-03 | 2.28E-03 |
| Resident Along Route | 3.24E-04 | 4.33E-04 | 7.37E-04 | 9.83E-04 |
| **Collective Population** | | | | |
| ***Routine Travel*** | | | | |
| Crew | 2.02E+00 | 2.70E+00 | 1.52E-02 | 2.03E-02 |
| On-Link | 1.13E+00 | 1.50E+00 | 6.26E-02 | 8.35E-02 |
| Off-Link | 8.21E-02 | 1.09E-01 | 6.84E-02 | 9.13E-02 |
| Handlers | 6.26E-02 | 8.35E-02 | 1.53E-01 | 2.04E-01 |
| ***Accident*** | | | | |
| Societal Accident Exposure | 2.16E-04 | 2.88E-04 | 1.16E-04 | 1.54E-04 |

**Table F-7. Comparison of Vehicle-related Risk for Trucking Waste versus Trucking and Rail Transport of Waste to Destination NNSS**

| Scenario | Emissions | Vehicle Travel | |
|---|---|---|---|
| | Fatal | Fatal | Non-Fatal |
| **Truck Transport Only** | | | |
| Truck to NNSS | 2.60E+01 | 7.15E+00 | 1.24E+02 |
| **Truck and Rail Transport** | | | |
| Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS | 6.91E+00 | 1.07E+00 | 1.27E+01 |

# 3. NATURAL PHENOMENA HAZARDS

Two natural hazards, tornados and earthquakes, are considered in this evaluation, since these are the most likely potential natural phenomena that could affect the EMDF. Floods were not considered because no portion of the EMDF or its support areas/facilities will be located within either the 100-year or 500-year floodplains of Bear Creek. Mass wasting phenomena, such as landslides or rock fall, in this region tend to be small and localized. The potential for mass wasting, and the means to prevent such events, is addressed as part of the design process, and is not considered here.

## 3.1 TORNADO RISKS

Potential risk to human health via exposure to contamination from on-site disposal facilities was assumed to occur through three natural phenomena mechanisms: earthquake activity, sinkhole development, and tornado activity. This assessment only analyzes risk posed by the occurrence of a tornado for the following reasons: the potential for release of contamination resulting from an earthquake is assumed to be addressed by the design of the disposal facility, and site-selection criteria preclude building the disposal facility at a location underlain by the karst geology, which is most likely to cause a sinkhole to develop. In the east Tennessee area, the probability of a tornado strike is estimated as $4.26\times10^{-5}$/year (FEMA 2009, NOAA 2011). Although a low probability is associated with this natural phenomenon, the consequences of such an event could be high. An estimate of the human health risk posed by a tornado striking the on-site disposal facility and releasing contamination was made using the RESRAD computer code, and is presented here. Note that this risk assessment, as with the transportation risk assessment, considers the risk posed by release of radioactively contaminated waste as far exceeding the risk posed to the public by any contained chemical hazards; therefore, only the radioactive portion of the waste is considered in the assessment.

### 3.1.1 Model Inputs and Assumptions

Two RESRAD models were considered for use in evaluating the risk to the public presented by an on-site disposal facility, RESRAD and RESRAD OFFSITE. RESRAD OFFSITE was not used in this evaluation. It was determined that RESRAD OFFSITE is more suited for risk of the landfill liner or cover system failing and affecting nearby residents. Such a risk would be evaluated when the design for a liner is being engineered. The model that was used in this evaluation is RESRAD. It was used to evaluate the human health risk presented assuming a scenario whereby a tornado hits the open face of the cell and disperses contaminated debris. Inputs required to evaluate this scenario include: radioactive species and concentrations; extent of contamination (area and depth); local environmental parameters (air, geology, hydrology inputs); human parameters (inhalation rates, population, etc.); and a specified time period for evaluation.

Based on the EMWMF safety basis and current operating procedures at EMWMF, the assumption was made that the maximum open face of the disposal cell is 15 acres (BJC 2009).

Additionally, as specified in the previous *EMWMF Remedial Investigation/Feasibility Study* (DOE 1998), the tornado is assumed to spread contaminated debris across a 10 square mile area (assumed circular – corresponds to a radius of approximately 1 ¾ miles). In reference to the open, exposed face (using the maximum open face of the cell, 15 acres) of the cell, a scour depth of 6 in. is assumed.

Mass-weighted averages were used as input to the RESRAD model and are given in Table F-1. Average radionuclide concentrations used in the model were determined from waste lots in waste disposed to date at EMWMF (see Chapter 2 and Appendix A of this RI/FS). These radionuclide concentrations were then assumed to be present in waste evaluated for natural phenomenon risk due to tornado strike. Radionuclide concentration data for waste lots that had an EMWMF WAC sum of fractions (SOFs) exceeding 0.05

were not excluded from the analysis. This approach is conservative because, in practice at EMWMF, the facility authorization basis and operational controls require adjustments to normal operating practices be made prior to disposal of waste lots with an audible safety analysis-derived WAC SOF that exceeds 0.05. These adjustments, such as containerizing waste or further limiting the open cell face area, would prevent release of the waste.

Site geology and hydrology parameters were input to the model based on several hydrologic reports conducted for ORNL (ORNL 1988, 1989, 1992, 2006). The specific values used in the model are listed below:

- Saturated zone porosity: 0.4
- Saturated zone hydraulic gradient: 0.05
- Well pump intake (meters below water table): 20 m
- Overburden (unsaturated zone thickness): 12 m

Model inputs for ingestion, occupancy, and dose remained as model default values.

### 3.1.2 Tornado Probability

Tornado probabilities are estimated based on frequency of occurrence (either based on historical data or contour maps developed from historical data), and parameters defining the severity of the tornadoes. The method used to calculate the probability is presented in the *Federal Emergency Management Agency* (*FEMA*) *Benefit-Cost Analysis Reengineering (BCAR) Version 4.5* (FEMA 2009). Historical data for the two counties in which the ORR resides (Anderson and Roane Counties) were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service Weather Forecast Office records (NOAA 2011). A probability of $4.26\times10^{-5}$ was estimated based on these two reference sources.

### 3.1.3 Modeling Results

Two RESRAD runs were made, with all input variables held constant with the exception of the duration. Long term effects were examined out to 100,000 years, which registered the highest risk within the first six years. Therefore, a second run was made with a six-year duration to focus on the highest risk data/output. The model was used to calculate the estimated Incremental Lifetime Cancer Risk (ILCR) resulting from the assumed activity (in this case tornado) based on conservative exposure pathways. Contamination pathways examined included incidental ingestion of soil, inhalation of contaminated dust, external exposure to gamma radiation, ingestion of contaminated food products (fish, milk, meat, vegetables), and exposure to contaminated ground water and surface water.

The ILCR as calculated by RESRAD from radiation exposure resulting from tornado-dispersed contamination is $2.90\times10^{-4}$ at the peak risk (immediately following dispersion). Applying the probability of tornado occurrence ($4.26\times10^{-5}$) and a 30-year operating window (which is somewhat higher than the current assumed life-cycle of 23 years) for the disposal facility results in a maximum total aggregate risk of $3.71\times10^{-7}$.

## 3.2 SEISMIC RISKS

DOE O 420.1A and Tennessee Department of Environment and Conservation Rule 0400-20-11-.16 (5) require that radiologic facilities be designed, constructed, and operated so that the public, employees, and environment are protected from the adverse impacts of natural phenomena hazards, including earthquakes. The ORR lies within the Eastern Tennessee Seismic Zone (ETSZ), a seismically active area that extends from central Alabama to southern West Virginia and is roughly coincident with the Valley

and Ridge Physiographic Province. Although there are a number of inactive faults formed during the late Paleozoic Era passing through the ORR, there are no known or suspected seismically capable faults[1]. A recent paleoseismic investigation (Vaughn et al., 2010) found preliminary evidence of surficial faulting near Dandridge, Tennessee, located approximately 75 km to the east of the ORR. The focal depths of most earthquakes in ETSZ range from 5–22 km (Vlahovic et al., 1998; Chapman et al., 2002).

### 3.2.1 Historical Seismicity

Numerous historical earthquakes have affected Eastern Tennessee. The series of three large earthquakes in 1811–1812 in the New Madrid Seismic Zone are believed to have resulted in a Modified Mercalli Intensity (MMI) of V to VI in Knoxville, Tennessee (Hough et al., 2000). Other smaller, nearby historical earthquakes in 1844, 1913, 1928, and 1956 produced epicentral MMI values between VI and VII (Stover and Coffman, 1993). See Figure F-3 for a description of the MMI scale.

| Intensity | Shaking | Description/Damage |
|---|---|---|
| I | Not felt | Not felt except by a very few under especially favorable conditions. |
| II | Weak | Felto nly by a few persons at rest,especially on upper floors of buildings. |
| III | Weak | Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated. |
| IV | Light | Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. |
| V | Moderate | Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. |
| VI | Strong | Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. |
| VII | Very strong | Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. |
| VIII | Severe | Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. |
| IX | Violent | Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. |
| X | Extreme | Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. |

**Figure F-3. Modified Mercalli Intensity Scale (from U.S. Geological Survey)**

Since 1970, there have been 68 recorded earthquakes with moment magnitudes (Ms) of 3.0 or greater within 200 km of the ORR (USGS 2014). The largest of these are the 1973 M4.7 Maryville, Tennessee, and the 1987 M4.3 Vonore, Tennessee earthquakes. However, Vaughn et al. (2010) found preliminary, paleoseismic evidence of one or more "strong" earthquakes during the late Quaternary period that suggest the potential for earthquakes larger than those recorded to date. Accordingly, recent values of the weighted average maximum earthquake magnitude associated with the ETSZ for seismic hazard mapping range from M6.6 to M6.8 (EPRI, 2008; 2012).

[1] As defined in 10 CFR 100, Appendix A, a seismically capable fault is one that has had movement at or near the ground surface at least once within the past 35,000 years, or recurrent movement within the past 500,000 years.

### 3.2.2 Future Seismicity

A site-specific seismic hazard study has not been performed to date, but a preliminary estimate of the future seismic hazard may be obtained from the U.S. Geological Survey (USGS) (Petersen et al., 2008). Figure F-4 shows the uniform hazard response spectrum for a reference firm rock site condition (Site Class B) for a 90% probability of non-exceedance during a 250-year period, which is the hazard level specified by the Tennessee Department of Solid Waste Management (1993) and corresponds to an annual frequency of exceedance of $4.2\times10^{-4}$ or a return period of 2,373 years (i.e., one event in 2,373 years). The peak ground acceleration (PGA) is approximately 0.22 g, and the maximum spectral acceleration ($S_a$) of approximately 0.49 g occurs at a period (T) of 0.1 sec.

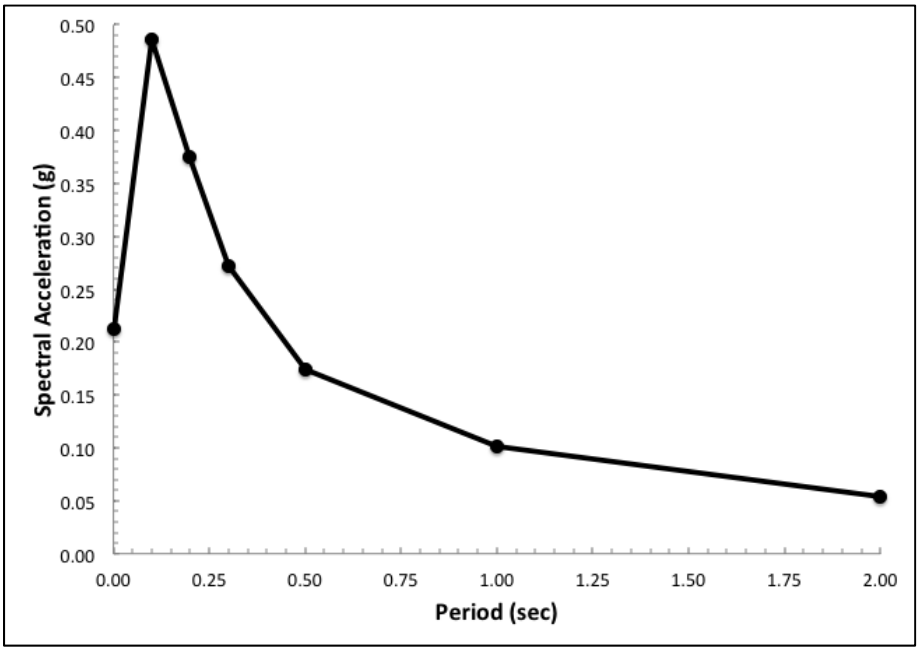



**Figure F-4. Uniform Hazard Response Spectrum for 90% Probability of Non-Exceedance in 250 years**

(Return Period = 2,373 years) for B/C Site Conditions Based on 2008 U.S. Geological Survey Seismic Hazard Maps

The dominant sources of the seismic hazard obtained via deaggregation of the probabilistic seismic hazard are approximately M4.8 and R = 14.3 km for short-period spectral accelerations (PGA and $S_a$ at T = 0.2 sec) and M7.7 and R = 448 km for long-period spectral accelerations ($S_a$ at T = 1.0 sec). These sources are consistent with the historical seismicity at ORR described previously.

Site-specific seismic hazard analyses and design calculations will be prepared for the EMDF following the methods given by the Tennessee Department of Solid Waste Management (TDSWM 1993) or other appropriate methodology. The EMDF will be designed to meet applicable seismic hazard design requirements.

# 4. FUGITIVE DUST EMISSIONS

For the On-site Disposal Alternative, estimates of fugitive dust emissions generated and transported during construction activities were determined and compared to National Ambient Air Quality Standards (NAAQS) limits for particulate emissions. U.S. Environmental Protection Agency (EPA) research has shown that particulate emissions from open sources such as unpaved roads, borrow areas, spoil areas, general grubbing, and disposal cell construction can contribute significantly to ambient air particulate matter (PM) concentrations. Regarding activities considered in the construction of an on-site disposal facility, the NAAQS PM limit of interest is $PM_{10}$ (particles with a mean aerodynamic diameter greater than 2.5 µm and less than or equal to 10 µm). The nearest residence to the construction site placed the location of interest at approximately 1,350 m horizontally distant from the proposed EMDF site in EBCV. The estimation of fugitive dust emission for this RI/FS follows guidance contained in the EPA's *Compilation of Air Pollutant Emission Factors* (AP-42, EPA 1995).

## 4.1 METHOD

Estimates of PM concentrations are based on activities assumed to take place throughout the life of the construction project. Four main activities were defined for on-site construction of a disposal facility, consisting of more specific, daily elements as follows:

**Activity 1 – Clearing and Grubbing**

- Bulldozing
- Material hauling
- Material loading and unloading
- Spoils handling/spreading

**Activity 2 – Topsoil Removal**

- Topsoil removal by scrapers
- Material hauling
- Material unloading
- Spoils handling/spreading

**Activity 3 – Excavation Earthwork**

- Dozers excavating
- Material loading and unloading
- Material hauling
- Spoils handling/spreading

**Activity 4 – Fill/Borrow Earthwork**

- Hauling on-site (only haul from State Route 95 to stockpile was considered)
- Unloading at stockpile
- Loading to go to cell
- Hauling to cell from stockpile
- Unloading at cell

- Grading with dozers at cell
- Compacting with rollers at cell

The main activities were assumed to take place in sequence, that is, only one main activity occurred at one time, with all daily elements occurring simultaneously. Particle emission rates (mass/time) were calculated for each daily element in the main activities. These emission rates are calculated based on several parameters and assumptions that are summarized in Table F-8. Methods used for calculating emission rates were those presented in AP-42 (EPA 1995).

**Table F-8. Summary of Inputs for Calculation of Emission Rates**

| **Parameters Used in Calculations of Emission Rates for Construction Activities (Non-site Specific):** |
|---|
| • Average 120 days of rain annually<br>• 250 work days per year<br>• Wind speed 4.1 mph<br>• Mean vehicle speed of 7.1 mph (applicable only to grading operations)<br>• Silt content of the gravel haul roads of 6% |
| **Assumptions:** |
| • Only one of the four main activities will occur at one time.<br>• All off-site areas (such as aggregate facility or borrow area) will be managed by the operator and would not need to be assessed in this evaluation.<br>• Vehicle emissions would be negligible in comparison to the dust generated by the construction activities (consequences of vehicle emissions are examined and discussed as part of the Transportation Risk – see Section 2.2.2).<br>• Salt is used on roads for ice control, not sand/gravel and; therefore, are removed from calculations.<br>• Unpaved roads travelled are considered as industrial (not public).<br>• The different materials handled during the various activities would have varying moisture and silt contents.<br>• The different materials handled during the various activities would result in varying mean vehicle weights. |

Emission rates may be reduced by implementing controls to reduce the dust generation/transport. Controls include spraying water to reduce dust generation, limiting speeds, using enclosures, sweeping, using coverings such as straw, revegetation, etc. For this study, emission rates for hauling activities/elements (on the existing gravel Haul Road) were adjusted by a 74% control efficiency for water and additionally, by a 44% control efficiency for setting a speed limit of 25 mph. These efficiency rates are based on documentation provided by the Western Regional Air Partnership's Fugitive Dust Handbook. Natural dust suppression caused by regional precipitation is already factored into the uncontrolled emission rate by the equation provided in the AP-42 document. Unloading topsoil from scrapers and spreading topsoil was modified by a 74% control efficiency for the application of water sprayed by water trucks, as was excavating operations involving dozing, loading, and unloading spoils. These credits reduced the emission rates significantly for the specified elements.

Emission rates were converted to per-unit-area rates based on footprints that were estimated for each sub-activity/element. Each element within a main activity has an assumed footprint. For example within activity 3 (excavation earthwork) a footprint for bulldozer excavations is specified, which is different from the dump truck hauling footprint, which is also different from the spoils handling/spreading

footprint. The area-based emission rates are input to the EPA code SCREEN3 (EPA 1995), along with other site-specific data such as distance to the location of interest (resident), to generate $PM_{10}$ concentrations. The resultant $PM_{10}$ concentrations are peak hourly concentrations that must be averaged over a 24-hour period (based on an eight hour work day) to obtain the $PM_{10}$ values for the nearest resident location. This 24 hour averaged $PM_{10}$ value is then compared to the EPA NAAQS $PM_{10}$ limit of 150 $\mu g/m^3$.

## 4.2 RESULTS

The column on the far right of Table F-9 lists the final 24-hour $PM_{10}$ total concentrations for each main activity. The values are obtained by summing the SCREEN3 output $PM_{10}$ concentrations for all elements in a given activity. As seen in the table, the $PM_{10}$ values for the site, with respect to the nearest resident location, fall below the $PM_{10}$ limit of 150 $\mu g/m^3$ specified in the NAAQS.

**Table F-9. East Bear Creek Valley Particulate Matter Calculations Summary**

| Activity (1-4) and Corresponding Elements, Grouped by Footprint | | | Emissions Rate (lb/hr) | Combined Emissions Rate for Application to Footprint | | SCREEN3 Inputs | | | SCREEN3 Output | 24-hr $PM_{10}$ for Each Activity at Residence ($\mu g/m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (lb/hr) | (g/s) | Footprint, Larger Side (m) | Footprint, Smaller Side (m) | Emission Rate ($g/s\text{-}m^2$) | $PM_{10}$ ($\mu g/m^3$) | |
| Activity 1- Site Clearing & Grubbing | Clearing Footprint | Clearing/Grubbing by Dozer | 1.34 | 1.34 | 0.17 | 63.7 | 63.7 | 4.16E-05 | 13.00 | 113 |
| | | Loading Veg into Dump Truck | 0.0024 | | | | | | | |
| | Haul | Hauling to Spoils | 13.4 | 13.4 | 1.69 | 1563.6 | 157.0 | 6.88E-06 | 86.00 | |
| | Spoils Footprint | Unloading Dump Truck | 0.0024 | 1.34 | 0.17 | 45.1 | 45.1 | 8.30E-05 | 13.67 | |
| | | Spreading Spoils | 1.34 | | | | | | | |
| Activity 2- Topsoil Removal | Clearing Footprint | Topsoil Removal | 6.29 | 6.29 | 0.79 | 98.8 | 98.8 | 8.13E-05 | 24.32 | 133 |
| | Haul | Hauling to Spoils | 9.43 * | 9.43 * | 1.19 | 1563.6 | 157.0 | 4.84E-06 | 60.33 | |
| | Spoils Footprint | Unloading Scraper | 3.33 * | 4.78 * | 0.60 | 49.4 | 49.4 | 2.47E-04 | 48.67 | |
| | | Spreading Topsoil with Dozer | 1.45 * | | | | | | | |
| Activity 3- Excavating Operations | Excavation Footprint | Dozer Excavating | 5.58 | 5.59 | 0.70 | 31.4 | 31.4 | 7.15E-04 | 25.33 | 102 |
| | | Loading into Dump Truck | 0.0088 | | | | | | | |
| | Haul | Hauling to Spoils | 8.05 * | 8.05 * | 1.01 | 1563.6 | 157.0 | 4.13E-06 | 51.33 | |
| | Spoils Footprint | Unloading Dump Truck | 5.58 | 5.59 | 0.70 | 40.2 | 40.2 | 4.35E-04 | 24.96 | |
| | | Spreading Spoils | 0.0088 | | | | | | | |
| Activity 4- Fill Placement | Haul Stock | Soil Hauling to Stockpile | 6.49 * | 6.49 * | 0.82 | 823.0 | 83.8 | 1.19E-05 | 60.66 | 144 |
| | Stockpile Footprint | Unloading at Stockpile | 0.029 | 0.044 | 0.01 | 38.7 | 38.7 | 3.70E-06 | 0.45 | |
| | | Loading at Stockpile | 0.015 | | | | | | | |
| | Haul | Hauling from Stockpile to Cell | 1.66 | 1.66 | 0.21 | 61.0 | 7.3 | 4.69E-04 | 17.67 | |
| | Fill Footprint | Unloading at Cell | 4.43 | 6.66 | 0.84 | 61.6 | 61.6 | 2.21E-04 | 66.33 | |
| | | Compacting at Cell | 2.21 | | | | | | | |
| | | Grading at Cell | 0.015 | | | | | | | |

* Value has been modified to take credit for dust controls by multiplying the original emissions rate by an appropriate control efficiency.

# 5. REFERENCES


ANL 1995. *RISKIND –A Computer Program for Calculating Radiological Consequences and Health Risks form Transportation of Spent Nuclear Fuel*, ANL/EAE-1, Argonne National Laboratory, November 1995, Argonne, IL.

ANL 2001. *User's Manual for RESRAD Version 6*, ANL/EAE-4, Argonne National Laboratory, July 2001, Argonne, IL.

EPA 1995.*Compilation of Air Pollutant Emission Factors*, AP-42 Fifth Addition, Environmental Protection Agency, January 1995, Research Triangle Park, NC.

BJC 2009. *Hazard Assessment Document for the Environmental Management Waste Management Facility*, HAE-YT-EMWMF-0020 Rev. 8, Bechtel Jacobs Company LLC, August 2009, Oak Ridge TN.

Chapman, M.C., Munsey, J.W., Powell, C.A., Whisner, S.C., and Whisner, J. (2002). "The Eastern Tennessee Seismic Zone: Summary after 20 years of Network Monitoring," *Seismological Research Letters*, 73(2), 245.

DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

DOE 2002. *A Resource Handbook on DOE Transportation Risk Assessment*, DOE/EM/NTP/HB-1, DOE Transportation Risk Assessment Working Group Technical Subcommittee, July 2002, Albuquerque, NM.

DOE 2003. *Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE) ISCORS Technical Report No. 1*, DOE/EH-412/0015/0802 rev.1, Department of Energy, January 2003, Washington DC.

Electric Power Research Institute. (2008). *White Paper on Seismic Hazard in the Eastern Tennessee Seismic Zone*. Prepared for EPRI by Risk Engineering, Inc., Boulder, CO. May 12.

Electric Power Research Institute. (2012). *Technical Report: Central and Eastern United States Seismic Source Characterization for Nuclear Facilities*. EPRI, Palo Alto, CA, U.S. DOE, and U.S. NRC: 2012.

FEMA 2009. *FEMA Benefit-Cost Analysis Reengineering (BCAR) Version 4.5: Tornado Safe Room Module*, BCAR Ver. 4.5, Federal Emergency Management Agency, May 2009, Washington DC.

Hough, S. E., Armbruster, J. G., Seeber, L., and Hough, J. F. (2000). "On the Modified Mercalli Intensities and Magnitudes of the 1811-1812 New Madrid Earthquakes," *Journal of Geophysical Research*, 105(B10), 23,839-23,864, October.

NOAA 2011. National Oceanic and Atmospheric Administration (NOAA) National Weather Service Weather Forecast Office Records, 1953 to June 2011, http://www.srh.noaa.gov/mrx/?n=mrx_tornado_db.

ORNL 1988. *Concepts of Groundwater Occurrence and Flow Near Oak Ridge National Laboratory, Tennessee*, ORNL/TM-10969, Oak Ridge National Laboratory, November 1988, Oak Ridge, TN.

ORNL 1989. *Groundwater Parameters and Flow Systems Near Oak Ridge National Laboratory*, ORNL/TM-11368, Oak Ridge National Laboratory, September 1989, Oak Ridge, TN.

ORNL 1992. *Status Report: A Hydrologic Framework for the Oak Ridge Reservation*, ORNL/TM-12026, Oak Ridge National Laboratory, May 1992, Oak Ridge, TN.

ORNL 1996. *Effective Porosity and Pore-Throat Sizes of Mudrock Saprolite from the Nolichucky Shale within Bear Creek Valley on the Oak Ridge Reservation: Implications for Contamination Transport and Retardation through Matrix Diffusion* , ORNL/GWPO-025, Oak Ridge National Laboratory, May 1996, Oak Ridge, TN.

ORNL 2000. *Transportation Routing Analysis Geographic Information System (WebTRAGIS) User's Manual*, ORNL/TM-2000/86, Oak Ridge National Laboratory, April 2000, Oak Ridge, TN.

ORNL 2006. *Oak Ridge Reservation Physical Characteristics and Natural Resources*, ORNL/TM-2006/110, Oak Ridge National Laboratory, September 2006, Oak Ridge, TN.

Petersen, M.D., A.D. Frankel, S.C. Harmsen, C.S. Mueller, K.M. Haller, R.L. Wheeler, R.L. Wesson, Y. Zeng, O.S. Boyd, D.M. Perkins, N. Luco, E.H. Field, C.J. Wills, and K.S. Rukstales (2008), "Documentation for the 2008 Update of the United States National Seismic Hazard Maps," U.S. Geological Survey Open-File Report 2008-1128, 61 p.Sandia 2009. *RadCat 3.0 User Guide*, SAND2009-5129, Sandia National Laboratories, May 2009, Albuquerque, NM.

Stover, C.W. and Coffman, J.L. 1993. Seismicity of the United States 1568 – 1989 (Revised). USGS Prof. Paper 1527.

TDSWM (Tennessee Department of Solid Waste Management), 1993. *Earthquake Evaluation Guidance Document*.

U.S. Geological Survey (2014). Earthquake Archive Search, http://earthquake.usgs.gov/earthquakes/search/, Accessed on 16 December 2014.

Vaughn, J. D., Obermeier, S. F., Hatcher, R. D., Howard, C. D., Mills, H. H., and Whisner, S. C. (2010). "Evidence for One or More Major Late-Quaternary Earthquakes and Surface Faulting in the East Tennessee Seismic Zone," *Seismological Research Letters*, 81(2), 323, March/April.

Vlahovic, G., Powell, C., Chapman, M., and Sibol, M. (1998). "Joint hypocenter-velocity inversion for the Eastern Tennessee seismic zone," *Journal of Geophysical Research*, 103(B3), 4879-4896.

# APPENDIX G:
# APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This page intentionally left blank.

# CONTENTS


ACRONYMS ..... G-4
1. INTRODUCTION ..... G-5
2. CERCLA ON-SITE CONSIDERATIONS ..... G-7
3. ROLE OF NUCLEAR REGULATORY COMMISSION REGULATIONS AND DOE ORDERS ..... G-7
4. WAIVERS OF ARARS ..... G-9
5. CHEMICAL-SPECIFIC ARARS/TBCS ..... G-11
   5.1 RADIATION PROTECTION ..... G-11
   5.2 PROTECTION FROM HAZARDOUS CONSTITUENTS ..... G-11
6. LOCATION-SPECIFIC ARARS/TBCS ..... G-11
   6.1 FLOODPLAINS/WETLANDS ..... G-11
   6.2 AQUATIC RESOURCES ..... G-12
   6.3 ENDANGERED, THREATENED, OR RARE SPECIES ..... G-12
   6.4 CULTURAL RESOURCES ..... G-13
7. ON-SITE DISPOSAL ALTERNATIVE – ACTION-SPECIFIC ARARS/TBCS ..... G-13
   7.1 GENERAL CONSTRUCTION STANDARDS – SITE PREPARATION, EXCAVATION ACTIVITIES, AND CONSTRUCTION ..... G-14
   7.2 WASTE MANAGEMENT ..... G-14
      7.2.1 Characterization ..... G-14
      7.2.2 Storage ..... G-14
      7.2.3 Waste Segregation ..... G-15
      7.2.4 Waste Treatment and Disposal ..... G-15
   7.3 DISPOSAL SITE SUITABILITY REQUIREMENTS ..... G-15
   7.4 WASTEWATER COLLECTION AND DISCHARGE ..... G-15
   7.5 DESIGN, CONSTRUCTION, AND OPERATION OF A MIXED (RCRA HAZARDOUS, TSCA CHEMICAL AND LOW-LEVEL RADIOACTIVE) WASTE LANDFILL ..... G-16
   7.6 CLOSURE ..... G-16
   7.7 POST-CLOSURE CARE ..... G-17
   7.8 ENVIRONMENTAL MONITORING DURING OPERATION, CLOSURE, AND POST-CLOSURE CARE ..... G-17
   7.9 OFF-SITE TRANSPORTATION AND DISPOSAL ..... G-18
8. OFF-SITE DISPOSAL ALTERNATIVE ARARS/TBCS ..... G-18
9. REFERENCES ..... G-74

# TABLES

Table G-1. Chemical-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-20
Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-21
Table G-3. Action-specific ARARs and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-30
Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-32
Table G-5. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-40
Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-43
Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-56
Table G-8. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative ..... G-68
Table G-9. Action-specific ARARs and TBC Guidance for CERCLA Waste Disposal, Off-site Disposal Alternative ..... G-72

# ACRONYMS

| | |
|---|---|
| AEA | Atomic Energy Act of 1954 |
| ALARA | as low as reasonably achievable |
| ARAP | Aquatic Resource Alteration Permit |
| ARAR | applicable or relevant and appropriate requirement |
| BMP | best management practice |
| CFR | Code of Federal Regulations |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CWA | Clean Water Act of 1972 |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| FFA | Federal Facility Agreement |
| FFS | Focused Feasibility Study |
| FR | Federal Register |
| FML | flexible membrane liner |
| GCL | geosynthetic clay liner |
| LDR | Land Disposal Restriction |
| LLW | low-level waste |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NRC | Nuclear Regulatory Commission |
| NT | Northern Tributary (to Bear Creek) |
| O | Order |
| ORR | Oak Ridge Reservation |
| OSHA | Occupational Safety and Health Administration |
| PCB | polychlorinated biphenyl |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RI/FS | Remedial Investigation/Feasibility Study |
| ROD | Record of Decision |
| SDWA | Safe Drinking Water Act of 1974 |
| TBC | to be considered |
| TDEC | Tennessee Department of Environment and Conservation |
| TSCA | Toxic Substances Control Act of 1976 |
| TWRCP | Tennessee Wildlife Resources Council Proclamation |
| U.S. | United States |
| USC | United States Code |
| WAC | waste acceptance criteria |

This page intentionally left blank.

# 1. INTRODUCTION

The purpose of this Appendix is to identify and describe applicable or relevant and appropriate requirements (ARARs) for the disposal alternatives considered in this Remedial Investigation/Feasibility Study (RI/FS).

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Section 121(d) (see United States [U.S.] Code Title 42, Chapter 103, Section 9621{d}), as amended, specifies that remedial actions for cleanup of hazardous substances must comply with requirements and standards under federal or more stringent state environmental laws and regulations that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site, or obtain a waiver under 40 Code of Federal Regulations (CFR) 300.430 (f)(1)(i)(B) and (C). Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured. This RI/FS evaluates waste disposition for the volume of CERCLA waste generated from cleanup actions on the U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) that exceeds the available capacity of the existing Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley on the ORR. The purpose of this appendix is to specify federal and state chemical-, location-, and action-specific ARARs for the On-site Disposal Alternative for construction and operation of an additional CERCLA waste disposal facility referred to as the Environmental Management Disposal Facility (EMDF), and the Off-site Disposal Alternative for transport of CERCLA waste to an approved off-site facility.

ARARs include only federal and state environmental or facility siting laws/regulations designed to protect the environment and the public; they do not include occupational safety or worker radiation protection requirements. The U.S. Environmental Protection Agency (EPA) requires compliance with the Occupational Safety and Health Administration (OSHA) standards under Section 300.150 of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) regulations at 40 CFR 300.150, independent of the ARARs process; therefore, the regulations promulgated by OSHA related to occupational safety are not addressed as ARARs. These regulations would appear in and be implemented by the appropriate health and safety plans for this action.

The following terms are used throughout this appendix:

- Applicable requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.” (40 CFR 300.5).
- Relevant and appropriate requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not ‘‘applicable’’ to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.” (40 CFR 300.5).
- To be considered (TBC) materials are non-promulgated advisories or guidance issued by Federal or State governments, are not legally binding, and do not have the status of potential ARARs. The TBC category consists of advisories, criteria, or guidance that were developed by EPA, other

federal agencies, or states that may be useful in developing CERCLA remedies per 40 CFR 300.400(g)(3). TBCs may be considered along with ARARs as part of the site risk assessment and may be used in determining the necessary level of cleanup for protection of health or the environment.

CERCLA on-site remedial response actions must comply only with the substantive requirements of a regulation related to federal, state, or local permits (CERCLA Section 121[e]). To ensure that CERCLA response actions proceed as rapidly as possible, EPA re-affirmed in the final NCP (59 Federal Register [FR] 47416, September 15, 1994) that on-site remedial response actions need only comply with substantive requirements. The term on-site means the real extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action. Substantive requirements pertain directly to actions or conditions at a site, while administrative requirements facilitate their implementation. EPA recognizes that certain of the administrative requirements (i.e., consultation with state agencies, reporting, etc.) are accomplished through the state involvement and public participation. These administrative requirements should also be observed if they are useful in determining cleanup standards at the site (59 FR 47416).

Federal Facility Agreement (FFA) (DOE 1992) participants have agreed that the DOE ORR CERCLA actions generating wastes and the disposal facility evaluated in that alternative are considered to be on the same site, with respect to addressing regulations that relate to transport of waste within a site or between sites. The basis for this determination is described in Chapter 2 of this Appendix.

In accordance with 40 CFR 300.400(g), ARARs and TBC guidance have been identified for the disposal alternatives evaluated in this RI/FS. In accordance with EPA guidance (EPA 1991), there are no ARARs/TBCs for the No Action Alternative. For the On-site Disposal Alternative actions, Table G-1 lists the chemical-specific ARARs/TBCs; Table G-2 lists the location-specific ARARs/TBCs; and Tables G-3 through G-8 list the action-specific ARARs/TBCs.

Table G-9 provides the action-specific ARARs/TBCs for the Off-Site Disposal Alternative. Chemical-specific and location-specific requirements may apply at the generator site or at the off-site disposal facility, but they are not ARARs for this alternative.

The On-site Disposal Alternative would comply with all ARARs with the exception of the following two requirements for which waivers would be requested:

1. The Toxic Substances Control Act of 1976 (TSCA) hydrologic conditions requirement that there be no hydraulic connection between the site and standing or flowing surface water and that a 50 ft vertical separation be maintained between the bottom of the landfill liner system or natural in-place soil barrier and the historic high water table (40 CFR 761.75[b][3]). A waiver for this requirement will be requested on the basis that the landfill design achieves "equivalent protectiveness" under 40 CFR 300.430 (f)(1)(ii)(C)(4).

2. The RCRA Land Disposal Restrictions (LDRs) (40 CFR 268 et seq.) prohibit placement of untreated hazardous wastes in a land disposal unit. DOE proposes to treat mercury-contaminated demolition debris by macroencapsulation (40 CFR 268.45, Table 1) within the EMDF, as described in Appendix C. A waiver to LDRs on the basis of an interim measure per 40 CFR 300.430(f)(1)(ii)(C)(1), to allow short-term placement prior to treatment to meet the LDR requirements, will be requested.

Waivers would need to be incorporated into the Record of Decision (ROD) if the On-site Disposal Alternative is the selected remedy. Rationale for waivers for these three requirements is provided in Chapter 4 of this Appendix.

## 2. CERCLA ON-SITE CONSIDERATIONS

CERCLA Section 121(e) exempts on-site CERCLA activities from administrative permitting requirements. Disposal of waste in a newly constructed on-site disposal facility, proposed as the On-site Disposal Alternative in this RI/FS, would consolidate wastes from cleanup of the ORR and associated sites into a new disposal facility on the ORR. CERCLA Section 104(d)(4), discretionary authority to treat noncontiguous facilities as one site, also supports considering consolidation of waste between the individual sites as an on-site action and allows the EPA to consider multiple facilities as one for the purpose of conducting response actions where two or more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment. The preamble to the NCP (at 55 FR 8690 [March 8, 1990]) clarifies that Section 104(d)(4) can be used when noncontiguous facilities are reasonably close to one another and wastes at the sites are compatible for a selected treatment or disposal approach. For purposes of not requiring a permit for the EMDF and the identification of ARARs, it is assumed that consolidation of wastes into a centralized disposal cell would be considered an on-site action under the CERCLA definition of "on site" and CERCLA Section 104(d)(4), as well as within the context of the FFA (see FFA Section IV, paragraph A).

Treating all areas of contamination within ORR as "on-site" for the purposes of waste disposal determinations is consistent both with the statute and EPA policy and the precedent set with approval of the EMWMF. The NCP, at 40 CFR 300.5, defines "on-site" as *"the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for the implementation of the response action."* An August 3, 1995, EPA memorandum from Stephen D. Luftig, Acting Director, EPA Office of Emergency and Remedial Response (EPA 1995) provides that, where federal facilities are listed on the National Priorities List, *"the CERCLA site consists of all contaminated areas within the area used to define the site."*

By virtue of its location within the contiguous geographical boundaries of ORR, a single disposal facility would constitute a "suitable area in very close proximity to the contamination" in the case of areas of contamination on the ORR. Accordingly, it would be appropriate to consider such a disposal facility as "on-site" for the purposes of evaluating potential on-site disposal alternatives. The disposal facility analyzed in the On-site Disposal Alternative would accept CERCLA wastes meeting the facility-specific waste acceptance criteria (WAC) from ORR sites and associated sites outside the ORR boundary but within the state of Tennessee that have been contaminated by the receipt or transport of material from past ORR operations conducted by DOE and its predecessors. No out of state waste would be accepted at the proposed disposal facility.

## 3. ROLE OF NUCLEAR REGULATORY COMMISSION REGULATIONS AND DOE ORDERS

DOE is legally exempt from any Nuclear Regulatory Commission (NRC) low-level radioactive waste regulations as ARARs at DOE environmental restoration sites, unless the particular facility is also an NRC-licensed facility. Under the Atomic Energy Act of 1954 (AEA), a single agency, the Atomic Energy Commission, had responsibility for the development and production of nuclear weapons and for both the development and the safe regulation of the civilian uses of nuclear materials. Under the Energy Reorganization Act of 1974, this function was split between two separate and unique agencies (NRC and DOE). DOE has responsibility for the development and production of nuclear weapons, promotion of nuclear power, and other energy-related work, as well as the regulation of defense nuclear facilities, and NRC has responsibility for the development and the safe regulation of civilian uses of nuclear materials.

NRC has promulgated its own regulations governing the facilities and activities it oversees and licenses. The regulations in 10 CFR 61 establish, for land disposal of radioactive waste, the procedures, criteria, and terms and conditions upon which the NRC issues licenses for the disposal of radioactive wastes containing byproduct, source and special nuclear material received from other persons. The regulations in 10 CFR 20 establish standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC. Note that both sets of regulations are legally applicable only to NRC-licensed facilities or activities.

Under its Agreement State program, NRC often relinquishes its regulatory authority over source, byproduct and special nuclear material to states, authorizing them to administer its program in their state over its NRC-licensed facilities. Tennessee is such an "NRC Agreement" state.

Similarly, DOE is legally responsible for the management of nuclear materials at its facilities and is responsible for developing its own set of orders in carrying out its statutory responsibilities under the AEA. DOE orders are not promulgated because they apply only to DOE facilities and operations, and do not apply to non-governmental entities, as NRC regulations do. Tennessee specifically exempts DOE and its contractors or subcontractors from its NRC-equivalent regulations in Tennessee Department of Environment and Conservation (TDEC) 0400-20-10-.06 and NRC exempts DOE from its definition of a "person" subject to its regulations in 10 CFR 20.1003. EPA's ARARs guidance (EPA 1989) recognizes DOE's unique role, stating that *"most of DOE's operations are exempt from NRC's licensing and regulatory requirements"* and DOE's requirements for *"radioactive waste management are spelled out in a series of internal DOE Orders…issued under the Atomic Energy Act [that] have the same force for DOE facilities or 'within DOE' as does a regulation."* The manual further states that, *"Because DOE's Orders typically incorporate requirements promulgated by other Federal agencies, they should be consistent with existing regulations."* (pp. 5–17 to 5–18).

DOE Order (O) 435.1-1, *Radioactive Waste Management*, is generally consistent with and typically includes equivalent 10 CFR 61 requirements that are appropriate or "well-suited" to DOE sites and waste management operations. That is, 10 CFR 61 requirements incorporated into DOE O 435.1-1 meet the "appropriateness" criteria of the term "relevant and appropriate." Conversely, 10 CFR 61 requirements that are not incorporated into DOE O 435.1-1 do not meet the "appropriateness" criteria and, as such, are not regarded as "relevant and appropriate" for DOE environmental restoration sites.

An example of this process is site selection for a new low-level radioactive waste disposal facility. As discussed in DOE Guide (G) 435.1-1, initial site selection for a new DOE low-level waste (LLW) disposal facility accepting only DOE waste is limited to the DOE reservation, focusing on identifying the best site within the reservation. This is different from the way sites are selected for commercial NRC-licensed LLW disposal facilities, which are selected from large geographic areas where ownership of the land may be under private or public control. Site selection processes for commercial facilities are directed toward identifying sites that meet geographic suitability requirements, considering seismic, hydrogeological, archaeological, and other physical conditions. For DOE site selection, rather than meeting such suitability criteria, which would be considered relevant but not appropriate under the ARARs process, the process seeks a site which will contribute to meeting the performance objectives under the DOE orders. While relevant, the suitability criteria are not appropriate since they are not well-suited to the site given the type of facility regulated by the state (a commercial, licensed LLW disposal facility) and the type of facility contemplated by the DOE CERCLA action (a non-commercial, non-licensed LLW disposal facility located on DOE property accepting only DOE waste). This can lead to DOE sites being selected that are located adjacent to or within land previously contaminated. DOE G 435.1-1 states that *"[i]t is not intended that the 435.1 criteria be used as exclusionary conditions to eliminate a site from being considered, but instead provide a measure of evaluation of the site's contribution to performance of the disposal facility. Use of existing facilities on DOE reservations should be considered to the extent practical."* (see DOE G 435.1-1, Chapter IV, pp.123–124).

NRC regulations and the TDEC rule equivalents are also not relevant and appropriate based on the preamble to the final rule establishing the NCP (55 FR 8744, March 8, 1990): *"EPA believes it is reasonable to consider the existence of waivers, exemptions, and variances under other laws because generally there are environmental or technical reasons for such provisions…These provisions are generally incorporated into national regulations because there are specific circumstances where compliance with a requirement may be inappropriate for technical reasons or unnecessary to protect human health and the environment."* Since DOE is specifically exempted from NRC regulations and the TDEC rule equivalents, and has equivalent requirements in its internal orders, it is, per EPA's own language, inappropriate and unnecessary to cite these as relevant and appropriate requirements.

# 4. WAIVERS OF ARARS

CERCLA Section 121(d)(4) allows for waivers of ARARs under certain circumstances for CERCLA actions. For this On-site Alternative, waivers for two requirements will be requested, as follows:

- A hydrologic conditions requirement under TSCA specifies that there be no hydraulic connection between the site and standing or flowing surface water and the bottom of the landfill liner system or natural in-place soil barrier of a chemical waste landfill must be at least 50 ft above the historical high water table (40 CFR 761.75[b][3]). Construction of a disposal facility at the EMDF site evaluated under the On-site Disposal Alternative would not meet this TSCA requirement.
- The RCRA LDRs (40 CFR 268 et seq.) prohibit the placement of untreated hazardous waste in land disposal units. DOE proposes to treat characteristic mercury-contaminated demolition debris by macroencapsulation in specially constructed forms within EMDF cells. Debris would be treated within a short time after placement, and any stormwater or other liquids would be collected and treated so that no contaminants exit the forms. A waiver will be requested to allow this operational approach to be implemented, as an interim action. Once treatment of the waste forms is completed, all applicable and relevant and appropriate requirements will have been met.

Supporting rationale for these waivers is provided in the following sections.

**TSCA Hydrologic Conditions (40 CFR 761.75[b][3]):** An "equivalent protectiveness" waiver of the TSCA hydrologic conditions requirement, including the 50 ft ground water buffer requirement would be requested as allowed by 40 CFR 300.430 (f)(1)(ii)(C)(4) on the basis that implementation of the more stringent leachate collection requirements under Resource Conservation and Recovery Act of 1976 (RCRA) result in a facility design that meets or exceeds the protectiveness anticipated under TSCA. The provision for a waiver under CERCLA based on protectiveness parallels TSCA regulations at 40 CFR 761.5(c)(4) allowing the EPA TSCA administrator to waive the requirement if protectiveness can be demonstrated.

The TSCA requirement that there shall be no hydraulic connection between the site and standing or following surface water is met through the landfill underdrain and drainage diversion design. The underdrain will act as a hydraulic break for any discharge of ground water to the former east branch of Northern Tributary (NT)-3 that currently flows through the site. Flow on Pine Ridge above the EMDF site that would normally enter the NT-3 or NT-2 drainage systems will be captured and re-routed by a French drain and surface water diversion ditch around the EMDF. The design adequately negates any hydraulic connection to surface water.

The TSCA requirement for minimum depth to the water table does not provide a true performance standard that can be evaluated. For example, gravel and highly fractured rock can have hydraulic conductivities as high as 1 cm/sec, compared to conductivities in the $10^{-7}$ cm/sec range for clay. Thus, for

a continuous 50 ft layer, the range of time for permeation could be anywhere from < 1 hour (clean gravel) to 482 years (clay). Therefore, without specifying the type of earthen material considered, the 50 ft buffer requirement is not technically meaningful with regard to delaying contaminant migration. A RCRA-type landfill would use a multiple liner system that could incorporate flexible membrane liners (FMLs), geosynthetic clay liners (GCLs), and low permeability compacted clay. The hydraulic conductivities for these materials range from $<1\times10^{-7}$ cm/sec for low permeability clay; $5\times10^{-9}$ cm/sec for GCLs; and between $1\times10^{-11}$ and $1\times10^{-13}$ cm/sec for FMLs depending on the type of materials used. In addition to a leachate collection/detection system, RCRA landfill design typically uses a 3 ft thick clay foundation layer and a 10 ft clay geologic buffer to isolate the disposal cell from the ground water table. This design is highly effective at preventing and retarding contaminant movement.

If on-site disposal is the selected remedy, waivers from the TSCA 50 ft buffer and LDR placement requirements would be requested on the basis of 40 CFR 300.430(f)(1)(ii)(C)(4), *"equivalent protectiveness."* The proposed EMDF design will *". . . attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach."* There is precedence for waiver of the TSCA hydrologic conditions requirement. It is commonly waived in the southeast because of high ground water tables; EPA Region 4 has waived this requirement in the past, including granting a similar waiver for the EMWMF.

**Placement of Untreated Waste (40 CFR 268):** LDR regulations at 40 CFR 268 require that hazardous wastes, including those that are hazardous by characteristic, be treated prior to placement in a land disposal unit. A sizeable volume of demolition debris to be disposed in the EMDF is expected to be hazardous or mixed waste by the toxicity characteristic because of mercury, and DOE plans to treat these wastes by macroencapsulation, as required in 40 CFR 268.45, Table 1. Macroencapsulation would be performed within the EMDF cells, as described in Appendix C, to enhance operational control, staging, and safety, and to reduce treatment costs. This approach constitutes "placement," which is prohibited by LDRs. Therefore, DOE will request a waiver from this provision to allow short-term placement prior to treatment to meet the LDR requirements.

Short-term placement in a macroencapsulation form contained entirely within a disposal cell carries little if any risk. The form itself is a barrier to migration and a means for collecting rainwater and mercury. The form is fully contained within a landfill cell that has a liner, leachate collection system, and a separate leak detection system, which provide multiple additional layers of containment. Macroencapsulation would be carried out in a reasonable amount of time, further reducing the chances of loss of containment. Further, in-cell macroencapsulation will improve operations and safety by co-locating treatment and disposal such that treatment is carried out at a single site, not multiple project sites. This has the added benefit of reducing overall costs, as well.

The waiver for temporary placement of untreated wastes within one or more landfill cells is justified on the basis that it is an interim action that is a part of a total remedial action that will achieve the LDR requirements at completion, as allowed under CERCLA section 121(d)(4)(A) and 40 CFR 300.430(f)(1)(ii)(C)(1). An April 24, 1991 memorandum from the EPA Office of General Counsel (L. Starfield) to S. Golian, Chief, EPA Remedial Guidance Section, and L. Boornazian, Chief, EPA CERCLA Compliance Division, concurred with a very similar approach at the Wasatch Chemical Superfund site (accessed at www.epa.gov/superfund/policy/remedy/pdfs/memo42491-s.pdf). This waiver request is limited to temporary placement for treatment, and does not affect other aspects of LDR compliance.

# 5. CHEMICAL-SPECIFIC ARARs/TBCs

Chemical-specific ARARs and TBC guidance provide health- or risk-based concentration or discharge limitations in various environmental media (i.e., surface water, ground water, soil, and air) for specific hazardous substances, pollutants, or contaminants. Because there is no particular operable unit or medium being remediated, there are no chemical-specific ARARs for cleanup levels for the alternatives. There are, however, chemical-specific ARARs limiting exposure to radioactivity identified for the On-site Disposal Alternative (see Table G-1) that are discussed below.

## 5.1 RADIATION PROTECTION

The radiation dose to members of the public must not exceed 100-mrem/year total effective dose equivalent from all sources excluding dose contributions from background radiation, medical exposures, or voluntary participation in medical/research programs and must be reduced below this limit as low as reasonably achievable (ALARA). This dose limit addresses exposure to radiation from all sources and activities as measured at the DOE facility boundary. In addition, DOE is required to use procedures to maintain the dose ALARA.

EPA Guidance Office of Solid Waste and Emergency Response Directive 9200.4-18 (EPA 1997) establishes cleanup levels for CERCLA sites with radioactive contamination. Responses to radionuclide releases will be consistent with this TBC guidance, which establishes cleanup levels based on the NCP range of an excess upper bound lifetime cancer risk to an individual of between $10^{-4}$ to $10^{-6}$ (40 CFR 300.430[e][2)(i][A][2]).

## 5.2 PROTECTION FROM HAZARDOUS CONSTITUENTS

Ground water monitoring will be conducted during landfill operation, closure, and post-closure. Monitoring wells will be installed at appropriate locations and depths to sample the ground water at the site. A list of analytes appropriate to the wastes disposed in the landfill will be developed and maintained. Sampling and analyses will be conducted and evaluated to statistically determine if, and at what concentrations, contaminants have been released to the environment. Analytic results will be compared to background values or to appropriate maximum contaminant limits set by regulation or agreement.

# 6. LOCATION-SPECIFIC ARARs/TBCs

Location-specific requirements (see Table G-2) establish restrictions on siting or requirements for how activities will be conducted solely because they will take place in special locations (e.g., wetlands, floodplains, critical habitats, historic districts, streams, presence of threatened or endangered species). Additional location-specific ARARs place restrictions on certain site attributes, such as hydrogeology or seismicity, that could affect the performance of a remedy. The location-specific ARARs discussed here are based on the siting of the proposed EMDF in East Bear Creek Valley immediately east of EMWMF. The Off-site Disposal and No-Action Alternatives would not impact any special locations.

## 6.1 FLOODPLAINS/WETLANDS

Activities that affect wetlands are regulated under federal and state law. Impacts to wetlands from siting a new disposal facility would be avoided whenever possible. If impacts were unavoidable, they would be minimized through steps such as project design changes or the implementation of best management practices (BMPs), erosion and sedimentation controls, and site restoration.

As described in Appendix E of this RI/FS, several wetlands have been identified within or near the EMDF site. If the On-site Disposal Alternative is the selected remedy in the ROD, certain wetlands would

be destroyed or adversely impacted and compensatory mitigation in the form of wetland restoration, creation, or enhancement would be carried out as required.

The conceptual design footprint of the EMDF, leachate storage tanks, contact water basins, access roads, and sediment basins are not within the 100-year or 500-year floodplain of Bear Creek; therefore, no regulations regarding potential impacts on floodplains are necessary for the On-site Disposal Alternative. Construction activities at the EMDF site would involve some disturbance of wetlands and aquatic resources and ARARs regarding those activities are included in Table G-2; mitigation activities are therefore assumed in the on-site cost estimate.

## 6.2 AQUATIC RESOURCES

The Fish and Wildlife Coordination Act of 1958 requires federal agencies to consider the effect of water-related projects on fish and wildlife resources and take action to prevent loss or damage to these resources. The provisions of the Act are not applicable to those projects or activities carried out in connection with land use and management programs carried out by federal agencies on federal lands under their jurisdiction; however, the provisions may be relevant and appropriate for such activities.

The TDEC Division of Water Pollution Control requires Aquatic Resource Alteration Permits (ARAPs) for alterations of waters of the state, including wetlands. Typical actions that trigger these requirements include the impoundment, diversion, stream location, or other control or modifications of any body of water or wetland. General permits are available for alteration of wet-weather conveyances, minor wetland alterations, minor road crossings, utility line crossings of streams, bank stabilization, sand and gravel dredging, debris removal, and stream and restoration habitat removal. Since this project would be implemented under CERCLA, proposed activities for development of an on-site disposal facility would be required to meet only the substantive requirements under the applicable General permit or individual ARAP process, including such elements as BMPs and erosion and sedimentation controls.

Implementation of the on-site EMDF would require substantial modification of NT-3 (i.e., construction over a portion of NT-3), site improvements, and potential construction of new bridges or culverts that would impact existing wetlands. Other direct impacts to aquatic resources are not expected to be required, based on the conceptual design. Actual design considerations will determine whether and to what extent aquatic impacts will occur.

## 6.3 ENDANGERED, THREATENED, OR RARE SPECIES

Tennessee lists state-specific threatened, endangered, and in-need-of-management animal species in Tennessee Wildlife Resource Conservation Proclamations (TWRCPs) 00-14 and 00-15, which supersede TWCRPs 94-16 and 94-17. The TDEC Division of Natural Areas Natural Heritage Program Rare Animal List (2009) was also consulted. The Tennessee endangered plant species are listed in Rule 0400-06-02-.04. The TDEC Division of Natural Areas Tennessee Natural Heritage Program Rare Plant List (2012) was also consulted for threatened and special status species.

As described in Appendix E, the EMDF site is not known to contain plants that are threatened or endangered, in need of management, or species of concern (Collins, et al, 2015; Baranski 2009). A biologic and wetlands survey was conducted, and no rare or status plants or habitats were identified within the area. If such plants were later discovered in the area, they would be protected and preserved per the Tennessee Rare Plant Protection and Conservation Act of 1985. The Tennessee dace (*Phoxinus tennesseensis*), which is listed as a "species in need of management" by the state of Tennessee and known to occur in Bear Creek and several of its tributaries, was not found in NT-3 upstream of the Haul Road. Should any actions associated with the selected remedy impact any state-listed threatened or rare animal species, impacts would be considered and mitigated as appropriate in accordance with the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act.

### 6.4 CULTURAL RESOURCES

There are no known significant historical or archaeological resources within the EMDF footprint, support facilities, or roadways (see Appendix E). No prehistoric sites are known to exist at the EMDF site and adjacent areas to be impacted by the proposed construction of support facilities and roadways. If such resources (e.g., Native American remains) are discovered during site grading and excavation activities, work will be suspended until applicable requirements are met. Several statutes and regulations protect cultural resources, such as Native American artifacts, that may be discovered. For the On-site Disposal Alternative, if such a discovery is made at any time during the project, it must be reasonably protected from disturbance and all activity in the discovery area must cease until the site and artifacts are properly evaluated.

## 7. ON-SITE DISPOSAL ALTERNATIVE – ACTION-SPECIFIC ARARs/TBCs

Under the On-site Disposal Alternative, most future-generated CERCLA waste in excess of the EMWMF capacity would be disposed of in a centralized, newly constructed engineered disposal facility on the ORR. This facility would be designed to manage radioactive LLW, RCRA characteristic waste, polychlorinated biphenyl (PCBs), and mixed waste consisting of combinations of these waste types. The anticipated small portion of CERCLA waste that does not meet the on-site disposal facility WAC (see Chapter 2, Section 2.1.3 of the main RI/FS document), including a minimal volume of disposal facility operations waste, would be shipped to an off-site commercial facility for disposal by the generating project and are not considered part of this RI/FS analysis nor part of the On-site Disposal Alternative.

Performance, design, or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous waste under the selected remedy (55 FR 8741, March 8, 1990). No one set of regulations is tailored to the combination of wastes which will be disposed. Selection of action-specific ARARs for the On-site and Off-site Disposal Alternatives is based on the overriding priority to manage wastes in a manner protective of human health and the environment over both the short-term and long-term. As previously stated, there are no ARARs for the No Action Alternative.

Action-specific ARARs for the On-site Disposal Alternative (see Tables G-3 through G-8) address:

- Siting requirements (Table G-3)
- Design requirements (Table G-4)
  - General landfill design
  - Landfill liner system
  - Storm water control for landfill
  - RCRA tanks system and
- Construction requirements (Table G-5)
- Operations requirements (Table G-6)
  - Emissions and effluents (note that most ARARs under this subheading are currently incorporated in the Integrated Water Management Focused Feasibility Study (see Section 7.4)
  - Secondary waste and waste acceptance criteria attainment
  - Transportation
  - General operations
- Environmental monitoring requirements (Table G-7)
  - Pre-operations monitoring

  - Operations and closure monitoring
  - Post-closure monitoring
- Closure and post-closure requirements (Table G-8)

A key assumption is that requirements for storage before transport, transportation requirements for moving wastes from individual response sites to the on-site disposal facility, and requirements for treatment of these wastes are not ARARs for the On-site Disposal Alternative because these requirements will be met by the individual waste generators prior to placement in the on-site facility. Some wastes (e.g., decontamination and decommissioning waste that exceeds WAC for the on-site disposal facility) may be managed at the generator site pending shipment to an off-site facility for treatment or disposal. In the event waste is determined to exceed WAC after receipt at the on-site disposal facility, the waste would be returned to the generator.

## 7.1 GENERAL CONSTRUCTION STANDARDS – SITE PREPARATION, EXCAVATION ACTIVITIES, AND CONSTRUCTION

Site preparation activities, such as excavation, earth-moving operations, and construction of support buildings would trigger requirements to prevent and minimize emission of radioactivity, fugitive dust, and storm-water runoff. These requirements, as listed in Table G-5, are ARARs for general construction activities under the On-site Disposal Alternative. Reasonable precautions include the use of BMPs for erosion prevention and sediment control to prevent runoff and application of water on denuded surfaces to prevent particulate matter from becoming airborne.

## 7.2 WASTE MANAGEMENT

Table G-6 lists ARARs and TBC guidance for characterization and management of different types of waste streams.

### 7.2.1 Characterization

All primary wastes (e.g., soil, scrap metal, and debris) delivered to the On-site EMDF and secondary wastes (e.g., contaminated personal protective equipment, dewatering fluids, decontamination wastewaters) generated during facility construction, operations, or closure will be appropriately characterized as either solid, hazardous, PCB-contaminated, radioactive, and/or mixed wastes and managed in accordance with appropriate RCRA, Clean Air Act of 1970, TSCA, or DOE requirements for each waste stream. Requirements for characterization and management of waste are triggered in all phases of implementation of the On-site Disposal Alternative. Other projects generating waste to be disposed of at an on-site (or off-site) facility are responsible for characterizing waste per these requirements and to confirm that that the waste meets the disposal facility's WAC. These waste streams must be characterized and managed as RCRA waste, TSCA waste, LLW, or mixed waste as appropriate.

### 7.2.2 Storage

RCRA-hazardous waste may be accumulated and temporarily stored in containers on-site provided that the containers meet substantive RCRA requirements and are properly marked as hazardous waste. Containers may be stored on-site provided that container integrity is ensured and precautions to prevent release of the waste are taken.

Storage areas must be properly designed and operated such that containers are not in prolonged contact with liquid from precipitation, and the area will contain any spilled materials. PCBs and PCB items must be properly marked and stored in containers per TSCA requirements. PCB and PCB radioactive waste may be stored in a PCB storage facility, or in a RCRA compliant storage facility.

### 7.2.3 Waste Segregation

TSCA waste must be segregated from incompatible wastes during management and storage. LLW should be segregated from mixed waste.

### 7.2.4 Waste Treatment and Disposal

RCRA waste may be land disposed only if it meets treatment standards or alternative treatment standards for hazardous waste (40 CFR 268) and requirements for ignitable, reactive, and incompatible waste. Hazardous waste may not be disposed of as free liquids and empty containers should be reduced in volume (e.g., shredded, compacted) prior to disposal. Treatment to meet LDRs will be accomplished, and a waiver from placement will be requested in order to treat mercury-contaminated debris by macroencapsulation within EMDF cells.

Bulk PCB remediation waste, other PCB cleanup wastes, and PCB bulk product waste may be disposed of in a RCRA-compliant land disposal facility or a chemical waste landfill or by performance or risk-based options per 40 CFR 761.61(b)(2).

Potentially biodegradable LLW bearing uranium and thorium shall be conditioned to minimize the generation and escape of biogenic gases. LLW must have structural stability by processing or packaging of the waste; void spaces must be reduced to the extent practicable.

## 7.3 DISPOSAL SITE SUITABILITY REQUIREMENTS

Siting and design requirements for land disposal facilities for RCRA-hazardous waste and LLW stipulate that facilities not be located in a 100-year floodplain or areas subject to seismic activity that could adversely affect the facility's stability or ability to meet performance standards. Performance standards for the facility include the requirement to achieve long-term stability of the disposal.

Location requirements for a chemical-waste landfill under TSCA are very similar to RCRA requirements for a hazardous waste landfill. However, the hydrologic requirements of TSCA specify that the bottom of the landfill liner system or natural in-place soil barrier must be located at least 50 ft above the historical high water table and prohibit any hydrologic connection between the site and any surface water. This depth requirement applies to all sites, regardless of underlying geology and soil type. The proposed EMDF location would not meet the TSCA hydrologic requirement. As noted in Chapter 4 of this Appendix, a waiver of the TSCA hydrologic conditions and 50 ft buffer requirement would be requested on the basis of equivalent protectiveness of landfill design (40 CFR 300.430 [f][1][ii][C][4]).

With the exception of the TSCA 50 ft buffer requirement, implementation of the On-site Disposal Alternative would meet all CERCLA ARARs. In addition, the risk assessment and preliminary WAC analyses (see Appendix F and Appendix H, respectively) indicate that there would be no risks above acceptable levels to human health or the environment as a result of constructing and operating an on-site disposal facility.

## 7.4 WASTEWATER COLLECTION AND DISCHARGE

Non-contact storm water generated during construction, operations, closure and post-closure will be collected in sedimentation basins to allow solids to settle out, and then released to surface streams.

At the request of TDEC and the EPA, a separate Focused Feasibility Study (FFS) that addresses leachate and contact water management for both the EMWMF and the EMDF is being prepared in parallel with this RI/FS. The FFS will identify a preferred leachate/contact water management alternative and provide appropriate ARARs. The preferred alternatives and ARARs from this RI/FS and the FFS will be merged

into a single Proposed Plan. Therefore, ARARs related to leachate/contact water management are not included in this appendix.

## 7.5 DESIGN, CONSTRUCTION, AND OPERATION OF A MIXED (RCRA HAZARDOUS, TSCA CHEMICAL AND LOW-LEVEL RADIOACTIVE) WASTE LANDFILL

Tables G-3 through G-8 lists RCRA and TSCA ARARs regarding design, construction and operation of a mixed waste landfill. RCRA and TSCA requirements regarding design and maintenance of a security system and access roads are applicable. TSCA requires pre-construction baseline sampling and sampling during operations of ground water and surface water. TSCA specifies leachate collection and liner design requirements for the landfill. If a synthetic liner is used, it must have a minimum thickness of 30 mils.

CERCLA differentiates between substantive and administrative requirements. Some requirements that would be considered administrative for most CERCLA response actions (and therefore would not be identified as ARARs) have nevertheless been identified as ARARs for the On-site Disposal Alternative because they are necessary to meet substantive requirements for an operating disposal facility. Operation of the on-site disposal facility will be in compliance with general facility requirements for security, inspection, training, construction quality assurance, contingency planning, preparedness and prevention, and inventory as identified in Table G-6.

RCRA regulations require that the landfill design must prevent leachate generation and release of hazardous constituents to ground water. Requirements stipulate that a disposal facility needs two or more liners, including a top liner and a bottom liner each with a leachate collection and removal system. The bottom liner will include a leak detection system. Facility design must also provide for run-on/runoff control systems and wind dispersion control systems. Construction and operation requirements include construction and post-construction inspections.

Treatment of mercury-contaminated wastes (i.e., those that fail the Toxicity Characteristic Leaching Procedure because of mercury) will be treated to meet LDRs as required in 40 CFR 268. It is anticipated that treatment will be conducted within one or more landfill cells to improve operational efficiency, improve worker health and safety, reduce environmental risk, and improve cost efficiency. Implementation of this treatment approach will require a waiver from 40 CFR 268 waste placement restrictions. This waiver will be requested on the basis that such treatment is an interim action leading to a fully compliant final remedial action, as allowed by the NCP. See Section 4 of this Appendix for a detailed discussion of this waiver request.

## 7.6 CLOSURE

After a disposal cell is filled to capacity, pursuant to RCRA, it must be covered with a final cover designed and constructed to provide long-term minimization of liquid migration through the capped area; function with minimum maintenance; promote drainage and minimize erosion or abrasion of the cover; and accommodate settling and subsidence so that the cover's integrity is maintained. Additionally, the cap must have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present to keep water and leachate from collecting in the waste.

Ground water detection monitoring will continue throughout closure and for the compliance period agreed upon by the FFA parties. Wells that are no longer needed for compliance monitoring must be permanently plugged and abandoned.

TSCA regulations do not specifically address capping individual cells or the chemical waste landfill, however, EPA guidance indicates that closure of a TSCA landfill should parallel closure requirements under RCRA.

## 7.7 POST-CLOSURE CARE

The owner of a RCRA landfill must have a post-closure plan and provide appropriate post-closure notices and surveys to the appropriate local authorities. Post-closure care must begin after closure and must continue for a period to be determined by the FFA parties. Property use must be restricted and the facility must be maintained to protect the integrity of the landfill cover and other components. General post-closure care includes site surveillance and maintenance, maintenance and operation of the leachate collection system as long as leachate is being generated, and environmental monitoring, including ground water detection monitoring.

## 7.8 ENVIRONMENTAL MONITORING DURING OPERATION, CLOSURE, AND POST-CLOSURE CARE

The owner of a RCRA landfill must conduct monitoring of leachate, surface water, and ground water during landfill operations, closure, and the post-closure care period. RCRA and TSCA provide requirements for construction of ground water monitoring wells, and RCRA further specifies ground water monitoring program, sample collection, and detection monitoring requirements.

The substantive requirements of RCRA detection and compliance monitoring at 40 CFR 264, Subpart F will be carried out, as applicable, during landfill operation, closure, and post-closure. An appropriate point of compliance and compliance period will be determined after discussions with regulators and recorded in appropriate FFA documents such as the Remedial Action Work Plan. Certain Subpart F ARARs relating to monitoring will be tailored to the specific wastes accepted by EMDF; tailoring of these ARARs are discussed further below and within Table G-7. Ground water detection monitoring is designed to detect a potential release from the landfill, and compliance monitoring is intended to be used to confirm a release and to assist with corrective actions in the event a leak is confirmed. In the event of a release, remedial actions would be planned and implemented under CERCLA, as applied by the FFA, and not RCRA.

RCRA and TSCA provide requirements for locating and constructing ground water monitoring wells. RCRA specifies ground water monitoring program requirements, sample collection, and analyses to be conducted at 40 CFR 264, Subpart F. DOE proposes to comply with substantive Subpart F requirements within the context of the CERCLA FFA process. Further, in recognition of the fact that the proposed EMDF is primarily a low-level radioactive waste landfill, DOE proposes certain modifications to Subpart F requirements that will make these requirements more suitable to a LLW landfill than a commercial hazardous waste landfill. Proposed modifications include:

- Subpart F requires that analyses conducted on ground water during detection and compliance monitoring are to include the constituents listed in 40 CFR 264, Appendix IX. This list is relevant but not appropriate since it (a) does not address radioactivity or radionuclides (primary contaminants of concern), and (b) includes a long list of organic compounds that are prohibited from disposal by the EMDF WAC. An appropriate analyte list will be provided in a monitoring plan to be prepared and approved by the FFA parties prior to waste receipt. It is noted that a constituent list that is appropriate for the EMDF should contain some radioactive parameters (alpha, beta) and certain radionuclides. These constituents are not subject to RCRA, but may be included as part of the expected CERCLA environmental monitoring program at the EMDF.

- The concentration limits set forth in 40 CFR 264.94 is not an ARAR because the National Oil and Hazardous Substance Pollution Contingency Plan (40 CFR 300.430[e][5][B] and [C]), requires that remedial actions conducted in surface or ground waters that are or may be used for drinking water must meet the Safe Drinking Water Act of 1974 (SDWA) maximum contaminant level goal, or if that is set to zero, the maximum contaminant level will apply. Therefore, because Tennessee classifies all ground water as potable water, unless otherwise classified, the Safe

Drinking Water Act limits are applicable to ground water contaminants that may originate from the EMDF. The SDWA limits are not applicable or relevant and appropriate for surface waters, which are classified for Recreational Use.

- Detection monitoring required by 40 CFR 264.98 will use indicator parameters and a short list of laboratory analytes to statistically determine if a release to ground water is indicated. Detection monitoring will either follow the statistical procedures defined in the regulation, or will develop an alternative procedure for approval by the FFA parties.

- Compliance monitoring will be carried out in the event that a leak is thought to have been detected. If a leak is confirmed, compliance monitoring plans will be approved by the FFA parties. It is anticipated that compliance monitoring would incorporate certain 40 CFR 264.99 requirements.

- The corrective action requirements of 40 CFR 264.100, are applicable, and will be met entirely through the CERCLA FFA process that is currently in place or as may be modified by future agreement among the FFA parties.

Reporting requirements of 40 CFR 264 Subpart F are administrative, and the FFA reporting requirements will be followed. The EMDF ROD, when approved, constitutes the necessary permit to operate a CERCLA landfill.

The effluent limitations contained in 40 CFR 445.1 are not ARARs because EMDF fits the definition of a captive landfill (40 CFR 445.1[e]) in that it is operated by and receives wastes from the industrial operation directly associated with the landfill (EPA 2000, see Sections 2.3a and 2.12 for discussion) and is therefore exempt from the landfill effluent limitations contained in 40 CFR 445.

### 7.9 OFF-SITE TRANSPORTATION AND DISPOSAL

ARARs for off-site transportation and disposal of hazardous waste, radioactive waste, LLW, PCB waste, and hazardous waste are listed in Table G-9 and discussed below in Chapter 8.

## 8. OFF-SITE DISPOSAL ALTERNATIVE ARARs/TBCs

Table G-9 lists action-specific ARARs for the Off-site Disposal Alternative and for off-site transportation and disposal of waste under the On-site Disposal Alternative. Any wastes that are transferred off-site or transported in commerce along public rights-of-way must meet the U.S. Department of Transportation (DOT) requirements summarized in Table G-9 for hazardous materials, as well as the specific requirements for the type of waste (e.g., RCRA, PCB, LLW, or mixed).

The DOT regulations for hazardous materials include requirements for marking labeling, placarding, and packaging. RCRA requires generators to ensure and document that the hazardous waste they generate is properly identified and transported to a treatment, storage, and disposal facility. Specific requirements are given for manifesting, packaging, labeling, marking, and placarding. In addition, there are record-keeping and reporting requirements. Pre-transport requirements reference the DOT regulations under 49 CFR 172, 173, 178, and 179.

CERCLA Section 121(d)(3) requires that the off-site transfer of any hazardous substance, pollutant, or contaminant generated during CERCLA response actions be to a facility that is in compliance with RCRA and applicable state laws. EPA has established the procedures and criteria for determining whether facilities are acceptable for the receipt of off-site waste at 40 CFR 300.440.

Any generator who relinquishes control of PCB wastes by transporting them to an off-site disposal facility must comply with the applicable provisions of TSCA (40 CFR 761.207 et seq.). Once wastes generated from a CERCLA response action are transferred off site, all administrative as well as substantive provisions of all applicable requirements must be met.

DOE's policy is to treat, store, and in the case of LLW, dispose of waste at the site where it is generated, if practical, or at another DOE facility if on-site capabilities are not practical and cost effective. The use of non-DOE facilities for storage, treatment, and disposal of LLW may be approved by ensuring, at a minimum, that the facility complies with applicable federal, state, and local requirements and has the necessary permit(s), license(s), and approval(s) to accept the specific waste.

**Table G-1. Chemical-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative**

| Chemical Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Activities causing radionuclide emissions | Emissions of radionuclides (other than radon) to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/year. | Radionuclide emissions from point sources at a DOE facility - **applicable** | 40 CFR 61.92<br>TDEC 1200-03-11-.08(6) | |
| Radon releases to environment | No source at a Department of Energy facility shall emit more than 20 picocuries per square meter per second (pCi/[$m^2$-sec]) (1.9 pCi/[$ft^2$-sec]) of radon-222 as an average for the entire source, into the air. This requirement will be part of any Federal Facilities Agreement reached between Environmental Protection Agency and Department of Energy. | Radon releases to the environment at a DOE facility - **applicable** | 40 CFR 61.192<br>TDEC 1200-03-11-.17 | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | | ***Wetlands*** | | |
| Presence of wetlands as defined in 10 CFR 1022.4 | Incorporate wetland protection considerations into its planning, regulatory, and decision-making processes, and shall, to the extent practicable, minimize the destruction, loss, or degradation of wetlands; and; preserve and enhance the natural and beneficial values of wetlands. | DOE actions that involve potential impacts to, or take place within wetlands - **applicable** | 10 CFR 1022.3(a)(7) and (8) | |
| | Undertake a careful evaluation of the potential effects of any proposed wetland action.<br>Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse wetland impacts. Avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of wetlands. Avoid direct and indirect development in a wetland wherever there is a practicable alternative. | | 10 CFR 1022.3(b), (c), (d) | |
| | Consider alternatives to the proposed action that avoid adverse impacts and incompatible development in a wetland area, including alternate sites, alternate actions, and no action. DOE shall evaluate measures that mitigate the adverse effects of actions in a wetland including, but not limited to, minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas. | | 10 CFR 1022.13(a)(3) | |
| | If no practicable alternative to locating or conducting the action in the wetland is available, then before taking action design or modify the action in order to minimize potential harm to or within the wetland, consistent with the policies set forth in Executive Order 11990. | | 10 CFR 1022.14(a) | |
| Presence of jurisdictional wetlands as defined in 40 CFR 230.3; 33 CFR 328.3(a), and 33 CFR 328.4 | The discharge of dredged or fill material into waters of the United States, including jurisdictional wetlands, is prohibited if there is a practical alternative that would have less adverse impact. No discharge shall be permitted that results in violation of state water quality standards, violates any toxic effluent standard, and/or jeopardizes an endangered species or its critical habitat. No discharge will be permitted that will cause significant degradation of waters of the United States. No discharge is permitted unless mitigation measures have been taken in accordance with 40 CFR 230, Subpart H. | Actions that involve discharge of dredged or fill material into waters of United States, including jurisdictional wetlands - **applicable** | 40 CFR 230.10(a), (b), (c) and (d)<br>40 CFR 230, Subpart H | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Mitigation of state wetlands as defined under TDEC 0400-40-07-.03 | If an applicant proposes an activity that would result in an appreciable permanent loss of resource value of wetlands, the applicant must provide mitigation, which results in no overall net loss of resource value. Compensatory measures must be at a ratio of 2:1 for restoration, 4:1 for creation and enhancement, and 10:1 for preservation, or at a best professional judgment ratio agreed to by the state. For any mitigation involving the enhancement or preservation of existing wetlands, to the extent practicable, the applicant shall complete the mitigation before any impact occurs to the existing state waters. For any mitigation involving restoration or creation of a wetland, to the extent practicable, the mitigation shall occur either before or simultaneously with impacts to the existing state waters. Mitigation actions for impacts to wetlands are prioritized as listed in TDEC 0400-40-07-.04 (7)(b)(1)(i) – (viii). | Activity that would cause loss of wetlands as defined in TDEC 0400-40-07-.03 - **applicable** | TDEC 0400-40-07-.04 (7)(b) | |
| ***Aquatic Resources*** | | | | |
| Within an area potentially impacting "waters of the State" as defined in TCA 69-3-103(33) - General Permit conditions | Must comply with the [substantive] requirements of the ARAP for erosion and sediment control to prevent pollution of waters of the state. Pollution control requirements, as detailed in each particular General Permit, include but are not limited to, the following:<br>• Activity must not result in discharge of waste or substances that may be harmful to humans or wildlife;<br>• Material may not be placed in a location or manner so as to impair surface water flow into or out of any wetland area;<br>• Work must be carried out in a manner that does not violate water quality criteria as stated in TDEC 0400-40-03-.03, including, but not limited to, prevention of discharges that cause a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of waters of the state for any of the designated uses for that water body by TDEC 0400-40-04;<br>• Excavation and fill activities shall be kept to a minimum, and all excess material shall be hauled upland and properly stabilized or disposed of.<br>• Sediment shall be prevented from entering waters of the state; erosion and sediment controls shall be designed according to the size and slope of disturbed or drainage to | Action potentially altering the properties of any "waters of the State" - **TBC** | TCA 69-3-108(1)<br>TDEC 0400-40-07-.01<br>TDEC Aquatic Resource Alteration General Permit (ARAP) Program Requirements | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | detain runoff and trap sediment, and shall be properly selected, installed, and maintained in accordance with manufacturer's specifications and good engineering practices.<br>• Erosion and sedimentation control shall be in place and functional before earthmoving operations begin and must be maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day but shall be replaced at the end of the work day.<br>• Litter, construction debris, and construction chemicals exposed to stormwater shall be picked up prior to anticipated storm events or otherwise prevented from becoming a pollutant source for stormwater discharges.<br>• Clearing, grubbing, or other disturbance of areas immediately adjacent to waters of the state shall be limited to the minimum necessary to accomplish the proposed activity. Unnecessary vegetation removal is prohibited, and disturbed areas shall be stabilized and re-vegetated as soon as practicable.<br>• Appropriate steps shall be taken to ensure petroleum products or other chemical pollutants are prevented from entering waters of the state, including ground water;<br>• Adverse impacts to T&E species or cultural, historical, or archeological features or sites are prohibited. | | | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Waters of the state as defined in TCA 69-3-103(33) – Bank stabilization | Bank stabilization activities along state waters must be conducted in accordance with the requirements of the ARAP Program (Rules of the TDEC, Chap. 0400-40-07). The general permit requirements for stream bank stabilization include the following:<br>• The erosion and sedimentation control practices indicated under the TDEC ARAP general conditions apply; in addition,<br>• Stream beds must not be used as transport routes for construction equipment;<br>• Temporary stream crossings shall be limited to one point in the construction area and erosion control measures shall be utilized where stream banks are disturbed; crossing shall be constructed so that stream flow is not obstructed;<br>• Following construction, all materials used for the temporary crossing shall be removed and disturbed banks shall be restored and stabilized if needed;<br>• Materials used in bank stabilization shall include clean rock, riprap, anchored trees or other non-erodible materials found in the natural environment; materials shall be free of contaminants including toxic pollutants, hazardous substances, waste metals, or construction debris, or other wastes.<br>• Activity may not be conducted in a manner that would permanently disrupt the movement of fish and aquatic life;<br>• Material may not be placed such that it impairs surface water flow into or out of any wetland area;<br>• Except under certain conditions detailed in the permit, length of bank stabilization is limited to 300 linear ft. | Bank-stabilization activities affecting waters of the state - **applicable** | TCA 69-3-108(l)<br>TDEC 0400-40-07-.01<br>TDEC ARAP General Permit for Bank Stabilization Activities (effective July 1, 2010) (TBC) | |
| Waters of the state as defined in TCA 69-3-103(33) – Culvert maintenance activities | The maintenance of existing serviceable structures or fills along waters of the state must be conducted in accordance with the requirements of the ARAP Program (Rules of the TDEC, Chap. 0400-40-07). The general permit requirements for maintenance activities include the following:<br>• The erosion and sedimentation control practices indicated under the TDEC ARAP general conditions apply; in addition,<br>• Placement of material for scour protection or repair shall be limited to clean rock, riprap, rock-filled wire baskets or mattresses, or concrete contained by formwork for footing | Maintenance activities affecting waters of the state - **applicable** | TCA 69-3-108(l)<br>TDEC 0400-40-07-.01<br>TDEC ARAP General Permit for Maintenance Activities (effective July 1, 2010) (TBC) | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | repair. Clean rock can be of various type and sizes depending on application. Clean rock shall not contain fines, soils, or other wastes or contaminants.<br>• Materials used in maintenance activities shall be free of contaminants, including toxic pollutants, hazardous substances, waste metal, construction debris and other wastes as defined by TCA 69-3-103-(18).<br>• Placement of material shall not impair flow or be conducted in a manner that would permanently disrupt the movement of fish or aquatic life.<br>• Streambeds shall not be used as transportation routes for construction equipment. Temporary stream crossings shall be limited to one point in the construction area and erosion control measures shall be utilized where stream banks are disturbed. Stream crossings shall be constructed of clean rock and stream flow shall be conveyed in appropriately sized pipe. Crossing shall be constructed so that stream flow is not obstructed. Following construction, all materials used for temporary crossing shall be removed and disturbed stream banks restored and stabilized if needed.<br>• Excavation and fill activities shall be kept to a minimum and shall be separated from flowing waters to the extent practicable and necessary. Activities shall be conducted in the dry to the maximum extent practicable by diverting flow utilizing cofferdams, berms, temporary channels, or pipes. Temporary diversion channels shall be protected by non-erodible material and lined to the expected high water level.<br>• Excavated materials, removed vegetation, construction debris, and other wastes shall be removed to an upland location and properly stabilized or disposed of in such a manner as to prevent reentry into the waterway.<br>• The placement of riprap shall be the minimum necessary to protect the structure or to ensure the safety of the structure.<br>• Sediment shall be prevented from entering waters of the state. Erosion and sediment control measures shall be designed according to the size and slope of the disturbed or drainage areas to detain runoff and trap sediment and shall be properly selected, installed, and maintained in accordance with the manufacturer's specifications and good | | | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | engineering practices.<br>• Erosion and sediment controls must be in place and functional before earth moving operations begin, and shall be constructed and maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day but replaced at the end of the work day.<br>• Litter, construction debris, and construction chemicals exposed to storm water shall be picked up prior to anticipated storm events, or otherwise prevented from becoming a pollutant source for storm water discharges. After use, silt fences should be removed.<br>• Clearing, grubbing, and other disturbance to riparian vegetation shall be kept to minimum necessary for slope construction and equipment operations. Unnecessary riparian vegetation removal, including trees, is prohibited.<br>• Material may not be placed in a location or manner so as to impair surface water flow into or out of any wetland area.<br>• Appropriate steps shall be taken to ensure that petroleum products or other chemical pollutants are prevented from entering waters of the state. All spills shall be reported to the appropriate emergency response agency and to TDEC and all measures taken immediately to prevent pollution of waters of the state, including ground water. | | | |
| Waters of the state as defined in TCA 69-3-103 (33) – Wet weather conveyances | Wet-weather conveyances may be altered provided the following conditions are met:<br>• The activity must not result in the discharge of waste or other substances that may be harmful to humans or wildlife;<br>• Material must not be placed in a location or manner so as to impair surface water flow into or out of any wetland area; and<br>• Sediment shall be prevented from entering other waters of the state:<br>- Erosion/sediment controls shall be designed according to size and slope of disturbed or drainage areas to detain runoff and trap sediment and shall be properly selected, installed, and maintained in accordance with manufacturer's specifications and good engineering practices.<br>- Erosion/sediment control measures must be in place and | Activities that alter wet-weather conveyances - **applicable** | TDEC 0400-40-07-.04(10)(a)<br>TDEC ARAP General Permit for Alteration of Wet Weather Conveyances (effective July 1, 2010) (TBC) | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | functional before earthmoving operations begin, and must be constructed and maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day, but shall be replaced at the end of the work day.<br>- Check dams must be utilized where runoff is concentrated. Clean rock, log, sandbag or straw bale check dams shall be properly constructed to detain runoff and trap sediment. Check dams or other erosion control devices are not to be constructed in stream. Clean rock can be of various type and size depending on the application and must not contain fines or other wastes or contaminants.<br>• Appropriate steps must be taken to ensure that petroleum products or other chemical pollutants are prevented from entering waters of the state. All spills must be reported to the appropriate emergency management agency and TDEC. In event of spill, measures shall be taken immediately to prevent pollution of waters of the state, including ground water. | | | |
| Within area impacting stream or any other body of water - *and*- presence of wildlife resources (e.g., fish) | The effects of water-related projects on fish and wildlife resources and their habitat should be considered with a view to the conservation of fish and wildlife resources by preventing loss of and damage to such resources. | Action that impounds, modifies, diverts, or controls waters, including navigation and drainage activities - **relevant and appropriate** | Fish and Wildlife Coordination Act (16 *USC* 662(a)) | |
| Location encompassing aquatic ecosystem as defined as 40 CFR 230.3(c) | The discharge of dredged or fill material into waters of the United States is prohibited if there is a practical alternative that would have less adverse impact. No discharge shall be permitted that results in violation of state water quality standards, violates any toxic effluent standard, and/or jeopardizes an endangered species or its critical habitat. No discharge will be permitted that will cause significant degradation of waters of the United States. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps in accordance with 40 CFR 230.70 et seq. are taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem. | Action that involves the discharge of dredged or fill material into "waters of the U.S.", including jurisdictional wetlands - **applicable** | 40 CFR 230.10(a), (b), (c) and (d)<br>40 CFR 230, Subpart H | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Mitigation of state waters other than wetlands | Must provide mitigation that results in no overall net loss of resource values for any activity that would result in appreciable permanent loss of resource value of a state water. For any mitigation involving relocation or re-creation of a stream segment, to extent practicable must complete mitigation before any impact occurs to existing state waters. Mitigation measures include but are not limited to: restoration of degraded stream reaches and/or riparian zones; new (relocated) stream channels; removal of pollutants from and hydrologic buffering of stormwater runoff; and other measures which have a reasonable likelihood of increasing the resource value of a state water. Mitigation measures or actions should be prioritized in the following order: restoration, enhancement, re-creation, and protection. | Action that impounds, modifies, diverts, or controls waters, including navigation and drainage activities - **relevant and appropriate** | TDEC 0400-40-07-.04(7)(a) | |
| ***Cultural Resources*** | | | | |
| Presence of archaeological resources | Must provide for the preservation of significant historical and archeological data which might otherwise be irreparably lost or destroyed as a result of any alternation of terrain caused as a result of any federal construction project. May not excavate, remove, damage, or otherwise alter or deface such resource unless by permit or exception. | Action that would impact archaeological resources on public land - **applicable** | 16 USC 469(a-c) (Archeological and Historic Preservation Act) (AHPA)<br>43 CFR 7.4(a) | |
| Presence of human remains, funerary objects, sacred objects, or objects of cultural patrimony for Native Americans | Must stop activities in the area of the discovery and provide immediate telephone notification of the inadvertent discovery, with written confirmation, to the responsible Federal agency official with respect to Federal lands, and, with respect to tribal lands, to the responsible Indian tribe official. Must take reasonable effort to secure and protect the objects discovered, including as appropriate, stabilization or covering. Must consult with Indian tribe likely to be affiliated with the objects to determine further disposition per 43 CFR 10.5. Federal agency officials should coordinate their responsibilities under these regulations with their emergency discovery responsibilities under the NHPA and the AHPA. | Excavation activities that inadvertently discover such resources on federal lands or under federal control - **applicable** | 25 USC 3002(d) (Native American Graves Protection and Repatriation Act) (NAGPRA)<br>43 CFR 10.4(b) through (d) and (f) | |
| | Must consult with Indian tribe likely to be affiliated with the objects to determine further disposition per 40 CFR 10.5(b). | | 43 CFR 10.4(d) | |

**Table G-2. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Location Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| ***Endangered, Threatened or Rare Species*** | | | | |
| Presence of Tennessee nongame species as defined in TCA 70-8-103 and listed in TWRA Proclamations 00-14 and 00-15 | May not take (i.e., harass, hunt, capture, kill or attempt to kill), possess, transport, export, or process wildlife species.<br><br>May not knowingly destroy the habitat of such wildlife species.<br><br>Upon good cause shown and where necessary to protect human health or safety, endangered or threatened species or "in need of management" species may be removed, captured, or destroyed. | Action impacting Tennessee nongame species, including wildlife species which are "in need of management" (as listed in TWRA Proclamations 00-14 and 00-15 as amended by 00-21) - **applicable** | TCA 70-8-104(c)<br>TCA 70-8-106(e)<br>TWRA Proclamations 00-14, Section II and 00-15, Section II, as amended by Proclamation 00-21 **(TBC)**<br>See also the TN Natural Heritage Program Rare Animal List (2009) | |
| Presence of Tennessee-listed endangered or rare plant species as listed in TDEC 0400-06-02-.04 | May not knowingly uproot, dig, take, remove, damage or destroy, possess or otherwise disturb for any purposes any endangered species. | Action impacting rare plant species including but not limited to federally listed endangered species - **relevant and appropriate** | TCA 70-8-309(a)<br>16 USC 1531 et seq.<br>TDEC 0400-06-02-.04 and Tennessee Natural Heritage Program Rare Plant List (2012) | |
| Presence of federally endangered or threatened species, as designated in 50 CFR 17.11 and 17.12 or critical habitat of such species | Actions that jeopardize the existence of a listed species or results in the destruction or adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken. | Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat - **applicable** | 16 U.S.C. 1531 et seq., Sect. 7(a)(2) | |
| Presence of migratory birds as defined in 50 CFR 10.13, and their habitats | Unlawful killing, possession, and sale of migratory bird species, as defined in 50 CFR 10.13, native to the U.S. or its territories is prohibited. | Action that is likely to impact migratory birds - **applicable** | 16 USC 703-704 | |
| | Requirements are as follows:<br>• avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency action;<br>• restore and enhance the habitats of migratory birds, as practicable;<br>• prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable. | Federal agency action that is likely to impact migratory birds - **TBC** | Executive Order 13186 | |

**Table G-3. Action-specific ARARs and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Siting of a RCRA landfill | A new facility where treatment, storage, or disposal of hazardous waste will be conducted must not be located within 200 ft of a fault which has had displacement in Holocene time. | Construction of a RCRA hazardous waste landfill - **applicable** | 40 CFR 264.18(a)(1) | |
| | A facility located in a 100 year floodplain (as defined in 40 CFR 264.18[b][2]) must be designed, constructed, operated and maintained to prevent washout of any hazardous waste, unless it can be demonstrated that procedures are in effect which will cause the waste to be removed safely, before flood waters can reach the facility | | 40 CFR 264.18(b)(1)<br>TDEC 0400-12-01-.06(2)(i) | |
| Siting requirements for a TSCA Landfill | Shall be located in thick, relatively impermeable formations such as large area clay pans. Where this is not possible, the soil shall have a high clay and silt content with the following parameters:<br>(i) In place soil thickness, 4-ft or compacted soil liner thickness, 3 ft;<br>(ii) Permeability (cm/sec), equal to or less than 1 x 10-7;<br>(iii) Percent soil passing No. 200 Sieve, >30;<br>(iv) Liquid Limit, >30; and<br>(v) Plasticity Index > 15. | Location of a TSCA Landfill- **applicable** | 40 CFR 761.75(b)(1) | |
| | The landfill must be located above the historical high ground water table. Floodplains, shorelands, and ground water recharge areas shall be avoided. There shall be no hydraulic connection between the site and standing or flowing surface water. The site shall have monitoring wells and leachate collection. The bottom of the landfill liner system or natural in-place soil barrier shall be at least 50 ft from the historical high water table. | Construction of a TSCA chemical waste landfill - **applicable** | 40 CFR 761.75(b)(3) | **Note: a waiver will be requested.** |
| | The landfill site shall be located in an area of low to moderate relief to minimize erosion and to help prevent landslides or slumping. | | 40 CFR 761.75(b)(5) | |

**Table G-3. Action-specific ARARs and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Siting of a Subtitle D landfill | Class I Disposal Facilities must be located, designed, constructed, operated, and maintained such that the fill areas are, at a minimum:<br>1. 100 feet from all property lines;<br>2. 500 feet from all residences, unless the owner of the residential property agrees in writing to a shorter distance;<br>3. 500 feet from all wells determined to be downgradient and used as a source of drinking water by humans or livestock; and<br>4. 200 feet from the normal boundaries of springs, streams, lakes, (except that this standard shall not apply to any wet weather conveyance nor to bodies of water constructed and designed to be a part of the facility);<br>5. A total site buffer with no constructed appurtenances within 50 feet of the property line. | Buffer zones for siting landfill - **relevant and appropriate** | TDEC 0400-11-01-.04(3)(a) | Also applicable under design, construction, operation. This is a Class II landfill requirement. |
| | Class II Disposal Facilities must meet the same buffer zone standards for siting as Class I facilities (subparagraph (a) of this paragraph). | Buffer zones for siting landfill - **relevant and appropriate** | TDEC 0400-11-01-.04(3)(b) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| ***General Landfill Design*** | | | | |
| Preparedness and prevention | Facilities must be designed, constructed, maintained, and operated to prevent any unplanned release of hazardous waste or hazardous waste constituents into the environment and minimize the possibility of fire or explosion. All facilities must be equipped with communication and fire suppression equipment and undertake additional measures as specified in 40 CFR 264.30 *et seq.* | Operation of a RCRA hazardous waste facility - **applicable** | 40 CFR 264.30-264.37<br>TDEC 0400-12-01-.06(3) | |
| ***Landfill Liner System*** | | | | |
| Liner design requirements for a TSCA landfill | Synthetic membrane liners shall be used when the hydrologic or geologic conditions at the landfill require such in order to achieve the permeability equivalent to the soils in paragraph (b)(1) of this section. Adequate soil underlining and cover shall be provided to prevent excessive stress or rupture of the liner. The liner must have a minimum thickness of 30 mils. | Design of a TSCA chemical waste landfill - **applicable** | 40 CFR 761.75(b)(2) | |
| Liner and leachate collection design for a RCRA landfill | The owner or operator of a landfill unit on which construction commences after January 29, 1992 must install two or more liners and a leachate collection and removal system above and between such liners. | Design of a RCRA landfill - **applicable** | 40 CFR 264.301(c)<br>TDEC 0400-12-01-.06(14)(b)(3) | |
| Liner system for RCRA landfill | (i) The liner system must include:<br>(A) A top liner, designed and constructed of materials (e.g., geomembrane) to prevent the migration of hazardous constituents into the liner during active life and the post closure period; and<br>(B) A composite bottom liner, consisting of at least two components. The upper component must be designed and constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into this component during the active life and post-closure care period. The lower component must be designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the upper component were to occur. The lower component must be constructed of at least 3 feet (91 cm) of compacted soil material with a hydraulic conductivity of no more than $1\times10^{-7}$ cm/sec.<br>(ii) Liners must comply with paragraphs (a)(1)(i), (ii), and (iii) of this section. | | 40 CFR 264.301(c)(1) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| Liner for a RCRA landfill | A liner that is designed, constructed, and installed to prevent any migration of wastes out of the landfill to the adjacent subsurface soil or ground water or surface water at anytime during the active life (including the closure period) of the landfill. The liner must be constructed of materials that prevent wastes from passing into the liner during the active life of the facility. The liner must be:<br>(i) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with the waste or leachate to which they are exposed, climatic conditions, or stress from installation or daily operation;<br>(ii) Placed on a foundation or base capable of supporting the liner and resistance to the pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression or uplift; and<br>(iii) Installed to cover all surrounding earth likely to be in contact with the waste or leachate. | | 40 CFR 264.301(a)(1)<br>TDEC 0400-12-01-.06(14)(b)1(i) | |
| Facility design, construction | Underlying the liners shall be a geologic buffer which shall have:<br>(i) A maximum hydraulic conductivity of $1.0\times10^{-5}$ cm/s and measures at least ten (10) feet from the bottom of the liner to the seasonal high water table of the uppermost unconfined aquifer or the top of the formation of a confined aquifer, or<br>(ii) Have a maximum hydraulic conductivity of $1.0\times10^{-6}$ cm/s and measures not less than five (5) feet from the bottom of the liner to the seasonal high water table of the uppermost unconfined aquifer or the top of the formation of a confined aquifer, or<br>(iii) Other equivalent or superior protection as defined in subpart (ii) of this part. | Design and construction of a solid waste landfill - **relevant and appropriate** | TDEC 0400-11-01-.04(4)(a)(2) | |
| Leachate collection and removal system | Must be designed, constructed, operated, and maintained to collect and remove leachate from the landfill during the active life and post closure period and ensure that the leachate depth over the liner does not exceed 30 cm. The leachate collection and removal system must comply with paragraphs (c)(3)(iii) and (iv) of this section. | | 40 CFR 264.301(c)(2)<br>TDEC 0400-12-01-.06(14)(b)1(ii) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| Leak detection system | The leachate collection and removal system between the liners, and immediately above the bottom composite liner in the case of multiple leachate collection and removal systems, is also a leak detection system. This leak detection system must be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner likely to be exposed to waste or leachate during the active life and post-closure care period. The requirements for a leak detection system in this paragraph are satisfied by installation of a system that is, at a minimum:<br>(i) Constructed with a bottom slope of one percent or more;<br>(ii) Constructed of granular drainage materials with a hydraulic conductivity of 1×10−2 cm/sec or more and a thickness of 12 inches (30.5 cm) or more; or constructed of synthetic or geonet drainage materials with a transmissivity of 3×10−5 m2/sec or more;<br>(iii) Constructed of materials that are chemically resistant to the waste managed in the landfill and the leachate expected to be generated, and of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and equipment used at the landfill;<br>(iv) Designed and operated to minimize clogging during the active life and post-closure care period; and<br>(v) Constructed with sumps and liquid removal methods (e.g., pumps) of sufficient size to collect and remove liquids from the sump and prevent liquids from backing up into the drainage layer. Each unit must have its own sump(s). The design of each sump and removal system must provide a method for measuring and recording the volume of liquids present in the sump and of liquids removed. | | 40 CFR 264(c)(3)<br>TDEC 0400-12-01-.06(14)(b)3(iii) | |
| Leak detection system action leakage rate | (a) The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding l foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS, and proposed response actions.<br>(b) To determine if the action leakage rate has been exceeded, the owner or operator must convert the weekly or monthly flow rate from the monitoring data obtained under part 264.303(c) of this paragraph to an average daily flow rate (gallons per acre per day) for each sump. | | 40 CFR 264.302<br>TDEC 0400-12-01-.06(c) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| ***Storm Water Control for Landfill*** | | | | |
| Run-on/runoff control systems | Run-on control system must be capable of preventing flow onto the active portion of the landfill during peak discharge from a 25-year storm event. | Design of a RCRA landfill - **applicable** | 40 CFR 264.301(g)<br>TDEC 0400-12-01-.06(14)(b)(7) | |
| | Run-off management system must be able to collect and control the water volume from a runoff resulting from a 24-hour, 25-year storm event. | | 40 CFR 264.301(h)<br>TDEC 0400-12-01-.06(14)(b)(8) | |
| ***RCRA Tank System and Impoundment Designs*** | | | | |
| Design of a RCRA Tank System | Must prepare an assessment attesting that the tank system design has sufficient structural integrity and is acceptable for the storing/treating of hazardous waste. The assessment must include the information specified in 40 CFR 264.192(a)(1)-(5) [TDEC 0400-12-01-.06(10)(c)(1)-(5)]. | Storage of RCRA hazardous waste in a new tank system – **relevant and appropriate** | 40 CFR 264.192(a)<br>TDEC 0400-12-01-.06(10)(c)(1) | |
| | Ancillary equipment (i.e., piping) must be supported and protected against physical damage and excessive stress due to settlement, vibration, expansion, or contraction. | | 40 CFR 264.192(e)<br>TDEC 0400-12-01-.06(10)(c)(5) | |
| | Must provide the degree of corrosion protection based upon the information in 40 CFR 264.192(a)(3) (TDEC 0400-12-01-.06[10][c][1][iii]) to ensure the integrity of the tank system during use. Installation of field fabricated corrosion protection system must be supervised by an independent corrosion expert. | | 40 CFR 264.192(f)<br>TDEC 0400-12-01-.06(10)(c)(6) | |
| | Must provide secondary containment in order to prevent release of hazardous waste or constituents into the environment. | | 40 CFR 264.193(a)(1)<br>TDEC 0400-12-01-.06(10)(d)(1) | |
| | Secondary containment systems must be:<br>• Designed, installed, and operated to prevent any migration of wastes or accumulated liquid out of the system to the soil, ground water, or surface water at any time during the use of the tank system; and<br>• Capable of detecting and collecting releases and accumulated liquids until the collected material is removed. | | 40 CFR 264.193(b)<br>TDEC 0400-12-01-.06(10)(d)(2) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| | Secondary containment systems must be at a minimum:<br>• Constructed of or lined with materials that are compatible with the wastes(s) to be placed in the tank system and must have sufficient strength and thickness to prevent failure owing to pressure gradients (including static head and external hydrological forces), physical contact with the waste to which it is exposed, climatic conditions, and the stress of daily operation (including stresses from nearby vehicular traffic).<br>• Placed on a foundation or base capable of providing support to the secondary containment system, resistance to pressure gradients above and below the system, and capable of preventing failure due to settlement, compression, or uplift;<br>• Provided with a leak-detection system that is designed and operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of hazardous waste or accumulated liquid in the secondary containment system within 24 hours, or at the earliest practicable time if the owner or operator can demonstrate to the Regional Administrator that existing detection technologies or site conditions will not allow detection of a release within 24 hours; and<br>• Sloped or otherwise designed or operated to drain and remove liquids resulting from leaks, spills, or precipitation. Spilled or leaked waste and accumulated precipitation must be removed from the secondary containment system within 24 hours, or in as timely a manner as is possible to prevent harm to human health and the environment, if the owner or operator can demonstrate to the Regional Administrator that removal of the released waste or accumulated precipitation cannot be accomplished within 24 hours. | | 40 CFR 264.193(c)<br>TDEC 0400-12-01-.06(10)(d)(3) | |
| | The secondary containment for tanks must include one or more of the following devices:<br>• a liner (external to the tank);<br>• a vault;<br>• a double-walled tank; or<br>• an equivalent device as approved by the EPA. | | 40 CFR 264.193(d)<br>TDEC 0400-12-01-.06(10)(d)(4) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| | External liner systems must be:<br>• designed and operated to contain 100 percent of the capacity of the largest tank within its boundary;<br>• designed or operated to prevent run-on or infiltration of precipitation into the secondary containment system unless the collection system has sufficient excess capacity to contain run-on or infiltration. (Such additional capacity must be sufficient to contain precipitation from a 25 year, 24-hour rainfall event);<br>• free of cracks or gaps; and<br>• designed and installed to surround the tank completely and to cover all surrounding earth likely to come into contact with the waste if the waste is released from the tank(s) (i.e., capable of preventing lateral as well as vertical migration of the waste). | | 40 CFR 264.193(e)(1)<br>TDEC 0400-12-01-.06(10)(d)(5)(i) | |
| | Vault system must be:<br>• designed or operated to contain 100 percent of the capacity of the largest tank within its boundary;<br>• designed or operated to prevent run-on or infiltration of precipitation into the secondary containment system unless the collection system has sufficient excess capacity to contain run-on or infiltration. (Such additional capacity must be sufficient to contain precipitation from a 25 year, 24-hour rainfall event);<br>• constructed of chemical-resistant water stops in all joints (if any);<br>• provided with an impermeable interior coating or lining that is compatible with the stored waste and that will prevent migration of the waste into the concrete;<br>• provided with a means to protect against formation of and ignition of vapors within the vault if the waste being stored or treated meets the definition of ignitable or reactive waste under 40 CFR 261.21 or 261.23; and<br>• provided with an exterior moisture barrier or otherwise designed or operated to prevent migration of moisture into the vault if the vault is subject to hydraulic pressure. | | 40 CFR 264.193(e)(2)<br>TDEC 0400-12-01-.06(10)(d)(5)(ii) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| | Double-walled tanks must be:<br>• designed as an integral structure (i.e., an inner tank completely enveloped within and outer shell) so that any release from the inner tank is contained by the outer shell;<br>• protected, if constructed of metal, from both corrosion of the primary tank interior and of the external surface of the outer shell; and<br>• provided with a built-in continuous leak detection system capable of detecting a release within 24 hours, or at the earliest practicable time. | | 40 CFR 264.193(e)(3)<br>TDEC 0400-12-01-.06(10)(d)(5)(iii) | |
| | Ancillary equipment must be provided with secondary containment (e.g., trench, jacketing, double-walled piping) that meets the requirements of 40 CFR 264.193(b) and (c) (TDEC 0400-12-01-.06[10][d][2] and [3]) except for:<br>• aboveground piping (exclusive of flanges, joints, valves, and other connections) that are visually inspected for leaks on a daily basis;<br>• welded flanges, welded joints and welded connections, that are visually inspected for leaks on a daily basis;<br>• seamless or magnetic coupling pumps and seal-less valves, that are visually inspected for leaks on a daily basis; and<br>• pressurized aboveground piping systems with automatic shut-off devices (e.g., excess flow check valves, flow metering shutdown devices, loss of pressure actuated shut-off devices) that are visually inspected for leaks on a daily basis. | | 40 CFR 264.193(f)<br>TDEC 0400-12-01-.06(10)(d)(6) | |
| Design and installation of a RCRA surface impoundment | Must install a liner system consisting of two or more liners and a leachate collection and removal system, constructed in accordance with 40 CFR 264.221(c)(1)-(4) (TDEC 0400-12-01-.06[11][b][3][i]-[iv]). | Storage of RCRA hazardous waste in a new surface impoundment - **relevant and appropriate** | 40 CFR 264.221(c)<br>TDEC 0400-12-01-.06(11)(b)(3) | |
| | Must implement a leak detection system capable of detecting, collecting and removing leaks of hazardous constituents from all areas of the top liner during the active life and post-closure care period. | | 40 CFR 264.221(c)(2)<br>TDEC 0400-12-01-.06(11)(b)(3)(ii) | |
| | Must design, construct and maintain dikes with sufficient structural integrity to prevent massive failure. | | 40 CFR 264.221(h)<br>TDEC 0400-12-01-.06(11)(b)(8) | |
| | Alternative design practices to those in 40 CFR 264.221(c) (TDEC 0400-12-01-.06[11][b][3]) may be approved by the Regional Administrator. | | 40 CFR 264.221(d)<br>TDEC 0400-12-01-.06(11)(b)(4) | |

**Table G-4. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| Design and operation of a RCRA container storage area | Storage areas that store containers holding only wastes that do not contain free liquids need not have a containment system defined by paragraph (b) of this section, except as provided by paragraph (d) of this section or provided that:<br>(1) Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or<br>(2) The containers must be elevated or otherwise protected from contact with accumulated liquid. | Storage of RCRA hazardous waste in containers that do not contain free liquids - **applicable** | 40 CFR 264.175(c)<br>TDEC 0400-12-01-.06(9)(f)(3) | |
| | Area must have a containment system designed and operated in accordance with 40 CFR 264.175(b) as follows:<br><br>• a base must underlie the containers which is free of cracks or gaps and is sufficiently impervious to contain leaks, spills and accumulated precipitation until the collected material is detected and removed;<br>• base must be sloped or the containment system must be otherwise designed and operated to drain and remove liquids resulting from leaks, spills or precipitation, unless the containers are elevated or are otherwise protected from contact with accumulated liquids;<br>• must have sufficient capacity to contain 10 percent of the volume of containers or volume of largest container, whichever is greater;<br>• run-on into the system must be prevented unless the collection system has sufficient capacity to contain along with volume required for containers; and<br>• spilled or leaked waste and accumulated precipitation must be removed from the sump or collection area in a timely manner as or necessary to prevent overflow. | Storage of RCRA hazardous waste with free liquids or F020, F021, F022, F023, F026 and F027 in containers - **applicable** | 40 CFR 264.175(a), (b), and (d)<br>TDEC 0400-12-01-.06(9)(f) | |

**Table G-5. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| Pre-construction activities | Prior to excavation, all bore holes drilled or dug during subsurface investigation of the site, piezometers, and abandoned wells which are either in or within 100 feet of the areas to be filled must be backfilled with a bentonite slurry or other sealant approved by the Commissioner to an elevation at least ten feet greater than the elevation of the lowest point of the landfill base (including any liner), or to the ground surface if the site will be excavated less than ten feet below grade. | Landfill site preparation activities - **relevant and appropriate** | TDEC 0400-11-01-.04(2)(l) | |
| Activities causing fugitive dust emissions | Shall take reasonable precautions to prevent particulate matter from becoming airborne. Reasonable precautions shall include, but are not limited to the following: | Fugitive emissions from land-disturbing activities (e.g., excavation, construction) - **applicable** | TDEC 1200-3-8-.01(1) | |
| | Use, where possible, of water or chemicals for control of dust in demolition of existing buildings or structures, construction operations, grading of roads, or the clearing of land; | | TDEC 1200-3-8-.01(1)(a) | |
| | Application of asphalt, oil, water, or suitable chemicals on dirt roads, materials stock piles, and other surfaces which can create airborne dusts; | | TDEC 1200-3-8-.01(1)(b) | |
| | Shall not cause or allow fugitive dust to be emitted in such a manner to exceed 5 minute/hour or 20 minute/day beyond property boundary lines on which emission originates. | | TDEC 1200-3-8-.01(2) | |
| Activities causing stormwater runoff (e.g., clearing, grading, excavation) | Implement good construction management techniques (including sediment and erosion, vegetative controls, and structural controls) in accordance with the substantive requirements of General Permit No. TNR10-0000 and TNR05-0000, to ensure stormwater discharge is properly managed.<br>• does not violate water quality criteria as stated in TDEC 0400-40-03-.03, including, but not limited to, prevention of discharges that cause a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of waters of the state for any of the designated uses for that water body by TDEC 0400-40-04;<br>• does not contain distinctly visible floating scum, oil, or other matter;<br>• does not cause an objectionable color contrast in the receiving stream; and<br>• results in no materials in concentrations sufficient to be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life, or fish and aquatic life in the receiving stream. | Stormwater discharges associated with construction activities at industrial sites - disturbance of ≥ 1 acre total - **relevant and appropriate** | TCA 69-3-108(1)<br>Tennessee General Permit No. TNR10-0000 (effective May 24, 2011) **(TBC)**<br>Tennessee General Permit No. TNR10-0000, Section 5.3.2<br>Tennessee General Permit No. TNR05-0000, Sector K **(TBC)** | |

**Table G-5. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| Construction quality assurance | During construction or installation, liners and cover systems must be inspected for uniformity, damage and imperfections (e.g., holes, cracks, thin spots, etc.). Immediately after construction or installation:<br>(1) Synthetic liners and covers must be inspected to ensure tight seams and joints and the absence of tears, punctures, or blisters; and<br>(2) Soil-based and admixed liners and covers must be inspected for imperfections including lenses, cracks, channels, root holes, or other structural non-uniformities that may cause an increase in the permeability of the liner or cover. | Construction of a RCRA landfill - **applicable** | 40 CFR 264.303(a)<br>TDEC 0400-12-01-.06(14)(d)(1) | |
| Construction of new outfall structure for discharge of wastewater | Construction, maintenance, repair, rehabilitation or replacement of intake or outfall structures shall be carried out in such a way that work:<br>• Does not violate water quality criteria as stated in TDEC 0400-40-03-.03 including but not limited to prevention of discharges that causes a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of waters of the state for any of the designated uses for that water body by TDEC 0400-40-04.<br>• Activities in non-navigable streams shall be conducted in the dry; in navigable streams, where impracticable to work in the dry, work may be conducted within the water column.<br>• Shall be located and oriented so as to avoid permanent alteration or damage to the integrity of the stream channel including the opposite stream bank. Alignment of the structure (except for diffusers) should be as parallel to the stream flow as is practicable, with the discharge pointed downstream. Diffusers may be placed perpendicular to stream flow for more complex mixing.<br>• Intake and outfall structures shall be designed to minimize harm and prevent impoundment of normal or base flows.<br>• Velocity dissipation devices shall be placed as needed at discharge locations to provide a non-erosive velocity from the structure.<br>• Activity may not be conducted in a manner that would permanently disrupt the movement of fish and aquatic life.<br>• Material may not be placed in a location or manner so as to impair surface water flow into or out of any wetland area.<br>• Backfill activities must be accomplished in a manner that stabilizes the streambed and banks to prevent erosion. All contours must be returned to pre-project conditions to the extent practicable and completed activities may not disrupt or impound stream flow.<br>• Stream beds must not be used as transportation routes for construction equipment;<br>• Temporary stream crossings shall be limited to one point in the construction area and erosion control measures shall be utilized where stream banks are disturbed. Crossing shall be constructed so that stream | Construction of intake and outfall structures in waters of the state - **applicable** | TCA 69-3-108(l)<br>TDEC 0400-40-07-.01<br>TDEC General Permit for Construction of Intake and Outfall Structures (effective July 1, 2010) (TBC) | From IWM FFS |

**Table G-5. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citations | Tailoring of Requirement |
|---|---|---|---|---|
| | flow is not obstructed. Following work, all materials used for temporary crossing must be removed and disturbed stream banks restored and stabilized.<br>• Materials used in intake and outfall structures must be free of contaminants and wastes as defined by TCA 69-3-103(18).<br>• Clearing, grubbing and other disturbances to riparian vegetation shall be kept to a minimum necessary for slope construction and equipment operations. Unnecessary tree removal is prohibited.<br>• Sediment shall be prevented from entering waters of the state. Erosion and sediment control measures shall be properly selected, installed, and maintained and must be in place and functional before earth moving operations begin.<br>• Litter, construction debris, and construction chemicals exposed to storm water shall be picked up prior to anticipated storm events or otherwise prevented from becoming a pollutant source during storms.<br>• Excavated materials, removed vegetation, construction debris, and other wastes shall be removed to an upland location and properly stabilized or disposed of to prevent reentry into the waterway.<br>• Take appropriate steps to ensure petroleum products or other chemical pollutants are prevented from entering waters of the state. In event of a spill, take immediate measures to prevent pollution of waters of the state. | | | |
| Pre-operation/operation of a RCRA tank system (tanks and piping) | Prior to use, must ensure that proper handling procedures are adhered to in order to prevent damage to the system during installation. | | 40 CFR 264.192(b)<br>TDEC 0400-12-01-.06(10)(c)(2) | From IWM FFS |
| | Prior to use, must inspect the system for the presence of weld breaks, punctures, scrapes of protective coatings, cracks, corrosion, other structural damage, or inadequate construction/installation. All discrepancies must be remedied before the system is covered, enclosed or placed in use. | | 40 CFR 264.192(b)(1)-(6)<br>TDEC 0400-12-01-.06(10)(c)(2)(i)-(vi) | From IWM FFS |
| | Prior to use, tanks and ancillary equipment must be tested for tightness. If a tank system is found not to be tight, all repairs necessary to remedy the leak(s) must be performed prior to the system being placed into use. | | 40 CFR 264.192(d)<br>TDEC 0400-12-01-.06(10)(c)(4) | From IWM FFS |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| ***In-Cell Waste Treatment (Macroencapsulation)*** | | | | |
| Placement of untreated waste in a land disposal facility | (a) This part identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may continue to be land disposed. | Treatment of characteristic hazardous waste - **applicable** | 40 CFR 268.1 (a) | Waiver requested on basis of CERCLA Sect. 121(d)(4)(A) and 40 CFR 268.1(d) for in-cell treatment of mercury-contaminated wastes by macroencapsulation |
| | (d) The requirements of this part shall not affect the availability of a waiver under section 121(d)(4) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). | | 40 CFR 268.1 (d) | |
| Treatment of waste for land disposal | (a) *Treatment standards.* Hazardous debris must be treated prior to land disposal as follows unless EPA determines under §261.3(f)(2) of this chapter that the debris is no longer contaminated with hazardous waste or the debris is treated to the waste-specific treatment standard provided in this subpart for the waste contaminating the debris:<br>(1) *General.* Hazardous debris must be treated for each "contaminant subject to treatment" defined by paragraph (b) of this section using the technology or technologies identified in Table 1 of this section.<br>(2) *Characteristic debris.* Hazardous debris that exhibits the characteristic of ignitability, corrosivity, or reactivity identified under §261.21, 261.22, and 261.23 of this chapter, respectively, must be deactivated by treatment using one of the technologies identified in Table 1 of this section.<br>(3) *Mixtures of debris types.* The treatment standards of Table 1 in this section must be achieved for each type of debris contained in a mixture of debris types. If an immobilization technology is used in a treatment train, it must be the last treatment technology used.<br>(4) *Mixtures of contaminant types.* Debris that is contaminated with two or more contaminants subject to treatment identified under paragraph (b) of this section must be treated for each contaminant using one or more treatment technologies identified in Table 1 of this section. If an immobilization technology is used in a treatment train, it must be the last treatment technology used.<br>(5) *Waste PCBs.* Hazardous debris that is also a waste PCB under 40 CFR part 761 is subject to the requirements of either 40 CFR part 761 or the requirements of this section, whichever are more stringent. | Treatment of characteristic hazardous waste - **applicable** | 40 CFR 268.45(a) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | (b) *Contaminants subject to treatment.* Hazardous debris must be treated for each "contaminant subject to treatment." The contaminants subject to treatment must be determined as follows:<br>(1) *Toxicity characteristic debris.* The contaminants subject to treatment for debris that exhibits the Toxicity Characteristic (TC) by §261.24 of this chapter are those EP constituents for which the debris exhibits the TC toxicity characteristic. | | 40 CFR 268.45(b)(1) | |
| | (c) *Conditioned exclusion of treated debris.* Hazardous debris that has been treated using one of the specified extraction or destruction technologies in Table 1 of this section and that does not exhibit a characteristic of hazardous waste identified under subpart C, part 261, of this chapter after treatment is not a hazardous waste and need not be managed in a subtitle C facility. Hazardous debris contaminated with a listed waste that is treated by an immobilization technology specified in Table 1 is a hazardous waste and must be managed in a subtitle C facility. | | 40 CFR 268.45(c) | |
| Macroencapsulation Treatment Standard | C. Immobilization Technologies<br>1. *Macroencapsulation:* Application of surface coating materials such as polymeric organics (e.g., resins and plastics) or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media.<br>Encapsulating material must completely encapsulate debris and be resistant to degradation by the debris and its contaminants and materials into which it may come into contact after placement (leachate, other waste, microbes). | | 40 CFR 268.45, Table 1 | Macroencapsulation would be conducted in concrete vaults within one or more constructed landfill cells. A waiver from placement would be required, as noted above. |
| ***Emissions and Effluents*** | | | | |
| Control of air emissions from an above-grade RCRA tank system | The requirements of 40 CFR 264 Subpart CC do not apply to a waste management unit that is used solely for on-site treatment or storage of hazardous waste that is generated as a result of implementing remedial activities required under CERCLA authorities. | Storage of RCRA hazardous waste in a new tank system - **relevant and appropriate** | 40 CFR 264.1080(b)(5)<br>TDEC 0400-12-01-.32(a)(2)(v) | From IWM FFS |
| Control of emissions from a WWTU treatment system | On-site remediation and treatment of contaminated water using air strippers is an exempted air contaminant source provided the emissions are no more than 5 tons per year of any regulated pollutant that is not a hazardous air pollutant and less than 1,000 pounds per year of each hazardous air pollutant. | Emissions of air pollutants from new air contaminant sources - **applicable** | TDEC 1200-03-09-.04(4)(d)(24) | From IWM FFS |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Activities causing stormwater runoff (e.g., during operations) | Shall develop and implement storm water management controls to insure compliance with the terms and conditions of *General Permit No. TNR050000* ("Stormwater Multi-Sector General Permit for Industrial Activities") or any applicable site-specific permit and with TDEC 0400-40-10.03(2)(c). | Storm water discharges associated with industrial activity **- applicable** | TCA 69-3-108(l) General Permit No. TNR05-0000, Sector K (effective June 1, 2009) (TBC guidance) | |
| | Shall develop and maintain a storm water pollution prevention/control plan prepared in accordance with good engineering practices and with the factors outlined in 40 CFR 125.3(d)(2) or (3) as appropriate and any additional requirements listed in Part XI for the particular sector of industrial activity. The plan shall identify potential sources of pollution that may reasonably be expected to affect the quality of storm water discharges associated with industrial activity. | | General Permit No. TNR050000,Section 4 | |
| | Storm water pollution prevention plans shall include, at a minimum, the items identified in *General Permit No. TNR050000 Sector K.3*, including a description of potential pollution sources, storm water management measures and controls, preventive maintenance, spill prevention and response procedures, and sediment and erosion controls. | Storm water discharges associated with industrial activity at hazardous waste treatment, storage or disposal facilities **- TBC** | General Permit No. TNR050000 Sector K.3 | |
| | Shall monitor at least annually the identified storm water outfalls in accordance with the monitoring requirements specified in General Permit No. TNR050000 Sector K.5 and the parameters listed in Table K-1 of General Permit No. TNR050000 Sector K, as appropriate. Sampling waivers are available under the conditions specified in General Permit No. TNR050000 Sector K.5.1.3. | | General Permit No. TNR050000 Sector K.5 | |
| ***Secondary Waste and Waste Acceptance Criteria Attainment*** | | | | |
| Characterization of solid waste (e.g., contaminated PPE, equipment, spent filters) | Must determine if waste is hazardous waste or if waste is excluded under 40 CFR 261.4; and | Generation of solid waste as defined in 40 CFR 261.2, and which is not excluded under 40 CFR 261.4(a) **- applicable** | 40 CFR 262.11(a) TDEC 0400-12-01-.03(1)(b)(1) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | Must determine if waste is listed under Subpart D of 40 CFR Part 261; or | | 40 CFR 262.11(b) TDEC 0400-12-01-.03(1)(b)(2) | |
| | Must characterize waste by using prescribed testing methods or applying generator knowledge based on information regarding material or processes used. | | 40 CFR 262.11(c) TDEC 0400-12-01-.03(1)(b)(3) | |
| Characterization of hazardous waste | If waste is determined to be hazardous, must refer to Parts 261, 262, 264, 266, 268, and 273 of Title 40 for possible exclusions or restrictions pertaining to management of the specific waste. | Generation of RCRA hazardous waste for storage, treatment or disposal - **applicable** | 40 CFR 262.11(d) TDEC 0400-12-01-.03(1)(b)(4) | |
| | Must obtain a detailed chemical and physical analysis of a representative sample of the waste(s) which at a minimum contains all the information which must be known to treat, store, or dispose of the waste in accordance with 40 CFR 264 and 268. | | 40 CFR 264.13(a)(1) TDEC 0400-12-01-.06(2)(d)(1) | |
| | Must determine if the waste meets the treatment standards in 40 CFR 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods or use of generator knowledge of waste. | | 40 CFR 268.7(a) TDEC 0400-12-01-.10(1)(g)(1) | |
| | Must determine each EPA Hazardous Waste Number (Waste Code) to determine the applicable treatment standards under 40 CFR 268.40 et seq. | | 40 CFR 268.9(a); TDEC 0400-12-01-.10(1)(i)(1) | |
| | Must determine the underlying hazardous constituents (as defined in 40 CFR 268.2[i]) in the waste. | Generation of RCRA characteristically hazardous waste (and is not D001 non-wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal - **applicable** | 40 CFR 268.9(a);TDEC 0400-12-01-.10(1)(i)(1) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Temporary storage of hazardous waste in containers (e.g., PPE, rags, spent filters, etc.) | A generator may accumulate hazardous waste at the facility provided that:<br><br>• the waste is placed in containers that comply with 40 CFR 264.171-173 (Subpart I); and<br>• container is marked with the date upon which each period of accumulation begins; and<br>• container is marked with the words "hazardous waste" or<br>• container may be marked with other words that identify contents. | Accumulation of RCRA hazardous waste on site as defined in 40 CFR 260.10 - **applicable** | 40 CFR 262.34(a)<br>TDEC 0400-12-01-.03(4)(e) | |
| Use and management of hazardous waste in containers | If container is not in good condition (e.g., severe rusting, structural defects) or if it begins to leak, must transfer waste into container in good condition. | Storage of RCRA hazardous waste in containers – **applicable** | 40 CFR 264.171<br>TDEC 0400-12-01-.06(9)(b) | |
| | Use container made or lined with materials compatible with waste to be stored so that the ability of the container is not impaired. | | 40 CFR 264.172<br>TDEC 0400-12-01-.05(9)(c) | |
| | (a) Container holding hazardous waste must always be kept closed during storage, except to add/remove waste.<br>(b) Container holding hazardous waste must not be opened, handled, or stored in a manner which may rupture the container or cause it to leak. | | 40 CFR 264.173<br>TDEC 0400-12-01-.05(9)(d) | |
| Management of PCB waste (e.g., contaminated PPE, equipment, wastewater) | Any person storing or disposing of PCB waste must do so in accordance with 40 CFR 761, Subpart D | Generation of waste containing PCBs at concentrations ≥ 50 ppm - **applicable** | 40 CFR 761.50(a) | |
| | Any person cleaning up and disposing of PCBs shall do so based on the concentration at which the PCBs are found. | Generation of PCB remediation waste as defined in 40 CFR 761.3 – **applicable** | 40 CFR 761.61 | |
| Disposal of bulk PCB remediation waste | Bulk PCB remediation waste with a PCB concentrations ≥ 50 ppm shall be disposed of in a hazardous waste landfill permitted by EPA under section 3004 of RCRA, or by a State authorized under §3006 of RCRA, or a PCB disposal facility approved under 40 CFR761.60. | Bulk PCB remediation waste (as defined in 40 CFR 761.3) which has been de-watered and with a PCB concentration ≥ 50 ppm - **applicable** | 40 CFR 761.61(a)(5)(i)(B)(2)(iii) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Disposal of PCB cleanup wastes (PPE, rags, non-liquid cleaning materials) | Non-liquid PCB waste generated through cleanup of PCB remediation waste shall be decontaminated in accordance with 40 CFR 761.79 or disposed of:<br><br>(3) A hazardous waste landfill permitted by EPA under section 3004 of RCRA, or by a State authorized under section 3006 of RCRA. | Generation of non-liquid PCBs at any concentration during and from the cleanup of PCB remediation waste - **applicable** | 40 CFR 761.61(a)(5)(v)(A)(3) | |
| Performance-based disposal of PCB bulk product waste | PCB bulk product waste may disposed of by one of the following:<br>• in a chemical waste landfill approved under Section 761.75;<br>• in a hazardous waste landfill permitted by EPA under §3004 of RCRA or by authorized state under §3006 of RCRA; | Disposal of PCB bulk product waste as defined in 40 CFR 761.3 - **applicable** | 40 CFR 761.62(a)(2) and (3) | Combined |
| Disposal of RCRA hazardous waste in a land-based unit | A prohibited waste identified in the table "Treatment Standards for Hazardous Wastes" may be land disposed only if it meets the requirements found in the table. | Land disposal, as defined in 40 CFR 268.2, of RCRA restricted waste - **applicable** | 40 CFR 268.40(a)<br>TDEC 0400-12-01-.10(3)(a) | |
| | Prior to land disposal, soil contaminated with hazardous waste must be treated to meet the applicable alternative treatment standards of 40 CFR 268.49(c) or according to the applicable Universal Treatment Standards in 40 CFR 268.48. These treatment standards may be modified through a treatment variance approved in accordance with 40 CFR 268.44. | Land disposal for soil that exhibits a characteristic of hazardous waste - **applicable** | 40 CFR 268.49(b)<br>TDEC 0400-12-01-.10(3)(j)(2) | |
| Disposal requirements for particular RCRA waste forms and types | Ignitable or reactive RCRA waste must not be placed in a landfill unless the waste and the landfill meet applicable provisions of 40 CFR Part 268; and (1) the resulting waste, mixture or dissolution of material no longer is reactive or ignitable; and(2) 40 CFR 264.17(b) is complied with (see below). | Disposal of ignitable or reactive RCRA waste – **applicable** | 40 CFR 264.312(a)<br>TDEC 0400-12-01-.06(14)(m)(1) | |
| Disposal of bulk or non-containerized liquids in a RCRA landfill | May not dispose of bulk or non-containerized liquid hazardous waste or hazardous waste containing free liquids in any landfill. | Placement of bulk or non-containerized RCRA hazardous waste - **applicable** | 40 CFR 264.314(a)<br>TDEC 0400-12-01-.06(14)(o)(1) | Free liquid wastes are prohibited from disposal in EMDF. |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Disposal of containers in RCRA landfill | May not place containers holding free liquid in a landfill unless the liquid is mixed with an absorbent, solidified, removed, or otherwise eliminated. | Placement of containers containing RCRA hazardous waste in a landfill - **applicable** | 40 CFR 264.314(c)<br>TDEC 0400-12-01-.06(14)(o)(3) | |
| | Sorbents used to treat free liquids to be disposed of in landfills must be non-biodegradable as described in 264.315(d)(1). | | 40 CFR 264.314(d)<br>TDEC 0400-12-01-.06(14)(o)(5) | |
| | Unless they are very small, containers must be either at least 90% full when placed in the landfill, or crushed, shredded, or similarly reduced in volume to the maximum practical extent before burial in the landfill. | | 40 CFR 264.315<br>TDEC 0400-12-01-.06(14)(p) | |
| Disposal of TSCA PCB wastes (e.g., from drained electrical equipment) | Bulk liquids not exceeding 500 ppm PCBs may be disposed of provided such waste is pretreated and/or stabilized (e.g., chemically fixed, evaporated, mixed with dry inert absorbent) to reduce its liquid content or increase its solid content so that a non-flowing consistency is achieved to eliminate the presence of free liquids prior to final disposal. PCB Container of liquid PCBs with a concentration between 50 and 500 ppm PCB may be disposed of if each container is surrounded by an amount of inert sorbent material capable of absorbing all of the liquid contents of the container. | Disposal of PCB container with liquid PCB between 50 ppm and 500 ppm - **applicable** | 40 CFR 761.75(b)(8)(ii) | |
| ***Transportation*** | | | | |
| Transportation of hazardous waste on-site | The generator manifesting requirements of 40 CFR 262.20-262.32(b) do not apply.<br><br>Generator or transporter must comply with the requirements set forth in 40 CFR 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way. | Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a | 40 CFR 262.20(f)<br>TDEC 0400-12-01-.03(3)(a)(6) | From IWM FFS |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | | public or private right-of-way-**applicable** | | |
| Transportation of universal waste off-site | Off-site shipments of universal waste by a large quantity handler of universal waste shall be made in accordance with 40 CFR 273-38 (TDEC 0400-1-11-.12[3][i]). | Preparation of off-site shipments of universal waste by a large quantity generator of universal waste-**applicable** | 40 CFR 273.38<br>TDEC 0400-1-11-.12(3)(i) | From IWM FFS |
| Transportation of used oil off-site | Except as provided in paragraphs (a) to (c) of this rule, generators must ensure that their used oil is transported by transporters who have obtained U.S. EPA ID numbers. | Preparation of off-site shipment of used oil by generators of used oil-**applicable** | 40 CFR 279.24<br>TDEC 0400-1-11-.11(3)(e) | From IWM FFS |
| Management of used oil | Used oil generators shall not store used oil in units other than tanks, containers, or units subject to regulation under parts 264 or 265 of this chapter.<br>Containers and aboveground tanks used to store used oil at generator facilities must be in good condition (no severe rusting, apparent structural defects or deterioration); and not leaking (no visible leaks).<br>Containers and aboveground tanks used to store used oil at generator facilities must be labeled or marked clearly with the words "Used Oil."<br>Upon detection of a release of used oil to the environment, a generator must stop the release; contain, clean up, and properly manage the released used oil; and, if necessary, repair or replace any leaking used oil storage containers or tanks prior to returning them to service. | Generation and storage of used oil, (as defined in 40 CFR 279.1) and possible release-**applicable** | 40 CFR 279.22<br>TDEC 0400-12-01-.11(3)(c) | From IWM FFS |
| ***General Operations*** | | | | |
| Incompatible wastes | Incompatible wastes must not be placed in the same landfill cell unless 40 CFR 264.17(b) is complied with. | Disposal of incompatible wastes in a RCRA landfill - **applicable** | 40 CFR 264.313<br>TDEC 0400-12-01-.06(14)(n) | |
| Security system | Must prevent the unknowing entry and minimize the possibility for unauthorized entry of persons or livestock onto active portion of the facility or comply with provisions of 40 CFR 264.14(b) and (c). | Operation of a RCRA landfill - **applicable** | 40 CFR 264.14<br>TDEC 0400-12-01-.06(2)(e) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | Unless a natural barrier adequately deters access by the general public, either warning signs and fencing must be installed and maintained as follows, or the requirements of paragraph (c)(1) of this section must be met.<br>(1) Warning signs must be displayed at all entrances and at intervals of 100 m (330 ft) or less along the property line of the site or along the perimeter of the sections of the site where asbestos-containing waste material is deposited. The warning signs must:<br>(i) Be posted in such a manner and location that a person can easily read the legend; and<br>(ii) Conform to the requirements of 51 cm × 36 cm (20″×14″) upright format signs specified in 29 CFR 1910.145(d)(4) and this paragraph; and<br>(iii) Display the following legend in the lower panel with letter sizes and styles of a visibility at least equal to those specified in this paragraph. | Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145 - **applicable** | 40 CFR 61.154(b)(1) | |
| | The perimeter of the disposal site must be fenced in a manner adequately to deter access by the general public. | | 40 CFR 61.154(b)(2) | |
| | (i) A 6-ft woven mesh fence, wall or similar device shall be placed around the site to prevent unauthorized access.<br>(ii) Roads shall be maintained to and within the site which are adequate to support the operation and maintenance of the site without causing safety or nuisance problems or hazardous conditions.<br>(iii) Site shall be operated and maintained to prevent hazardous conditions resulting from spilled liquids and windblown materials. | Construction of a TSCA chemical waste landfill - **applicable** | 40 CFR 761.75(b)(9) | |
| General inspections | Operators must inspect facility for malfunctions and deterioration, operator errors, and discharges, often enough to identify and correct any problems. | Operation of a RCRA landfill - **applicable** | 40 CFR 264.15(a)<br>TDEC 0400-12-01-.06(2)(f)(1) | |
| | Operators must remedy any deterioration or malfunction of equipment or structures on a schedule that ensures that the problem does not lead to an environmental or human health hazard. | | 40 CFR 264.15(c)<br>TDEC 0400-12-01-.06(2)(f)(3) | |
| Personnel training | Operators must ensure personnel adequately trained in hazardous waste, emergency response, monitoring equipment maintenance, alarm system procedures, etc. | | 40 CFR 264.16<br>TDEC 0400-12-01-.06(2)(g) | |
| Construction quality assurance program | Operators must develop and implement a Construction Quality Assurance Program to ensure that the unit meets or exceeds all design criteria and specifications for all physical components including: foundations, dikes, liners, geomembranes, leachate collection and removal systems, leak detection systems and final covers in accordance with remaining provisions of 40 CFR 264.19. | | 40 CFR 264.19<br>TDEC 0400-12-01-.06(2)(j) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Contingency plan | Operators must have a contingency plan, designed to minimize hazards to human health and the environment from fires, explosions or other unplanned sudden releases of hazardous waste to air, soil, or surface water in accordance with 40 CFR 264.52. | | 40 CFR 264.51<br>TDEC 0400-12-01-.06(4)(b) | |
| | Operators must have at least one emergency coordinator on the facility premises responsible for coordinating emergency response measures in accordance with 40 CFR 264.56. | | 40 CFR 264.55<br>TDEC 0400-12-01-.06(4)(f) | |
| Inventory requirements | The owner or operator of a landfill must maintain the following items in the operating record required under §264.73:<br>(a) On a map, the exact location and dimensions, including depth, of each cell with respect to permanently surveyed benchmarks; and<br>(b) The contents of each cell and the approximate location of each hazardous waste type within each cell. | | 40 CFR 264.309<br>TDEC 0400-12-01-.06(14)(j) | |
| | Maintain, until closure, records of the location, depth and area, and quantity in cubic yards of asbestos containing material within the disposal site on a map or diagram. | Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145 - **applicable** | 40 CFR 61.154(f) | |
| | Disposal records shall include information on the PCB concentration in the liquid wastes and the three dimensional burial coordinates for PCBs and PCB items. | Operation of a TSCA chemical waste landfill – **applicable** | 40 CFR 761.75(b)(8)(iv) | |
| | The boundaries and locations of each disposal unit must be accurately located and mapped by means of a land survey. | Land disposal of LLW - **relevant and appropriate** | TDEC 0400-12-01-.17(3)(g) | |
| Disposal of TSCA PCB wastes | PCBs and PCB items shall be placed in a manner that will prevent damage to containers or articles. | Disposal of PCBs or PCB items in chemical waste landfill - **applicable** | 40 CFR 761.75(b)(8)(i) | |
| Leak detection system operation | Must collect and remove liquids in the leak detection system sumps to minimize the head on the bottom liner. | Operation of a RCRA landfill - **applicable** | 40 CFR 264.301(c)(4)<br>TDEC 0400-12-01-.06(14)(b)3(iv) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Run-on/runoff control systems | Collection and holding facilities must be emptied or otherwise expeditiously managed after storm events to maintain design capacity of the system | | 40 CFR 264.301(i)<br>TDEC 0400-12-01-.06(14)(b)(9) | |
| Wind dispersal control system | Must cover or manage the landfill to control wind dispersal of particulate matter | | 40 CFR 264.301(j)<br>TDEC 0400-12-01-.06(14)(b)(10) | |
| Control wind dispersal of asbestos wastes | Must be no visible emissions to the outside air; or | Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145 - **applicable** | 40 CFR 61.154(a) | |
| | Rather than meet the no visible emission requirement of paragraph (a) of this section, at the end of each operating day, or at least once every 24-hour period while the site is in continuous operation, the asbestos-containing waste material that has been deposited at the site during the operating day or previous 24-hour period shall:<br>(1) Be covered with at least 15 centimeters (6 inches) of compacted non-asbestos-containing material, or<br>(2) Be covered with a resinous or petroleum-based dust suppression agent that effectively binds dust and controls wind erosion. Such an agent shall be used in the manner and frequency recommended for the particular dust by the dust suppression agent manufacturer to achieve and maintain dust control. | | 40 CFR 61.154(c) | |
| Inspection of landfill following storms | Must inspect landfill weekly and after storm events to ensure proper functioning of:<br>(i) Deterioration, malfunctions, or improper operation of run-on and run-off control systems;<br>(ii) Proper functioning of wind dispersal control systems, where present; and<br>(iii) The presence of leachate in and proper functioning of leachate collection and removal systems, where present. | Operation of a RCRA landfill - **applicable** | 40 CFR 264.303(b)<br>TDEC 0400-12-01-.06(14)(d)(2) | |
| Inspection of landfill | Must record the amount of liquids removed from the leak detection system sumps at least weekly during the active life and closure period. | | 40 CFR 264.303(c)(1)<br>TDEC 0400-12-01-.06(14)(d)(3)(i) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Response actions for leak detection system | Must have a response action plan which sets forth the actions to be taken if action leakage rate has been exceeded. | Operation of a RCRA landfill leak detection system – **applicable** | 40 CFR 264.304(a)<br>TDEC 0400-12-01-.06(14)(e)(1) | |
| | Must determine to the extent practicable the location, size and cause of any leak. | Flow rate into the leak detection system exceeds action leakage rate for any sump - **applicable** | 40 CFR 264.304(b)(3)<br>TDEC 0400-12-01-.06(14)(e)(2)(iii) | |
| | Must determine whether waste receipt should cease or be curtailed; whether any waste should be removed from the unit for inspection, repairs, or controls, and whether or not the unit should be closed. | | 40 CFR 264.304(b)(4)<br>TDEC 0400-12-01-.06(14)(e)(2)(iv) | |
| | Must determine any other short or long-term actions to be taken to mitigate or stop leaks. | | 40 CFR 264.304(b)(5)<br>TDEC 0400-12-01-.06(14)(e)(2)(v) | |
| | To make the leak and/or remediation determinations, must:<br>(1) (i) Assess the source and amounts of the liquids by source;<br>(ii) Conduct a hazardous constituent or other analyses of the liquids in the leak detection system to identify sources and possible location of leaks, and the hazard and mobility of the liquid; and<br>(iii) Assess the seriousness of leaks in terms of potential for escaping into the environment; or<br>(2) Document why such assessments are not needed. | Leak and/or remediation determinations required - **applicable** | 40 CFR 264.304(c)<br>TDEC 0400-12-01-.06(14)(e)(3) | |
| Operation of a RCRA tank system | Hazardous wastes or treatment reagents must not be placed in the tank system if they could cause the tank, its ancillary equipment or the containment system to rupture, leak, corrode, or otherwise fail. | Storage of RCRA hazardous waste in a new tank system - **relevant and appropriate** | 40 CFR 264.194(a)<br>TDEC 0400-12-01-.06(10)(e)(1) | |

**Table G-6. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | Must use appropriate controls and practices to prevent spills an overflows from the tank or containment system. These include at a minimum:<br>• spill prevention controls (e.g., check valves, dry disconnect couplings);<br>• overfill prevention controls (e.g., level sensing devices, high level alarms, automatic feed cutoff, or bypass to a standby tank; and<br>• maintenance of sufficient freeboard in uncovered tanks to prevent overtopping by wave or wind action or by precipitation. | | 40 CFR 264.194(b)<br>TDEC 0400-12-01-.06(10)(e)(2) | |
| | Must comply with the requirements of 40 CFR 264.196 (TDEC 0400-12-01-.06[10][g]) if a leak or a spill occurs in the tank system. | | 40 CFR 264.194(c)<br>TDEC 0400-12-01-.06(10)(e)(3) | |
| Operation of a RCRA surface impoundment | Design and operate facility to prevent overtopping resulting from normal or abnormal operations; overfilling; wind and wave action; rainfall; run-on; malfunctions of level controllers, alarms and other equipment; and human error. | Storage of RCRA hazardous waste in a surface impoundment-**relevant and appropriate** | 40 CFR 264.221(g)<br>TDEC 0400-12-01-.06(11)(b)(7) | |
| | Remove surface impoundment from operation if the dike leaks or if there is a sudden drop in liquid level. | | 40 CFR 264.227<br>TDEC 0400-12-01-.06(11)(h) | |
| Operation of a landfill accepting asbestos waste | Either discharge no visible emissions to the outside air; or | Disposal of asbestos-containing material – **applicable** | 40 CFR 61.154(a)(1) | |
| | At the end of each operating day, or at least once every 24-hour period while the site is in continuous operation, the asbestos-containing waste material that has been deposited at the site during the operating day or previous 24-hour period shall:<br>(1) Be covered with at least 15 centimeters (6 inches) of compacted non-asbestos-containing material. | | 40 CFR 61.154(c)(1) | |
| | Warning signs must be displayed at all entrances and at intervals of 100 m (330 ft) or less along the property line of the site or along the perimeter of the sections of the site where asbestos-containing waste material is deposited. The warning signs must:<br>(i) Be posted in such a manner and location that a person can easily read the legend. | | 40 CFR 61.154(b)(1)(i) | |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| ***Pre-Operations Monitoring*** | | | | |
| Ground water and surface water monitoring | The ground water and surface water from the disposal site area must be sampled prior to commencing operation for use as baseline data | Construction of TSCA chemical waste landfill - **applicable** | 40 CFR 761.65(b)(6)(i)(A) | |
| ***Operations and Closure Monitoring*** | | | | |
| Surface water monitoring | Designated surface water course shall be sampled at least monthly when the landfill is being used for disposal. | Operation of a TSCA chemical waste landfill - **applicable** | 40 CFR 761.75(b)(6)(i)(B) | |
| Leachate collection system | Leachate collection systems shall be monitored monthly for quantity and physicochemical characteristics of leachate produced. The leachate should be either treated to acceptable limits for discharge in accordance with a State or Federal permit or disposed of by another State or Federally approved method. Water analysis shall be conducted as provided in paragraph (b)(6)(iii) of this section. | Operation of a TSCA chemical waste landfill - **applicable** | 40 CFR 761.75(b)(7) | |
| Monitoring well construction and operation | All monitoring wells shall be cased and the annular space between the monitor zone (zone of saturation) and the surface shall be completely backfilled with Portland cement or an equivalent material and plugged with Portland cement to effectively prevent percolation of surface water into the well bore. The well opening at the surface shall have a removable cap to provide access and to prevent entrance of rainfall or stormwater runoff. The ground water monitoring well shall be pumped to remove the volume of liquid initially contained in the well before obtaining a sample for analysis. The discharge shall be treated to meet applicable State or Federal standards or recycled to the chemical waste landfill. | Construction and operation of a TSCA ground water monitoring well - **applicable** | 40 CFR 761.75(b)(6)(ii)(B) | |
| Applicability to hazardous waste landfills | The regulations under this subpart apply during the active life of the regulated unit (including the closure period). | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.90 (c)(2)TDEC 0400-12-01-.06(6)(a)(3)(ii) | Site-specific applications of §264.99 and §264.100 are applicable as outlined below. |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Applicability to hazardous waste landfills | (f) The Regional Administrator may replace all or part of the requirements of §264.91 through 264.100 applying to a regulated unit with alternative requirements for ground water monitoring and corrective action for releases to ground water set out in the permit (or in an enforceable document) (as defined in 40 CFR 270.1(c)(7)) where the Regional Administrator determines that: (1) The regulated unit is situated among solid waste management units (or areas of concern), a release has occurred, and both the regulated unit and one or more solid waste management unit(s) (or areas of concern) are likely to have contributed to the release; and (2) It is not necessary to apply the ground water monitoring and corrective action requirements of §264.91 through 264.100 because alternative requirements will protect human health and the environment. | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.90 (f)(2)<br>TDEC 0400-12-01-.06(6)(a)(6)(ii) | Alternate monitoring requirements are proposed at §264.91, §264.93, §264.94, §264.95, §264.98, and §264.99. Requirements proposed at §264.100 will follow the FFA process. **All references to permits are understood to refer to the applicable ROD.** |
| Required monitoring programs | (a) Owners and operators subject to this subpart must conduct a monitoring and response program as follows:<br>(1) Whenever hazardous constituents under §264.93 from a regulated unit are detected at a compliance point under §264.95, the owner or operator must institute a compliance monitoring program under §264.99. Detected is defined as statistically significant evidence of contamination as described in §264.98(f);<br>(2) Whenever the ground-water protection standard under §264.92 is exceeded, the owner or operator must institute a corrective action program under §264.100. Exceeded is defined as statistically significant evidence of increased contamination as described in §264.99(d);<br>(3) Whenever hazardous constituents under §264.93 from a regulated unit exceed concentration limits under §264.94 in ground water between the compliance point under §264.95 and the downgradient facility property boundary, the owner or operator must institute a corrective action program under §264.100; or<br>(4) In all other cases, the owner or operator must institute a detection monitoring program under §264.98. | | 40 CFR 264.91(a)<br>TDEC 0400-12-01-.06(6)(b)(1) | This provision will be tailored to the specific conditions expected or experienced at the EMDF, as outlined at ARARs discussions at §264.92, §264.93, §264.94, §264.95, §264.98, §264.99, and §264.100, below. |
| Hazardous constituents | (a) The Regional Administrator will specify in the facility permit the hazardous constituents to which the ground-water protection standard of §264.92 applies. Hazardous constituents are constituents identified in appendix VIII of part 261 that are reasonably expected to be in or derived from waste contained in a regulated unit, unless the Regional Administrator has excluded them under paragraph (b) of this section.<br>(b) The Regional Administrator will exclude an Appendix VIII constituent from the list of hazardous constituents specified in the facility permit if he finds that the constituent is not capable of posing a substantial present or potential hazard to human health or the environment. In deciding whether to grant an exemption, the Regional | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.93<br>TDEC 0400-12-01-.06(6)(d) | An EMDF-specific list of hazardous constituents will be developed and maintained as an alternative to §261 Appendix VIII (and §264 Appendix IX), a site-appropriate list of radioactive and hazardous constituents, as appropriate to the contaminants identified in actual waste |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | Administrator will consider the following:<br>(1) Potential adverse effects on ground-water quality, considering: (i) The physical and chemical characteristics of the waste in the regulated unit, including its potential for migration; (ii) The hydrogeological characteristics of the facility and surrounding land; (iii) The quantity of ground water and the direction of ground-water flow; (iv) The proximity and withdrawal rates of ground-water users; (v) The current and future uses of ground water in the area; (vi) The existing quality of ground water, including other sources of contamination and their cumulative impact on the ground-water quality; (vii) The potential for health risks caused by human exposure to waste constituents; (viii) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; (ix) The persistence and permanence of the potential adverse effects; and<br>(2) Potential adverse effects on hydraulically-connected surface water quality, considering: (i) The volume and physical and chemical characteristics of the waste in the regulated unit; (ii) The hydro-geological characteristics of the facility and surrounding land; (iii) The quantity and quality of ground water, and the direction of ground-water flow; (iv) The patterns of rainfall in the region; (v) The proximity of the regulated unit to surface waters; (vi) The current and future uses of surface waters in the area and any water quality standards established for those surface waters; (vii) The existing quality of surface water, including other sources of contamination and the cumulative impact on surface-water quality; (viii) The potential for health risks caused by human exposure to waste constituents; (ix) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; and (x) The persistence and permanence of the potential adverse effects. | | | profiles. The initial list will be based on constituents identified in waste profiles accepted at the EMWMF, and is expected to include primarily radionuclides and metals. The list will be modified, as needed, to incorporate new constituents that may be identified in future EMDF waste profiles.<br>This approach will be more protective because it focuses on the actual constituents present in waste lots accepted for disposal. It is more cost-efficient because it does not require sampling and analyses of constituents not known or likely to be found in accepted wastes. |
| Concentration Limits | The Regional Administrator will specify in the facility permit concentration limits in the ground water for hazardous constituents established under §264.93. The concentration of a hazardous constituent:<br>(1) Must not exceed the background level of that constituent in the ground water at the time that limit is specified in the permit; or<br>(2) For any of the constituents listed in Table 1 (see p 28. for Table 1), must not exceed the respective value given in that table if the background level of the constituent is below the value given in Table 1; or<br>(3) Must not exceed an alternate limit established by the Regional Administrator under paragraph (b) of this section. | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.94(a)<br>TDEC 0400-12-01-.06(6)(e) | Concentration limits will be set at Safe Drinking Water Act Maximum Contaminant Levels in accord with the NCP [40 CFR 300.430(e)(5)(B) and (C)] |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Point of Compliance | (a) The Regional Administrator will specify in the facility permit the point of compliance at which the ground-water protection standard of §264.92 applies and at which monitoring must be conducted. The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units.<br>(b) The waste management area is the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit.<br>(1) The waste management area includes horizontal space taken up by any liner, dike, or other barrier designed to contain waste in a regulated unit.<br>(2) If the facility contains more than one regulated unit, the waste management area is described by an imaginary line circumscribing the several regulated units. | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.95<br>TDEC 0400-12-01-.06(6)(f) | The primary compliance point shall be defined in general accordance with §264.95(b). However, the placement of wells to monitor the point of compliance will be dictated by site hydrogeology as determined by site characterization studies. Note however, that because the EMDF is within the brownfield area of east BCV, the point of compliance for long-term clean up may be redefined in accordance with FFA remedial actions. |
| Compliance Period | (a) The Regional Administrator will specify in the facility permit the compliance period during which the ground-water protection standard of §264.92 applies. The compliance period is the number of years equal to the active life of the waste management area (including any waste management activity prior to permitting, and the closure period.)<br>(b) The compliance period begins when the owner or operator initiates a compliance monitoring program meeting the requirements of §264.99.<br>(c) If the owner or operator is engaged in a corrective action program at the end of the compliance period specified in paragraph (a) of this section, the compliance period is extended until the owner or operator can demonstrate that the ground-water protection standard of §264.92 has not been exceeded for a period of three consecutive years. | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.96<br>TDEC 0400-12-01-.06(6)(g) | The FFA parties shall determine the compliance period at the time that remedial actions are determined to be necessary. The FFA parties will consider site-specific information when determining what compliance period should be established. This would include the possibility of establishing a longer or shorter compliance period. |
| General ground water monitoring requirements | The owner or operator must comply with the following requirements for any ground-water monitoring program developed to satisfy §264.98, §264.99, or §264.100:<br>(a) The ground-water monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths to yield ground-water samples from the uppermost aquifer that:<br>(1) Represent the quality of background ground water that has not been affected by leakage from a regulated unit;<br>(i) A determination of background ground-water quality may include sampling of wells that are not hydraulically upgradient of the waste | Operation of a detection monitoring program under 40 CFR 264.98 - **applicable** | 40 CFR 264.97(a) through (f)<br>TDEC 0400-12-01-.06(6)(h)(1) through (6) | Ground water monitoring requirements will be conducted in general accord with the substantive requirements of 40 CFR 264, Subpart F, as modified to meet site conditions and FFA requirements. |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | management area where:<br>(A) Hydrogeologic conditions do not allow the owner or operator to determine what wells are hydraulically upgradient; and<br>(B) Sampling at other wells will provide an indication of background ground-water quality that is representative or more representative than that provided by the upgradient wells; and<br>(2) Represent the quality of ground water passing the point of compliance.<br>(3) Allow for the detection of contamination when hazardous waste or hazardous constituents have migrated from the waste management area to the uppermost aquifer.<br>(b) If a facility contains more than one regulated unit, separate ground-water monitoring systems are not required for each regulated unit provided provisions for sampling the ground water in the uppermost aquifer will enable detection and measurement at the compliance point of hazardous constituents from the regulated units that have entered the ground water in the uppermost aquifer.<br>(c) All monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hold. This casing must be screened or perforated and packed with gravel or sand, where necessary to enable collection of ground water sampler. The annular space above the sampling depth must be sealed to prevent contamination of ground water and samples.<br>(d) Ground water monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide a reliable indication of ground water quality below the waste management area.<br>At a minimum the program must include procedures and techniques for:<br>(1) Sample collection<br>(2) Sample preservation and shipment<br>(3) Analytical procedures<br>(4) Chain of custody control<br>(e) The ground-water monitoring program must include sampling and analytical methods that are appropriate for ground-water sampling and that accurately measure hazardous constituents in ground-water samples.<br>(f) The ground-water monitoring program must include a determination of the ground-water surface elevation each time ground water is sampled. | | | |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Sample collection | In detection monitoring or where appropriate in compliance monitoring, data on each hazardous constituent specified in the permit will be collected from background wells and wells at the compliance point(s). The number and kinds of samples collected to establish background shall be appropriate for the form of statistical test employed, following generally accepted statistical principles. The sample size shall be as large as necessary to ensure with reasonable confidence that a contaminant release to ground water from a facility will be detected. The owner or operator will determine an appropriate sampling procedure and interval for each hazardous constituent listed in the facility permit which shall be specified in the unit permit upon approval by the Regional Administrator. This sampling procedure shall be: (1) A sequence of at least four samples, taken at an interval that assures, to the greatest extent technically feasible, that an independent sample is obtained, by reference to the uppermost aquifer's effective porosity, hydraulic conductivity, and hydraulic gradient, and the fate and transport characteristics of the potential contaminants, or (2) an alternate sampling procedure proposed by the owner or operator and approved by the Regional Administrator. | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.97(g)<br>TDEC 0400-12-01-.06(6)(h)(7) | |
| General ground water monitoring requirements | The owner or operator will specify one of the following statistical methods to be used in evaluating ground-water monitoring data for each hazardous constituent which, upon approval by the Regional Administrator, will be specified in the unit permit. The statistical test chosen shall be conducted separately for each hazardous constituent in each well. Where practical quantification limits (pql's) are used in any of the following statistical procedures to comply with §264.97(i)(5), the pql must be proposed by the owner or operator and approved by the Regional Administrator. Use of any of the following statistical methods must be protective of human health and the environment and must comply with the performance standards outlined in paragraph (i) of this section.<br>(1) A parametric analysis of variance (ANOVA) followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's mean and the background mean levels for each constituent.<br>(2) An analysis of variance (ANOVA) based on ranks followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's median and the background median levels for each constituent.<br>(3) A tolerance or prediction interval procedure in which an interval for | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.97(h)<br>TDEC 0400-12-01-.06(6)(h)(8) | |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | each constituent is established from the distribution of the background data, and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit.<br>(4) A control chart approach that gives control limits for each constituent.<br>(5) Another statistical test method submitted by the owner or operator and approved by the Regional Administrator. | | | |
| | Any statistical method chosen under §264.97(h) for specification in the unit permit shall comply with the following performance standards, as appropriate: (1) The statistical method used to evaluate ground-water monitoring data shall be appropriate for the distribution of chemical parameters or hazardous constituents. If the distribution of the chemical parameters or hazardous constituents is shown by the owner or operator to be inappropriate for a normal theory test, then the data should be transformed or a distribution-free theory test should be used. If the distributions for the constituents differ, more than one statistical method may be needed. (2) If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a ground-water protection standard, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I experiment-wise error rate for each testing period shall be no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals or control charts. (3) If a control chart approach is used to evaluate ground-water monitoring data, the specific type of control chart and its associated parameter values shall be proposed by the owner or operator and approved by the Regional Administrator if he or she finds it to be protective of human health and the environment. (4) If a tolerance interval or a prediction interval is used to evaluate ground water monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain, shall be proposed by the owner or operator and approved by the Regional Administrator if he or she finds these parameters to be protective of human health and the environment. These parameters will be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern. (5) The statistical method shall account for data below the limit of detection with one or more statistical procedures that are protective of human health and the environment. Any practical quantification limit (pql) | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.97(i)TDEC 0400-12-01-.06(6)(h)(9) | |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | approved by the Regional Administrator under §264.97(h) that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions that are available to the facility. (6) If necessary, the statistical method shall include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data. | | | |
| Detection monitoring | (a) The owner or operator must monitor for indicator parameters (e.g., specific conductance, total organic carbon, or total organic halogen), waste constituents, or reaction products that provide a reliable indication of the presence of hazardous constituents in ground water. The Regional Administrator will specify the parameters or constituents to be monitored in the facility permit, after considering the following factors: (1) The types, quantities, and concentrations of constituents in wastes managed at the regulated unit; (2) The mobility, stability, and persistence of waste constituents or their reaction products in the unsaturated zone beneath the waste management area; (3) The detectability of indicator parameters, waste constituents, and reaction products in ground water; and (4) The concentrations or values and coefficients of variation of proposed monitoring parameters or constituents in the ground-water background.(b) Must install a ground water monitoring system at the compliance point as specified under 40 CFR 264.95 that complies with 264.97(a)(2), (b), and (c).(c) The owner or operator must conduct a ground-water monitoring program for each chemical parameter and hazardous constituent specified in the permit pursuant to paragraph (a) of this section in accordance with §264.97(g). The owner or operator must maintain a record of ground-water analytical data as measured and in a form necessary for the determination of statistical significance under §264.97(h).(d) The Regional Administrator will specify the frequencies for collecting samples and conducting statistical tests to determine whether there is statistically significant evidence of contamination for any parameter or hazardous constituent specified in the permit conditions under paragraph (a) of this section in accordance with §264.97(g). (e) The owner or operator must determine the ground-water flow rate and direction in the uppermost aquifer at least annually.(f) The owner or operator must determine whether there is statistically significant evidence of contamination for any chemical parameter of hazardous constituent specified in the permit pursuant to paragraph (a) of this section at a frequency specified under paragraph (d) of this section.(1) In determining whether statistically significant evidence of contamination exists, the owner or operator must use the method(s) specified in the | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.98(a) through (f)<br>TDEC 0400-12-01-.06(6)(i)(1) through (6) | DOE will establish and implement a list of site-appropriate water quality indicator parameters (e.g., conductivity, pH, temperature), as well as a limited list of indicator analytes for measurement in a laboratory using appropriate methods, such as those in EPA SW-846. See discussion at §264.95 and §264.97. DOE will maintain a record of detection monitoring results in the Oak Ridge Environmental Information System (OREIS). The detection monitoring program, including sampling and analysis frequency, will be defined in EMDF environmental monitoring plans approved by the FFA parties. |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | permit under §264.97(h). These method(s) must compare data collected at the compliance point(s) to the background ground-water quality data.(2) The owner or operator must determine whether there is statistically significant evidence of contamination at each monitoring well as the compliance point within a reasonable period of time after completion of sampling. The Regional Administrator will specify in the facility permit what period of time is reasonable, after considering the complexity of the statistical test and the availability of laboratory facilities to perform the analysis of ground-water samples. | | | |
| | If the owner or operator determines pursuant to paragraph (f) of this section that there is statistically significant evidence of contamination for chemical parameters or hazardous constituents specified pursuant to paragraph (a) of this section at any monitoring well at the compliance point, he or she must:<br>(2) Immediately sample the ground water in all monitoring wells and determine whether constituents in the list of Appendix IX of this part are present, and if so, in what concentration. However, the Regional Administrator, on a discretionary basis, may allow sampling for a site-specific subset of constituents from the Appendix IX list of this part and other representative/related waste constituents.<br>(3) For any Appendix IX compounds found in the analysis pursuant to paragraph (g)(2) of this section, the owner or operator may resample within one month or at an alternative site-specific schedule approved by the Administrator and repeat the analysis for those compounds detected. If the results of the second analysis confirm the initial results, then these constituents will form the basis for compliance monitoring. If the owner or operator does not resample for the compounds in paragraph (g)(2) of this section, the hazardous constituents found during this initial Appendix IX analysis will form the basis for compliance monitoring. | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.98(g)(2) through (g)(3)<br>TDEC 0400-12-01-.06(6)(i)(7)(i) through (v) | The established FFA reporting methods will be followed as appropriate.Appendix IX constituent list is replaced with site-specific list developed as discussed at §264.94 Notification and data will be provided within the FFA framework. Feasibility studies and other documentation will be prepared as required and funded within the FFA. |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | (6) If the owner or operator determines, pursuant to paragraph (f) of this section, that there is a statistically significant difference for chemical parameters or hazardous constituents specified pursuant to paragraph (a) of this section at any monitoring well at the compliance point, he or she may demonstrate that a source other than a regulated unit caused the contamination or that the detection is an artifact caused by an error in sampling, analysis, or statistical evaluation or natural variation in the ground water. | | 40 CFR 264.98(g)(6)<br>TDEC 0400-12-01-.06(6)(i)(7)(vi) | An attempt to determine if a source other than the EMDF is responsible for the detected contaminants will be made. Notification of findings will occur as required by the FFA-defined process.<br><br>A process for modifying the detection monitoring program to meet new and/or changed conditions will be included in the EMDF Environmental Monitoring Plan or functional equivalent. No ROD modification is required. |
| Compliance monitoring | An owner or operator required to establish a compliance monitoring program under this subpart must, at a minimum, discharge the following responsibilities:(a) The owner or operator must monitor the ground water to determine whether regulated units are in compliance with the ground-water protection standard under §264.92. The Regional Administrator will specify the ground-water protection standard in the facility permit, including: (1) A list of the hazardous constituents identified under §264.93; (2) Concentration limits under §264.94 for each of those hazardous constituents; (3) The compliance point under §264.95; and (4) The compliance period under §264.96.(b) The owner or operator must install a ground-water monitoring system at the compliance point as specified under §264.95. The ground-water monitoring system must comply with §264.97(a)(2), (b), and (c).(c) The Regional Administrator will specify the sampling procedures and statistical methods appropriate for the constituents and the facility, consistent with §264.97 (g) and (h).(1) The owner or operator must conduct a sampling program for each chemical parameter or hazardous constituent in accordance with §264.97(g). (2) The owner or operator must record ground-water analytical data as measured and in form necessary for the determination of statistical significance under §264.97(h) for the compliance period of the facility.(d) The owner or operator must determine whether there is statistically significant evidence of increased contamination for any chemical parameter or hazardous constituent specified in the permit, pursuant to paragraph (a) | Monitoring of hazardous waste landfill - **applicable** | 40 CFR 264.99(a) through (e)<br>TDEC 0400-12-01-.06(6)(j)(1) through (6) | The compliance monitoring system is expected to be identical to the detection monitoring system, unless new data indicates a more appropriate approach, in which case the system will be modified as needed. Compliance monitoring may be used initially to confirm a release, and thereafter will be modified as necessary to suit the FFA remedial action. Procedures will be defined and approved as part of the EMDF Environmental Monitoring Plan (or functional equivalent) approved by the FFA Parties. |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | of this section, at a frequency specified under paragraph (f) under this section.(1) In determining whether statistically significant evidence of increased contamination exists, the owner or operator must use the method(s) specified in the permit under §264.97(h). The methods(s) must compare data collected at the compliance point(s) to a concentration limit developed in accordance with §264.94.(2) The owner or operator must determine whether there is statistically significant evidence of increased contamination at each monitoring well at the compliance point within a reasonable time period after completion of sampling. The Regional Administrator will specify that time period in the facility permit, after considering the complexity of the statistical test and the availability of laboratory facilities to perform the analysis of ground-water samples.(e) The owner or operator must determine the ground-water flow rate and direction in the uppermost aquifer at least annually. | | | |
| Compliance monitoring | (g) Annually, the owner or operator must determine whether additional hazardous constituents from Appendix IX of this part, which could possibly be present but are not on the detection monitoring list in the permit, are actually present in the uppermost aquifer and, if so, at what concentration, pursuant to procedures in §264.98(f). To accomplish this, the owner or operator must consult with the Regional Administrator to determine on a case-by-case basis: which sample collection event during the year will involve enhanced sampling; the number of monitoring wells at the compliance point to undergo enhanced sampling; the number of samples to be collected from each of these monitoring wells; and, the specific constituents from Appendix IX of this part for which these samples must be analyzed. If the enhanced sampling event indicates that Appendix IX constituents are present in the ground water that are not already identified in the permit as monitoring constituents, the owner or operator may resample within one month or at an alternative site-specific schedule approved by the Regional Administrator, and repeat the analysis. If the second analysis confirms the presence of new constituents, the owner or operator must report the concentration of these additional constituents to the Regional Administrator and add them to the monitoring list. If the owner or operator chooses not to resample, then he or she must report the concentrations of these additional constituents to the Regional Administrator and add them to the monitoring list. | | 40 CFR 264.99(g)<br>TDEC 0400-12-01-.06(6)(j)(7) | Procedures will be defined and approved as part of the EMDF Environmental Monitoring Plan (or functional equivalent) approved by the FFA parties.As noted at §264.93, a site-specific constituent list will be substituted for Appendix IX.If judged necessary, an attempt will be made to determine if a source other than the EMDF is responsible for the detected contaminants. Notification of findings will occur as required by the FFA-defined process. A process for modifying the detection monitoring program to meet new and/or changed conditions will be included in the EMDF Environmental Monitoring Plan or functional equivalent. No ROD modification is required. |

**Table G-7. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| Corrective action at a hazardous waste landfill | An owner or operator required to establish a corrective action program under this subpart must, at a minimum, discharge the following responsibilities:(a) The owner or operator must take corrective action to ensure that regulated units are in compliance with the ground-water protection standard under §264.92. The Regional Administrator will specify the ground-water protection standard in the facility permit, including: (1) A list of the hazardous constituents identified under §264.93; (2) Concentration limits under §264.94 for each of those hazardous constituents; (3) The compliance point under §264.95; and (4) The compliance period under §264.96. | Corrective actions at a hazardous waste landfill - **applicable** | 40 CFR 264.100 (a)<br>TDEC 0400-12-01-.06(6)(k)(1) | Remedial actions will be implemented within the context of the FFA, as approved in any associated ROD or ROD modification. Alternate monitoring requirements are proposed at §264.91, §264.93, §264.94, §264.95, §264.98, and §264.99.All references to permits are understood to refer to the applicable ROD or other applicable CERCLA document. |
| | (e) In addition to the other requirements of this section, the owner or operator must conduct a corrective action program to remove or treat in place any hazardous constituents under §264.93 that exceed concentration limits under §264.94 in ground water. | | 40 CFR 264.100 (e)<br>TDEC 0400-12-01-.06(6)(k)(5) | Will propose and implement remedial actions within the context of the FFA, as approved in any associated ROD. |
| ***Post-Closure Monitoring*** | | | | |
| Operation of leachate collection system | After the cover is installed, must record the amount of liquids removed from the leak detection system at least monthly. If the liquid level in the sump stays below the pump operating level for two consecutive months, the amount of liquids in the sumps must be recorded at least quarterly. If the liquid level in the sump stays below the pump operating level for two consecutive quarters, the amount of liquids in the sumps must be recorded at least semi-annually. If at any time during the post-closure care period the pump operating level is exceeded at units on quarterly or semi-annual recording schedules, the owner or operator must return to monthly recording of amounts of liquids removed from each sump until the liquid level again stays below the pump operating level for two consecutive months. | Closure of a RCRA landfill - **applicable** | 40 CFR 264.303(c)(2)<br>TDEC 0400-12-01-.06(14)(d)(3)(ii) | |
| General Post-Closure Care | Must maintain and monitor a ground water monitoring system and comply with all other applicable provisions of 40 CFR 264, Subpart F. | | 40 CFR 264.310(b)(4)<br>TDEC 0400-12-01-.06(14)(k)(2)(iv) | |
| Surface water monitoring post-closure | Designated surface water course shall be sampled on a frequency of no less than once every six months after final closure of the disposal area. | Closure of a TSCA chemical waste landfill - **applicable** | 40 CFR 761.75(b)(6)(i)(C) | |

**Table G-8. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | | ***Closure*** | | |
| Decontamination/disposal of equipment | During the partial and final closure periods, all equipment, structures, etc. must be properly disposed of or decontaminated unless otherwise specified in §§ 264.197, 264.228, 264.258, 264.280 or § 264.310. | Closure of a RCRA landfill - **applicable** | 40 CFR 264.114<br>TDEC 0400-12-01-.06(7)(e) | |
| Closure of RCRA landfill and other RCRA hazardous waste management units | Must close the unit in a manner that:<br>(a) Minimizes the need for further maintenance; and<br>(b) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and<br>(c) Complies with the closure requirements of this part, including, but not limited to, the requirements of §§264.178, 264.197, 264.228, 264.258, 264.280, 264.310, 264.351, 264.601 through 264.603, and 264.1102. | Closure of a RCRA hazardous waste management facility - **applicable** | 40 CFR 264.111<br>TDEC 0400-12-01-.06(7)(b) | |
| Closure of RCRA landfill | Must cover the landfill or cell with a final cover designed and constructed to:<br>(1) Provide long-term minimization of migration of liquids through the closed landfill;<br>(2) Function with minimum maintenance;<br>(3) Promote drainage and minimize erosion or abrasion of the cover;<br>(4) Accommodate settling and subsidence so that the cover's integrity is maintained; and<br>(5) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present. | | 40 CFR 264.310(a)<br>TDEC 0400-12-01-.05(14)(k) | |
| Clean closure of a RCRA container storage area | Must remove all hazardous waste and residues from containment system. Remaining containers, liners, bases and soil containing or contaminated with hazardous waste or residues must be decontaminated or removed. | Management of RCRA hazardous waste in a container storage area - **applicable** | 40 CFR 264.178<br>TDEC 0400-12-01-.06(9)(i) | |
| Clean closure of TSCA storage facility | A TSCA/RCRA storage facility closed under RCRA is exempt from the TSCA closure requirements of 40 CFR 761.65(e). | Closure of TSCA/RCRA storage facility - **applicable** | 40 CFR 761.65(e)(3) | |
| Closure of ground water monitoring well(s) | Shall be accomplished by a licensed driller. | Permanent plugging and abandonment of a well - **relevant and appropriate** | TDEC 0400-45-09-.16(2) | |

**Table G-8. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| | Shall be completely filled and sealed in such a manner that vertical movement of fluid either into or between formation(s) containing ground water classified pursuant to rule 0400-45-06-.05(1) through the bore hole is not allowed. | | TDEC 0400-45-06-.09(6)(d) | |
| | Shall be performed in accordance with the provisions for Seals at 400-45-06-(6)(e), (f), and (g), for Fill Materials at 0400-45-06-.09(6)(h) and (i), for Temporary Bridges at 0400-45-06-.09(6)(j), for Placement of Sealing Materials at 0400-45-06-.09(7)(a) and (b), and Special Conditions at 0400-45-06-09(8)(a) and (b), as appropriate | | TDEC 0400-45-06-.09(6)(e) through (j)<br>TDEC 0400-45-06.09(7)<br>TDEC 0400-45-06.09(8)(a)<br>TDEC 0400-45-06.09(8)(b) | |
| Closure of a RCRA tank system | Must remove or decontaminate all waste residues, contaminated containment system components (liners, etc.) contaminated soils, and structures and equipment contaminated with waste, and manage them as hazardous waste, unless 40 CFR 261.3(d) (TDEC 0400-12-01-.02[1][c][4]) applies.If all contents cannot be practicably removed or decontaminated, consider the tank system a landfill and close in accordance with the landfill closure requirements of 40 CFR 264.310 (TDEC 0400-12-01-.06[14][k]). | Closure of a RCRA hazardous tank system - **relevant and appropriate** | 40 CFR 264.197(a) and (b)TDEC 0400-12-01-.06(10)(h)(1) and (2) | From IWM FFS.<br>Applies if waste water is determined to be hazardous. |
| Closure and post-closure care of a surface impoundment | Must remove or decontaminate all waste residues and contaminated materials; otherwise free liquids must be removed, the remaining wastes stabilized to a bearing capacity sufficient to support final cover, and the facility closed and covered with a final cover designed in accordance with 40 CFR 264.228(a)(2)(iii)(A)-(E) (TDEC 0400-12-01-.06[11][i][1][ii][III]).<br>If some waste residues or contaminated materials are left in place at final closure, must comply with all postclosure requirements contained in §§264.117 through 264.120 (TDEC 0400-12-01-.06[7][h] through [k]), including maintenance and monitoring throughout the postclosure period. Must also:<br>• maintain integrity and effectiveness of final cover, making repairs to the cap as necessary;<br>• maintain and monitor leak detection system;<br>• maintain and monitor ground water monitoring system;<br>• prevent run-on and runoff from eroding or otherwise damaging final cover. | Closure of a hazardous waste surface impoundment - **relevant and appropriate** | 40 CFR 264.228(a) and (b) TDEC 0400-12-01-.06(11)(i)(1) and (2) | From IWM FFS.<br>Applies if waste water is determined to be hazardous. |

**Table G-8. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| ***Post-closure*** | | | | |
| Survey plat | Must submit to the local zoning authority or the authority with jurisdiction over local land use, a survey plat indicating the location and dimensions of landfill cells, with respect to permanently surveyed benchmarks. The plat must contain a note, prominently displayed which states the owner/operator obligation to restrict disturbance of the landfill. | Closure of a RCRA landfill - **applicable** | 40 CFR 264.116<br>TDEC 0400-12-01-.06(7)(g) | |
| | Within 60 days of a site becoming inactive and after the effective date of this subpart, record, in accordance with State law, a notation on the deed to the facility property and on any other instrument that would normally be examined during a title search; this notation will in perpetuity notify any potential purchaser of the property that:<br>(1) The land has been used for the disposal of asbestos-containing waste material;<br>(2) The survey plot and record of the location and quantity of asbestos-containing waste disposed of within the disposal site required in §61.154(f) have been filed with the Administrator; and<br>(3) The site is subject to 40 CFR part 61, subpart M. | Closure of an asbestos-containing waste disposal site - **applicable** | 40 CFR 61.151(e) | |
| Duration | Post closure care must begin after closure and continue for at least 30 years after that date. | Closure of a RCRA landfill - **applicable** | 40 CFR 264.117(a)<br>TDEC 0400-12-01-.06(7)(h) | |
| Protection of facility | Post-closure use of property must never be allowed to disturb the integrity of the final cover, liners, or any other components of the containment system or the facility's monitoring system unless necessary to reduce a threat to human health or the environment. | | 40 CFR 264.117(c)<br>TDEC 0400-12-01-.06(7)(h)(3) | |
| Post-closure plan | Must have a written post-closure plan which identifies planned monitoring activities and frequency at which they will be performed for ground water monitoring, containment systems and cap maintenance. | | 40 CFR 264.118<br>TDEC 0400-12-01-.06(7)(i) | |
| Post-closure notices | Must submit to the local zoning authority a record of the type, location, and quantity of hazardous wastes disposed of within each cell of the unit. | | 40 CFR 264.119(a)<br>TDEC 0400-12-01-.06(7)(j)(1) | |
| Survey plat | Must record, in accordance with State law, a notation on the deed to the facility property - or on some other instrument which is normally examined during a title search - that will in perpetuity notify any potential purchaser of the property that the land has been used to manage hazardous wastes, and its use is restricted. | | 40 CFR 264.119(b)<br>TDEC 0400-12-01-.06(7)(j)(2) | |

**Table G-8. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring of Requirement |
|---|---|---|---|---|
| General post-closure care | After final closure, owner or operator must:<br>(i) Maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.;<br>(ii) Continue to operate the leachate collection and removal system until leachate is no longer detected;<br>(iii) Maintain and monitor the leachate detection system in accordance with 40 CFR 264.301(a)(3)(iv) and (4) and 40 CFR 264.303(c);<br>(iv) Maintain and monitor a ground water monitoring system and comply with all other applicable provisions of 40 CFR 264, Subpart F;<br>(v) Prevent run-on and run-off from eroding or otherwise damaging final cover; and<br>(vi) Protect and maintain surveyed benchmarks used to locate waste cells. | | 40 CFR 264.310(b)<br>TDEC 0400-12-01-.06(14)(k)(2) | |
| Waste left in place | Institutional controls are required and shall include, at a minimum, deed restrictions for sale and use of property and securing area to prevent human contact with hazardous substances. | Hazardous substances left in place which may pose an unreasonable threat to public health, safety, or the environment - **relevant and appropriate** | TDEC 0400-15-01-.08(10) | |

**Table G-9. Action-specific ARARs and TBC Guidance for CERCLA Waste Disposal, Off-site Disposal Alternative**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring to Requirements |
|---|---|---|---|---|
| Transportation of hazardous materials | Shall be subject to and must comply with all applicable provisions of the HMTA and HMR at 49 CFR 171-180. | Any person who, under contract with a department or agency of the federal government, transports "in commerce", or causes to be transported or shipped, a hazardous material - **applicable** | 49 CFR 171.1(c) | |
| Transportation of PCB wastes off-site | Must comply with the manifesting provisions at 40 CFR 761.207 through 218. | Relinquishment of control over PCB wastes by transporting, or offering for transport - **applicable** | 40 CFR 761.207(a) | |
| Transportation of hazardous waste off-site | Must comply with the generator requirements of 40 CFR 262.20-23 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding, Sect. 262.41(a) for record keeping requirements, and Sect. 262.12 to obtain EPA ID number. | Off site transportation of RCRA hazardous waste - **applicable** | 40 CFR 262.10(h) TDEC 0400-12-01-.03(1)(a)(8) | |
| | Must comply with the requirements of 40 CFR 263.11-263.31. (Standards applicable to transporters of hazardous waste.) | Transportation of hazardous waste within the United States requiring a manifest - **applicable** | 40 CFR 263.11 - 263.31 | |
| | A transporter who meets all applicable requirements of 49 CFR 171-179 and the requirements of 40 CFR 263.11 and 263.31 will be deemed in compliance with 40 CFR 263. | Transportation of hazardous waste within the United States requiring a manifest - **applicable** | 40 CFR 263.10(a) | |

**Table G-9. Action-specific ARARs and TBC Guidance for CERCLA Waste Disposal, Off-site Disposal Alternative (Continued)**

| Action Characteristic | Requirements | Prerequisite | EMDF Citation | Tailoring to Requirements |
|---|---|---|---|---|
| Transportation of hazardous waste on-site | The generator manifesting requirements of 40 CFR 262.20-262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 CFR 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way. | Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way – **applicable** | 40 CFR 262.20(f) | |
| Transportation to disposal facility | The waste must meet packaging, labeling, marking, placarding and pre-transport requirements in accordance with DOT regulations. | Transportation of hazardous and radioactive materials above exempt quantities – **applicable** | 49 CFR 171, 172, 173, 174, 177, 178, and 179 | |
| | Must meet packaging requirements based on the maximum activity of radioactive material in a package. | Packaging of radioactive materials above exempt quantities for public transport – **applicable** | 49 CFR 173.431; 49 CFR 173.433; 49 CFR 173.435; 49 CFR 173.411 | |
| | Must be marked with hazardous waste marking, generator's name and address, and the manifest docket number. | Transportation of hazardous waste in containers of 110 gal or less – **applicable** | 40 CFR 262.32(b) | |
| | Shipment must be manifested according to 40 CFR 262 and 40 CFR 263. | Transportation of hazardous waste for off-site TSD – a**pplicable** | 40 CFR 262 Subpart B; 40 CFR 263 Subpart B | |

This page intentionally left blank.

# 9. REFERENCES


Baranski, M.L. 2009, *Natural Areas Analysis and Evaluation, Oak Ridge Reservation*. ORNL/TM-2009/201, Oak Ridge National Laboratory, November 2009, Oak Ridge TN.

DOE 1992. *Federal Facility Agreement for the Oak Ridge Reservation*, U.S. Department of Energy, U.S. Environmental Protection Agency Region 4, and Tennessee Department of Environment and Conservation, DOE/OR-1014.

EPA 1989. *CERCLA Compliance with Other Laws Manual: Part II*. EPA/540/G-89/009, OSWER 9234.1-02, August, 1989.

EPA 1991. *ARARs Q's &A's: General Policy, RCRA,CWA, SDWA, Post-ROD Information, and Contingent Waivers*. Publication 9234.2-01/FS-A Office of Solid Waste and Emergency Response, July 1991. EPA, Washington, D.C.

EPA 1995. *Clarification of NPL Listing Policy. Memorandum from Stephen D. Luftig, Acting Director, Office of Emergency and Remedial Response to Division Directors*, August 4, 1995. EPA, Washington, DC.

EPA 1997. *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, OSWER No. 9200.4-18, U.S. Environmental Protection Agency, August 22, 1997, Washington, D.C.

EPA 2000. *Development Document for Final Effluent Limitations Guidelines and Standards for the Landfills Point Source Category*. EPA-821-R-99-019.

This page intentionally left blank.

# APPENDIX H:
# ON-SITE DISPOSAL FACILITY
# PRELIMINARY WASTE ACCEPTANCE CRITERIA

# CONTENTS


1. INTRODUCTION ..... H-8
   1.1 WASTE ACCEPTANCE CRITERIA COMPONENTS ..... H-8
   1.2 FINALIZATION OF WASTE ACCEPTANCE CRITERIA ..... H-10
   1.3 APPENDIX ORGANIZATION ..... H-10
2. CONCEPTUAL SITE MODEL ..... H-11
   2.1 EMDF SITE DESCRIPTION ..... H-11
   2.2 CONCEPTUAL MODEL AND EXPOSURE PATHWAYS ..... H-13
   2.3 HYPOTHETICAL RECEPTOR ..... H-14
   2.4 RECEPTOR LOCATION ..... H-16
   2.5 RISK CRITERIA ..... H-18
3. PRELIMINARY WAC DEVELOPMENT AND MODELS ..... H-19
   3.1 OVERVIEW OF PREWAC DEVELOPMENT ..... H-19
   3.2 MODELS USED TO SUPPORT PREWAC DEVELOPMENT ..... H-21
      3.2.1 HELP Model ..... H-21
      3.2.2 MODFLOW and MODPATH Models ..... H-21
      3.2.3 MT3D Model ..... H-22
      3.2.4 PATHRAE-HAZ/RAD Model ..... H-23
4. DEVELOPMENT OF SITE-SPECIFIC MODELS ..... H-24
   4.1 HELP MODEL APPLICATION ..... H-24
      4.1.1 Site-specific HELP Model Development ..... H-24
      4.1.2 HELP Model Assumptions ..... H-25
      4.1.3 HELP Model Results ..... H-28
   4.2 GROUND WATER FLOW (MODFLOW/MODPATH) MODELS APPLICATION ..... H-30
      4.2.1 Site-specific MODFLOW/MODPATH Model Development ..... H-30
      4.2.2 MODFLOW/MODPATH Model Assumptions ..... H-41
      4.2.3 MODFLOW/MODPATH Model Results ..... H-42
   4.3 FATE-TRANSPORT (MT3D) MODEL APPLICATION ..... H-46
      4.3.1 Site-specific MT3D Model Development ..... H-46
      4.3.2 MT3D Model Assumptions ..... H-48
      4.3.3 MT3D Model Results ..... H-48
   4.4 PATHRAE MODELING AND RISK/DOSE ANALYSIS ..... H-49
      4.4.1 Site-specific PATHRAE Model Development ..... H-49
      4.4.2 PATHRAE Model Assumptions ..... H-54
      4.4.3 PATHRAE Model Results ..... H-60
5. ANALYTIC PRELIMINARY WASTE ACCEPTANCE CRITERIA ..... H-70
   5.1 CARCINOGENIC PREWAC CALCULATIONS ..... H-70

5.1.1 Carcinogenic Preliminary Waste Acceptance Criteria for Radioactive Contaminants of Potential Concern ..... H-70
5.1.2 Carcinogenic PreWAC for Hazardous COPCs ..... H-74
5.2 HAZARDOUS (HAZARD INDEX) PRELIMINARY WASTE ACCEPTANCE CRITERIA CALCULATIONS ..... H-74
5.3 DISCUSSION OF PREWAC RESULTS ..... H-78
5.4 COMPARISON TO ENVIORNMENTAL MANAGEMENT WASTE MANAGEMENT FACILITY ANALYTIC WASTE ACCEPTANCE CRITERIA ..... H-83
6. REFERENCES ..... H-91
APPENDIX H - ATTACHMENT A: CONTAMINANTS OF POTENTIAL CONCERN ..... H-96
APPENDIX H - ATTACHMENT B: SUPPLEMENTAL MODELING INFORMATION ..... H-97

# FIGURES

Figure H-1. Conceptual Layout of the Proposed EMDF in East Bear Creek Valley ..... H-12
Figure H-2. Conceptual Site Model and Hypothetical Receptor Scenario ..... H-15
Figure H-3. Proposed EMDF Location and Zone 3 (*DOE-controlled Industrial Use*) Boundaries ..... H-17
Figure H-4. PreWAC Model Linkage and Application ..... H-19
Figure H-5. Upper Bear Creek Valley Model Domain (Current 2012 Condition) ..... H-32
Figure H-6. Upper Bear Creek Valley Model Domain with New Disposal Cell (EMDF Future Condition) ..... H-33
Figure H-7. Upper Bear Creek Valley Model Cross-Sections ..... H-34
Figure H-8. Upper Bear Creek Valley MODFLOW Model Drainage Representation ..... H-35
Figure H-9. Upper Bear Creek Valley Model Recharge Distribution (ft/day) ..... H-36
Figure H-10. Upper Bear Creek Valley Model Hydraulic Conductivity Field in Layer 1 ..... H-38
Figure H-11. Upper Bear Creek Valley Model Hydraulic Conductivity Field in Cross Section ..... H-38
Figure H-12. MODPATH Model Predicted Potentiometric Lines and Flow Field in the Shallow Aquifer ..... H-43
Figure H-13. MODPATH Model Predicted Potentiometric Lines and Flow Field in the Intermediate Aquifer ..... H-44
Figure H-14. MODPATH Predicted Particle Tracks ..... H-45
Figure H-15. Source Leaching Representation in the MT3D Model and the Hypothetical Receptor Well Location ..... H-47
Figure H-16. MT3D Model Predicted Plume of Maximum Contaminant Concentration in All Model Layers for EMDF ..... H-50
Figure H-17. MT3D Model Predicted Plume of Average, Relative Contaminant Concentration for Model Layers 5–8 ..... H-51
Figure H-18. MT3D Model Predicted Steady-state Plume from the EMDF in Cross-section ..... H-52
Figure H-19. MT3D Model Predicted Ground Water Well Concentrations (Relative to Leachate) with Time ..... H-53
Figure H-20. Contaminant Leaching/Transport Analysis and Exposure Conceptual Model ..... H-55
Figure H-21. Relative Concentration in Landfill of Radioactive COPCs with Half-lives under 55 Years ..... H-79
Figure H-22. Relative Concentration in Landfill of Radioactive COPCs with Half-lives under 500 Years ..... H-80
Figure H-23. Relative Concentration in Landfill of Radioactive COPCs with High Partition Coefficients ..... H-80
Figure H-24. Relative Concentration of Ni-59 in Landfill due to Decay+Leaching versus Decay Only… ..... H-81
Figure H-25. Relative Concentration of Tc-99 in Landfill due to Decay+Leaching versus Decay Only… ..... H-81

Figure H-26. EMWMF Conceptual Design, EMWMF As-built, EMDF Conceptual Design, and Hypothetical Receptor Well Locations ..... H-90

# TABLES

Table H-1. EMDF Conceptual Design Profile and Material Characteristics ..... H-27
Table H-2. HELP Model Predicted Mass Balance and Infiltration Rates for Long-term Performance (Worst Case) ..... H-29
Table H-3. UBCV MODFLOW Ground Water Model Parameter Summary (Future Condition) ..... H-39
Table H-4. Key PATHRAE Parameters ..... H-56
Table H-5. Parameters for Use in PATHRAE Modeling and PreWAC Calculations ..... H-59
Table H-6. PATHRAE-RAD Results and Peak Effective Risk for Radionuclide COPCs Determined on the Basis of 1Ci/$m^3$ COPC Source ..... H-64
Table H-7. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous COPCs Determined on the Basis of 1 kg/$m^3$ COPC Source ..... H-66
Table H-8. EMDF Analytic PreWAC for Radionuclides ..... H-72
Table H-9. Isotopic Decay Pairs Considered for Further Adjustments to PreWAC ..... H-73
Table H-10. EMDF Analytic PreWAC for Hazardous Constituents ..... H-75
Table H-11. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC ..... H-85

# ACRONYMS

| | |
|---|---|
| ASA | Auditable Safety Analysis |
| BCV | Bear Creek Valley |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CFR | Code of Federal Regulations |
| COPC | contaminant of potential concern |
| DF | dilution factor |
| DOE | U.S. Department of Energy |
| EBCV | East Bear Creek Valley |
| ELCR | Excess Lifetime Cancer Risk |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| EU | equivalent uptake |
| FFA | Federal Facility Agreement |
| FML | flexible membrane layer |
| FS | Feasibility Study |
| GCL | geosynthetic clay liner |
| HDPE | high-density polyethylene |
| HELP | Hydrologic Evaluation of Landfill Performance |
| HI | hazard index |
| K | hydraulic conductivity |
| $K_d$ | solid-to-liquid partition coefficient |
| LDR | land disposal restrictions |
| LLW | low-level waste |
| MCL | maximum concentration limit |
| MEI | maximally exposed individual |
| MOC | Method of Characteristic |
| MSL | mean sea level |
| NRC | Nuclear Regulatory Commission |
| NT | Northern Tributary |
| O | Order |
| ORR | Oak Ridge Reservation |
| PreWAC | Preliminary Waste Acceptance Criteria |
| RAO | Remedial Action Objective |
| RCRA | Resource Conservation and Recovery Act of 1976 |

| | |
|---|---|
| RI/FS | Remedial Investigation/Feasibility Study |
| ROD | Record of Decision |
| SA | specific activity |
| SOF | sum of fractions |
| SPSS | sulfur polymer stabilization/solidification |
| TCLP | toxicity characteristic leaching procedure |
| TMR | telescopic mesh refinement |
| U.S. | United States |
| UBCV | Upper Bear Creek Valley |
| USGS | U.S. Geological Survey |
| VWSF | volume weighted sum of fractions |
| WAC | waste acceptance criteria |
| Y-12 | Y-12 National Security Complex |

# 1. INTRODUCTION

The purpose of this Appendix is to develop preliminary analytic concentration limits for contaminants of potential concern (COPCs), referred to as Preliminary Waste Acceptance Criteria (PreWAC), which would meet the applicable risk and dose criteria specified in the remedial action objectives (RAOs), using fate and transport analysis based on a resident farmer scenario for the proposed Environmental Management Disposal Facility (EMDF). This analysis provides the basis for demonstrating that the proposed EMDF conceptual design and site would be protective of human health and the environment and be a viable disposal option for most future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste. In demonstrating the ability to meet RAOs that ensure protection of human health and the environment, the modeling conducted to define PreWAC serves to fulfill the CERCLA risk evaluation, which in this instance forecasts long-term effectiveness (protectiveness in terms of residual risk) of the alternative.

Future CERCLA waste will be generated from environmental cleanup and deactivation and decommissioning activities on the United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR). The On-site Disposal Alternative in this Remedial Investigation (RI)/Feasibility Study (FS) evaluates a proposed site in East Bear Creek Valley (EBCV) for disposal of future CERCLA waste after the Environmental Management Waste Management Facility (EMWMF) reaches maximum capacity. The proposed EMDF site is located adjacent to and east of the current EMWMF site and has similar engineering design and hydrogeologic attributes.

## 1.1 WASTE ACCEPTANCE CRITERIA COMPONENTS

A negotiated waste acceptance criteria (WAC) attainment process was developed for the EMWMF (DOE/OR/01-1909&D3), which involves the designation of four separate types of WAC requirements (DOE 2001a) to define and limit acceptable wastes. Similar tri-party negotiations would result in a WAC attainment process for this proposed on-site facility to be documented in a primary Federal Facility Agreement (FFA) document, the WAC Attainment Plan (see Section 1.2 for more information). EMWMF WAC include:

- **Administrative WAC:** Derived from applicable or relevant and appropriate requirements in the EMWMF Record of Decision (ROD) (DOE 1999a), and from other agreements between the DOE, the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation.
- **Auditable Safety Analysis (ASA)-derived WAC:** Derived from facility authorization basis documentation for the EMWMF.
- **Physical WAC:** Derived from operational constraints and contractual agreements for EMWMF operations.
- **Analytic WAC:** Derived from the approved risk assessment model in the EMWMF RI/FS and RI/FS Addendum (DOE 1998a, DOE 1998b) for the EMWMF.

The first three WAC are not addressed in this RI/FS, but will be negotiated by the FFA parties and incorporated into the WAC Attainment Plan. The first WAC, administrative WAC, includes limits on disposal of greater than Class C waste and compliance with Resource Conservation and Recovery Act of 1976 (RCRA) land disposal restrictions. The administrative WAC also prohibits disposal of transuranic waste, high-level waste, spent nuclear fuel, or Atomic Energy Act of 1954 Section 11e(2) byproduct waste, and places limits on total uranium concentrations in waste separate from and in addition to analytic WAC considerations. Administrative WAC thus address the short-term and long-term risks associated with disposal of radioactive and hazardous waste. Administrative WAC allow the FFA parties to set

limits when necessary, when other WAC do not fully address protectiveness concerns (e.g., in the case of transuranic waste).

The second WAC, ASA-derived WAC, control disposal of radionuclides based on a maximum credible release of material that would occur during an extreme wind event during operations at the facility. These limits are also separate from and in addition to analytic WAC considerations. These WAC thus mainly address short-term external exposure risk to workers.

The third WAC, physical WAC, address the physical form of acceptable waste items such as length of piping, waste containers size and weight, dimensions of concrete rubble, addresses voids, etc. that are manageable from an facility operations point of view.

The focus of this Appendix is the risk-based analytic PreWAC for the proposed EMDF. The analytic PreWAC are numerical limits developed by applying fate and transport analysis based on site hydrogeology and using conceptual design elements of the EMDF and risk/dose analytical approaches. Beyond fate and transport analysis, the development of the PreWAC for the proposed EMDF consider protection of natural resources, and take into account increased decay product concentrations. An analytic WAC is the numerical concentration limit of a single radioactive or hazardous constituent such that, if the landfill were fully occupied by only this contaminant at the stated concentration, cancer risk or hazard index (HI) to a hypothetical public receptor would not exceed a specified criteria over an evaluated period of time (up to 1,000 years, or to peak risk occurrence, if that peak occurs after 1,000 years). In this respect, the determination of analytic PreWAC is a preview of the long-term protectiveness of the alternative, solely in terms of the mobility of the contaminant in the environment. This means that if a contaminant is NOT mobile (e.g., has a high affinity to remain attached to soil particles) and/or has a short half-life (e.g., up to several hundreds of years, meaning its concentration decays relatively quickly) it likely will not have an analytic limit.

In practice, a single waste contaminant would not occupy the entire facility. Rather, the disposal cell will ultimately contain many waste streams of various volumes, each containing multiple radiological and chemical contaminants at various concentrations. To accommodate these different waste streams, an approach to apply the contaminant-specific analytic WAC limits was developed for and fully documented in the EMWMF WAC Attainment Plan (DOE/OR/01-1909&D3). The sum of fractions (SOFs) calculation method is applied to each waste lot to account for the presence of multiple contaminants. To consider incorporation of that waste lot into the entire EMWMF landfill, a volume-based weighting factor is applied to the SOF of each waste lot for all waste lots already in the landfill, waste lots proposed for acceptance in the landfill, and some forecasted future waste lots to determine a “landfill-wide” SOF. This method is referred to as the volume-weighted sum of fractions (VWSF), which allows an evaluation of the acceptance of a waste lot into the disposal facility as a whole. It maximizes the capacity of the landfill in terms of radioactive inventory, while ensuring that the landfill as a whole does not exceed the cancer risk or hazard index from which the analytic WAC limits for each contaminant were derived.

The four separate WAC types and compliance process for the EMWMF are the result of formal negotiations between FFA parties during the pre-ROD and post-ROD stages of the CERCLA process. Likewise, these four WAC types will have to be renegotiated for a future on-site disposal facility, and will be documented in final form in the WAC Attainment Plan for that facility. At this RI/FS stage, PreWAC are proposed in this document, and will be carried forward in the Proposed Plan and ROD. It is assumed that administrative, ASA-derived, and physical WAC components for the new facility as well as a WAC compliance approach, including the waste lot SOF and some additional calculations to determine waste acceptance for the facility as a whole, would be similar to the WAC components and compliance approach for EMWMF.

## 1.2 FINALIZATION OF WASTE ACCEPTANCE CRITERIA

The analytic PreWAC will be finalized as the design for the disposal facility proceeds and final design parameters, site layout, and additional site-specific characterization data are available. Final analytic WAC will be determined in parallel with final design. It is emphasized that the analytic PreWAC results presented in this Appendix are a preliminary data set, based on the mobility of the contaminants in the hydrogeological environment assuming the current facility conceptual design and resulting exposure to a hypothetical receptor, and additionally, protection of natural resources. The analytic PreWAC are developed to provide protectiveness and evaluate the viability of land disposal at the proposed site, based on a conceptual design. If on-site disposal is the selected remedy as determined by the CERCLA process, final analytic WAC for a new facility will be developed based not only on mobility in the environment and hypothetical receptor exposure, but also on external exposures to inadvertent intruders as required by DOE Order (O) 435.1, and will continue to demonstrate achievement of the RAOs and any applicable or relevant and appropriate requirements. They will be documented in a primary, tri-party-approved FFA document (WAC Attainment Plan). Administrative, ASA-derived, and physical WAC, along with a process to determine attainment of the WAC, will be negotiated and documented in the WAC Attainment Plan. The method or process to determine attainment of the WAC may differ from the attainment process described above (VWSF) for the EMWMF.

## 1.3 APPENDIX ORGANIZATION

The site conceptual model and exposure pathways are discussed in Chapter 2. PreWAC development and the computer models used are introduced in Chapter 3. Chapter 4 describes site-specific model development and assumptions for the proposed EMDF site and risk/dose modeling and calculations. Chapter 5 provides analytic PreWAC calculations and results, PreWAC adjustments for daughter products and maximum contaminant levels, and compares EMDF results to the EMWMF WAC. Chapter 6 lists references used in the analysis. Attachment A is a summary of COPC information and parameters used in modeling. Attachment B provides supplemental modeling information.

# 2. CONCEPTUAL SITE MODEL

The proposed EMDF would be an on-site, radioactive low-level waste (LLW) and mixed waste landfill for disposal of waste generated by cleanup of the ORR. The facility would be designed to receive wastes resulting from remediation of contaminated areas and demolition of contaminated buildings from CERCLA cleanup projects. The proposed EMDF has a conceptual design capacity of 2.5 million $yd^3$. Figure H-1 illustrates the site plan of the proposed EMDF.

The conceptual design of the EMDF is described in Section 6.2 of the RI/FS and site characteristics are described in Appendix E. Summary information about the proposed site characteristics, site conceptual model, risk exposure pathways, receptor, receptor location, and risk criteria is provided below.

## 2.1 EMDF SITE DESCRIPTION

The proposed EMDF site is located in EBCV on the ORR. The EMDF site lies on the southern slopes of Pine Ridge between Bear Creek Northern Tributary (NT)-2 and NT-3. Bear Creek is roughly 1,100 ft south of the site at the nearest point. In the vicinity of the site, the elevation of Pine Ridge ranges from 1,180–1,260 ft above mean sea level (MSL). The elevation of the Bear Creek Valley (BCV) floor ranges from about 940–1,000 ft-MSL.

The stratigraphic section in BCV includes rocks ranging in age from early to late Cambrian. The three rock sequences in the BCV (Rome Formation, Conasauga Group, and Knox Group) comprise a complex stratigraphic assemblage of shales, limestones, dolomites, siltstones, and sandstones (DOE 1998a). A more detailed description of site geology is provided in Appendix E.

The early Cambrian Rome Formation, which is the oldest unit exposed in the site area, outcrops on the ridge top of Pine Ridge and like all the formations in BCV dips typically 45° to the southeast beneath BCV. The Rome Formation consists of variegated shale, interbedded with siltstone, sandstone, and minor amounts of dolomite. Overlying the Rome Formation, and underlying the southern slope of Pine Ridge, is the middle to late Cambrian Conasauga Group, a sequence of primarily shales with some interbedded limestones and dolomites. Within BCV, the Conasauga Group is subdivided into six formations: Pumpkin Valley, Rutledge, Rogersville, Maryville, Nolichucky, and Maynardville. Of these formations, only the Pumpkin Valley through Maryville formations directly underlie the footprint of the proposed EMDF. The Maynardville Formation, composed mostly of limestone, underlies the lowest portions of the valley floor south of the EMDF. The Knox Group of late Cambrian is composed primarily of massive, siliceous dolomite that forms Chestnut Ridge on the south side of BCV.

Small-scale geologic features, such as fractures in clastic formations and solution features primarily in the Maynardville, are a major factor in ground water movement through the formations underlying the BCV. Master fractures may exist; however, extensive conduit systems are not likely given that shales and shaley carbonates are the dominant lithologies underlying the EMDF area. These bedrock features provide the pathways for ground water flow through geologic formations, such as shales and limestones, which typically have little intrinsic permeability. Fractures occur in all stratigraphic units as a result of tectonic activity and geostatic relief, and are the most pervasive ground water transmitting feature on the ORR (Hatcher et al. 1992). The most prominent and well-developed fracture sets are oriented parallel to geologic strike and result in dominant strike-parallel ground water flow paths. Fracture aperture width and frequency generally decrease with depth in all formations and thus restrict the depth of active ground water circulation. The unconsolidated materials, or regolith, overlying bedrock in the EBCV site include a thin topsoil layer underlain by a clayey residuum and bedrock remnants and weathered bedrock (saprolite) above less weathered to unweathered variably fractured bedrock. Porous unconsolidated colluvium and alluvium occur as shallow surficial mixtures of clay, silt, sand, and gravel along and adjacent to the tributary valley floors at and near the EMDF.

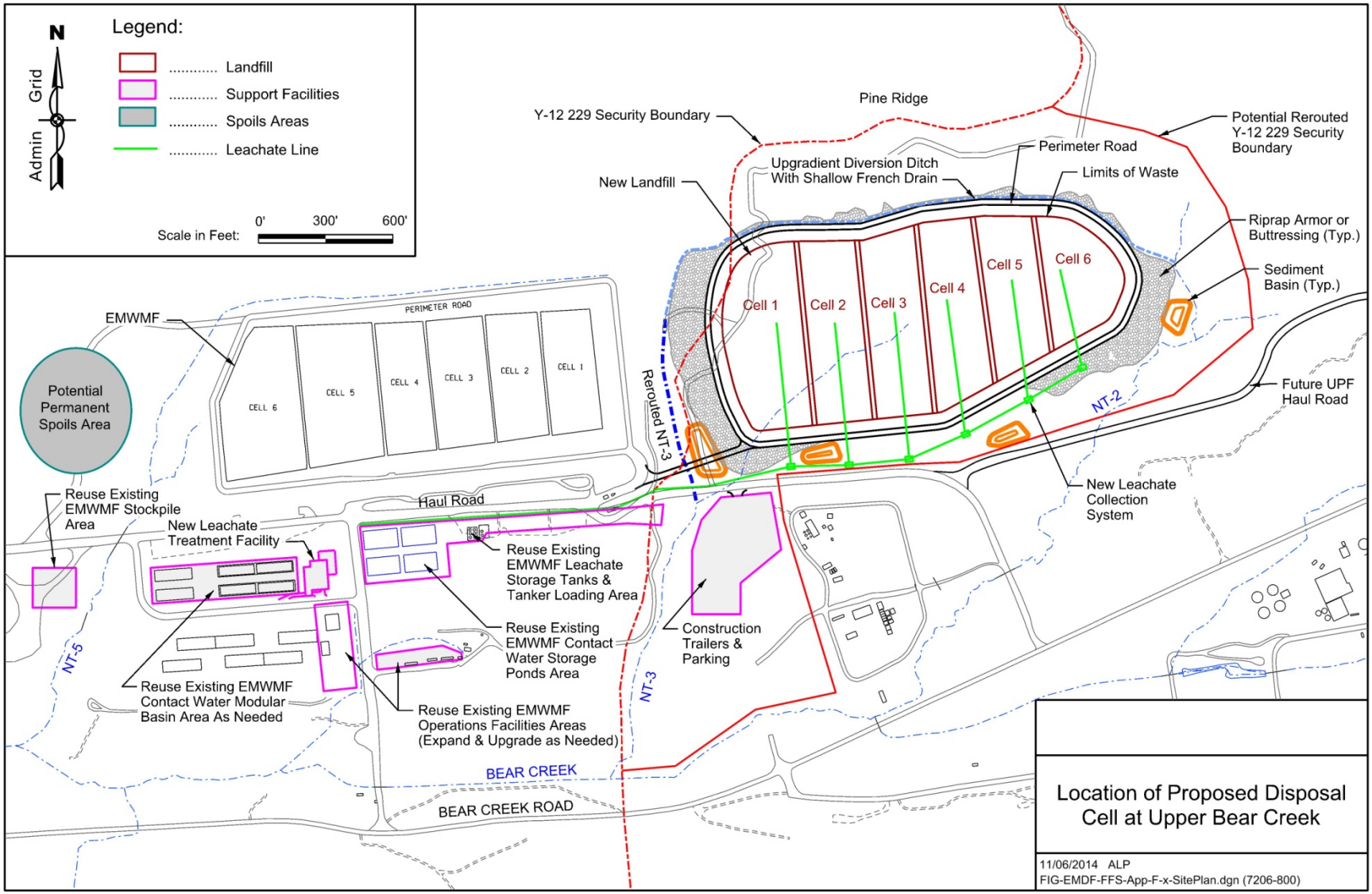



**Figure H-1. Conceptual Layout of the Proposed EMDF in East Bear Creek Valley**

Within BCV, the majority of ground water flow occurs primarily within the upper 100 ft of the aquifer system (Solomon et al. 1992). Ground water flow at and near the EMDF mimics surface topography and moves from higher upland areas such as Pine Ridge and subsidiary ridges to lower elevation valley floors where tributary streams convey surface water runoff and ground water discharge toward Bear Creek. Shallow to intermediate ground water flow converges toward the valley floors of NT-2 and NT-3 that cross the EMDF footprint. According to the subsurface hydrologic framework of Solomon et al (1992), ground water flux occurs predominantly via a near surface stormflow zone that may account for as much as 90% of the estimated subsurface water flux with relatively rapid discharge to streams and valley floors after rainfall events. Ground water that is not diverted laterally via the stormflow zone moves through preferential pathways in the underlying vadose zone to a water table interval that transmits 8% or more of the estimated ground water flux. Below the water table interval, the intermediate ground water interval accounts for <2% of the estimated ground water flux. The deep ground water interval accounts for <1% of the estimated flux. The decreasing ground water flux is attributed to the decrease in the effective porosity and permeability of the regolith and weathered and unweathered bedrock with depth (see Appendix E for additional details related to site hydrogeology and the site conceptual model). Documented hydraulic conductivity and ground water flow rates decrease progressively from the stormflow zone to the water table interval and into the intermediate and deep intervals of the saturated zone as the number, width, density and interconnectivity of fractures decreases. The occurrence and movement of ground water in the bedrock is closely related to the presence of bedding planes, joints, and fractures, and of solution cavities within carbonate beds of the Maynardville Limestone and Copper Ridge Dolomite. In general, ground water in the bedrock occurs under water-table conditions but becomes increasingly confined with depth. Downward recharge to the ground water system occurs along the flanks of Pine Ridge and Chestnut Ridge which appears to result in upward hydraulic gradients deeper in the subsurface and further downslope toward ground water discharge zones along the valley floors.

BCV hydrogeologic units behave as an anisotropic system in all three dimensions, as evidenced by the elongated drawdown along strike direction observed during pumping tests and the spatial distribution of contaminant plumes and ground water tracers. The anisotropic nature of hydraulic conductivity associated with the bedrock underlying BCV results from the orientation and intersection of fractures, joints, and/or bedding planes. Due to this anisotropy, a large portion of ground water flow moves primarily along strike (i.e., east to west) with discharge along topographically lower tributaries or fractures that trend perpendicular to strike and eventually flow into Bear Creek and the Maynardville Limestone.

Bear Creek flows southwestward from its headwaters for approximately 4.5 miles along the BCV axis, and then turns northward, cutting through a water gap in Pine Ridge to flow into East Fork Poplar Creek. The drainage area of BCV is approximately 5.2 square miles (Robinson and Johnson 1995). Most of the tributaries of Bear Creek originate along the flanks of the Pine Ridge.

## 2.2 CONCEPTUAL MODEL AND EXPOSURE PATHWAYS

Development of a conceptual model of the site is necessary prior to evaluating the likely impact of potential contaminants that might emanate from the proposed EMDF. A conceptual site model identifies the key elements of fate and transport, which include the media that contaminants may move through and the receptor(s) that could become exposed to such contaminants. The primary pathways for contaminant migration are associated with ground and surface water that could be impacted by potential future leakage of contaminants from the EMDF. Ground water modeling used to simulate future contaminant migration treats the subsurface as an equivalent porous medium, meaning that while flow actually occurs in pores and fractures, at the scale of the model these can be considered as one system, similar to a porous medium such as sandstone. While a conceptual site model, in general, is a simplification of the fate and transport processes, it provides a visualization and general understanding that can be used to develop the WAC modeling processes. See Section 2.2 of Appendix E for additional geological information about the conceptual site model for the EMDF.

Figure H-2 shows the conceptual disposal cell, leachate movement, and generalized ground and surface water flow paths in the area of concern. Contaminant migration pathways include leachate movement through the waste, liner, and geologic buffer; through the vadose zone below the landfill; and into ground water and surface water. After closure of the disposal cell and degradation of synthetic components in the cap and liner, water is able to infiltrate the waste and leach contaminants from the waste. Contaminants would then migrate vertically through the unsaturated (vadose) zone and into the ground water (saturated) zone where they could be transported horizontally to a nearby well and discharged to surface water. Most of the ground water flow occurs in the upper part of the soil and bedrock system with discharge into nearby surface water bodies, NT-2 and NT-3 tributaries and Bear Creek. The modeling process allows calculation of risks related to contaminant exposure for a defined hypothetical residential receptor, a maximally exposed individual (MEI), which is the most conservative land use assumption. Ground water from the well is assumed to be used for drinking water, and surface water is assumed to be used for watering livestock and irrigating crops, resulting in further uptake by the MEI from consumption of crops, milk, and meat. Development of the analytic PreWAC is based on an evaluation of this hypothetical residential exposure scenario.

An inadvertent intruder (e.g., someone digging through the final cap and being directly exposed to the waste after landfill closure) will be examined as part of the DOE O 435.1 compliance.

## 2.3 HYPOTHETICAL RECEPTOR

For the proposed EMDF, concentration-based "analytic" PreWAC are developed assuming a hypothetical resident farmer receptor as the MEI. The receptor scenario involves a family of four using ground water from a well between the facility and Bear Creek for domestic needs and surface water from Bear Creek for agricultural purposes. In accordance with current practices in Tennessee, the upper, more active weathered bedrock part of the unconfined aquifer (nominally a 30–50 ft stratum between the water table and competent bedrock) would not be used for domestic water supplies. Therefore, the well configuration assumes that the shallow weathered bedrock and the top 20 ft of the competent bedrock are cased and the well is screened an additional 80 ft below the casing as shown in Figure H-2 from 70–150 ft below ground surface. An average of 240 gallons per day is pumped from the well, based on domestic needs of a family of four.

The contaminant leaching/transport analysis and exposure conceptual model is presented in Figure H-2. For a rural residential farmer (who represents the MEI) there is a potential for exposure to contaminated media through the following activities:

- Ingestion of ground water from a domestic well.
- Consumption of home-grown vegetables/fruits irrigated with surface water.
- Consumption of milk and meat from livestock drinking surface water and fed with vegetation irrigated using surface water.

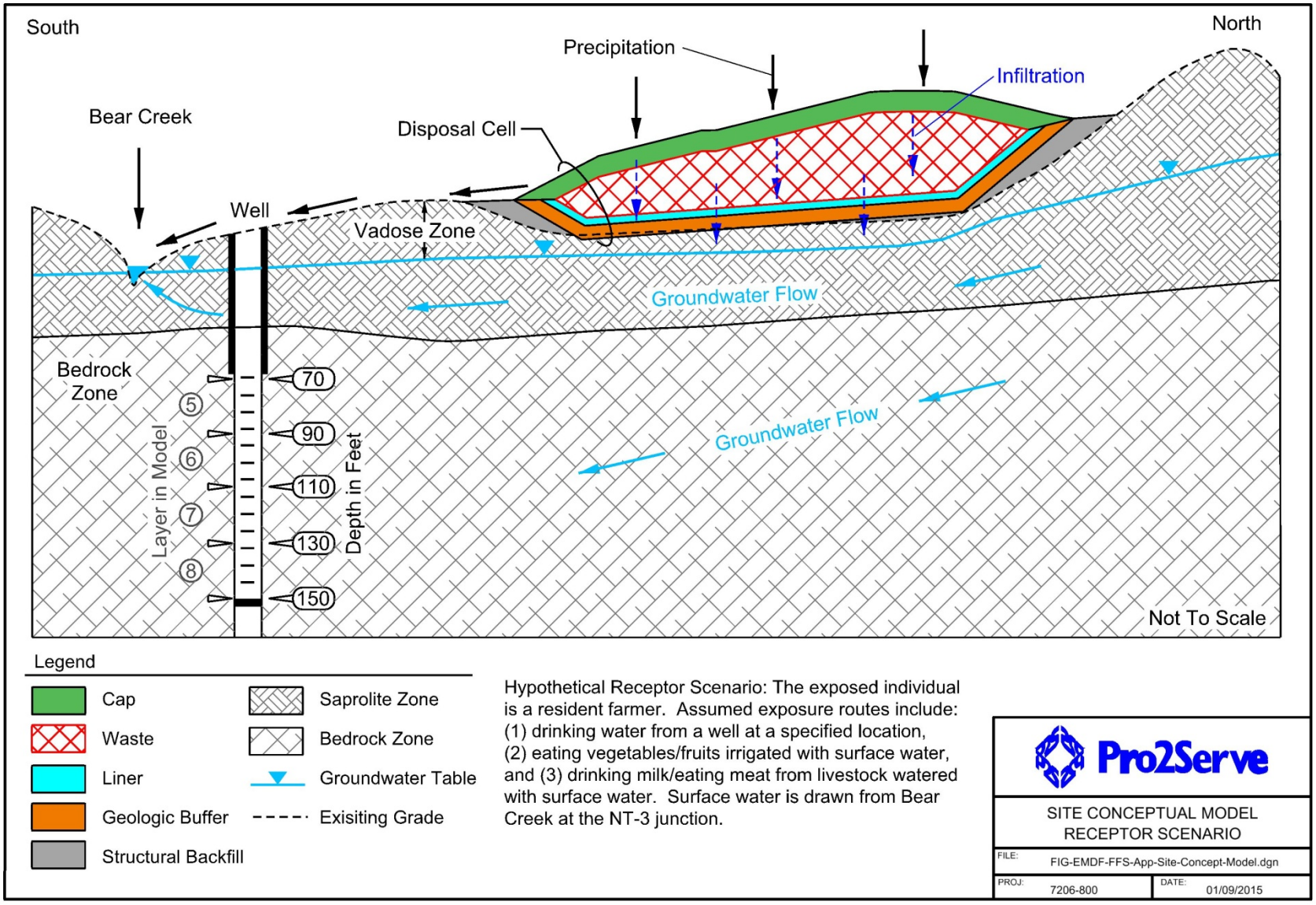



**Figure H-2. Conceptual Site Model and Hypothetical Receptor Scenario**

## 2.4 RECEPTOR LOCATION

A further key assumption in the resident scenario development and risk evaluation is the location of the hypothetical receptor. As this is the location at which the proposed alternative must meet the CERCLA defined risk criteria (e.g., $10^{-4}$ to $10^{-6}$ Excess Lifetime Cancer Risk [ELCR]), it is appropriate to look to CERCLA guidance on placement of the future hypothetical receptor. Per EPA's *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation manual (Part A)* [EPA 1989], this placement or location is the "exposure point." This is the point where MEI contact with the highest contaminant concentration is made "if the site is currently used, if access to the site under current conditions is not restricted or otherwise limited (e.g., by distance), or if contact is possible under an alternate future land use." In this case, the proposed EMDF site is within Zone 3 of Bear Creek with a future land use designation of "DOE-controlled Industrial Use," access is restricted by DOE, and for the foreseeable future will be under DOE control as described in the BCV Phase I ROD (DOE 2000). This future land use designation has been supported and approved by public stakeholders in the End Use Working Group (documented in the *Final Report of the Oak Ridge Reservation End Use Working Group*, July 1998). Accordingly, the nearest possible exposure point for a future hypothetical resident, and point of highest expected concentration based on ground water and surface water flows, would be the intersection of the "DOE-controlled Industrial Use" Zone 3 boundary with Bear Creek shown in Figure H-3, approximately 1.5 miles to the west of the EMDF.

Ultimately, a much more conservative approach is preferred, and the receptor location was selected based in part on historical records (prior to DOE's land ownership) that indicate several homes were located along Bear Creek in the general area being considered (Tennessee Valley Authority Maps and Surveys Division Quadrangle map 1935, 1941, see Appendix E, Figure E-5 and Section 2.1). A second consideration was to use a location that would provide the most consistent annual surface water flow. A surface water location at the junction of tributary NT-3 and Bear Creek was selected because year-round flow is more typically encountered there than in surface water tributaries closer to the landfill, and the concentration would be expected to be highest there as surface water locations closer to the cell would see only portions of the landfill contaminants in comparison. The well was assumed to be located nearby on the BCV floor between the EMDF and Bear Creek as shown in Figure H-3, at a distance of 460 m from the edge of the landfill. This location is also consistent with topographical and geomorphic features, lithostratigraphic and hydrogeological conditions, and ground water modeling results.

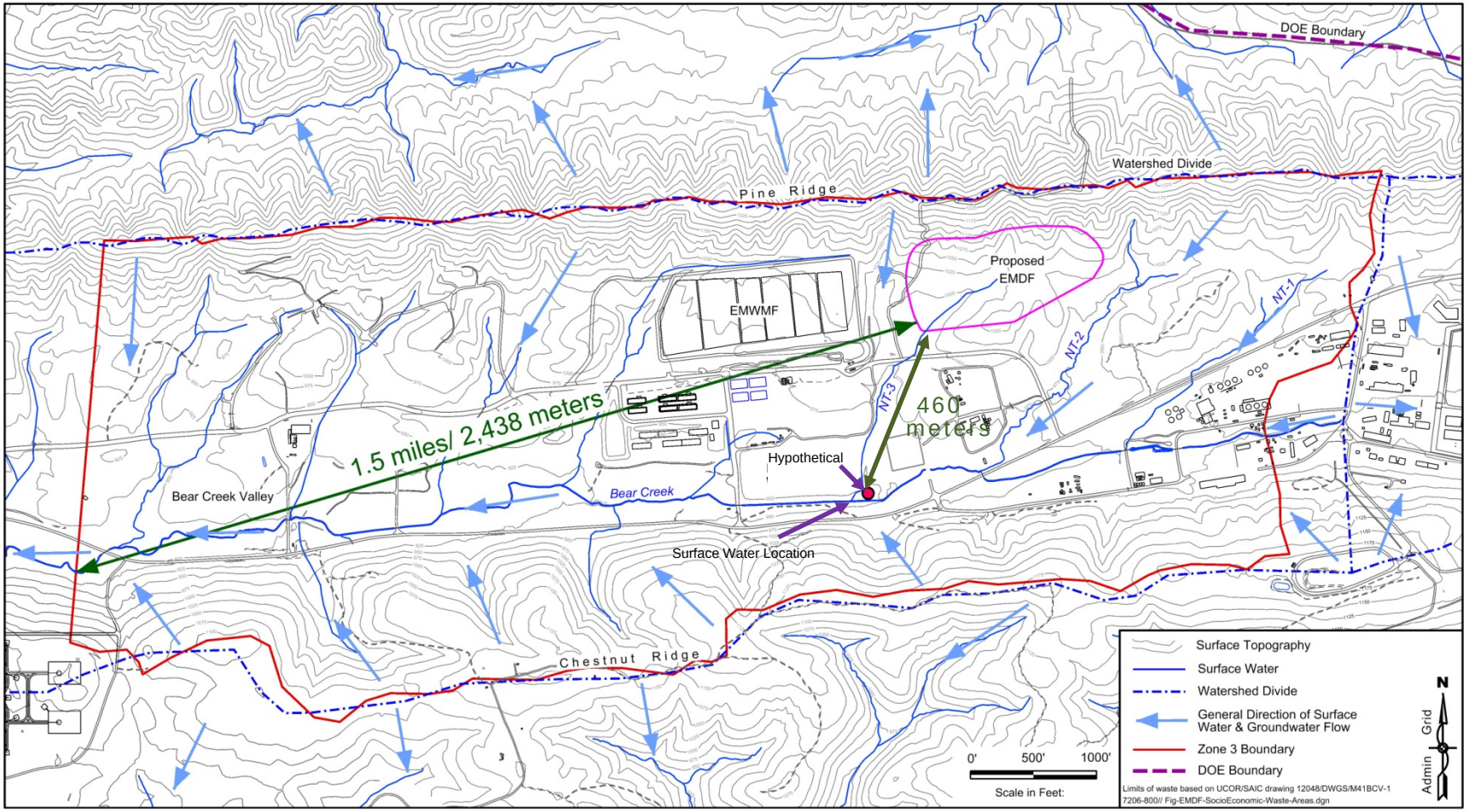



**Figure H-3. Proposed EMDF Location and Zone 3 (*DOE-controlled Industrial Use*) Boundaries**

## 2.5 RISK CRITERIA

DOE performed this analysis of the proposed low-level waste disposal facility using a performance-based approach with little to no reliance on long-term maintenance and the man-made components of the landfill (i.e., geosynthetics) for a performance period of 1,000 years beginning at closure of the landfill. Radioactive contaminants whose concentrations peak in ground water or surface water after 1,000 years are modeled to their peak concentrations, requiring modeling past 1,000 years. Isotopes that peak beyond 1,000 years are modeled under the recognition that the modeling results for these much greater time lengths have a higher degree of uncertainty.

The following risk goals (RAOs) for the aggregate radiological and chemical impacts to the hypothetical receptor from all waste disposed in the proposed EMDF were used for development of the analytic PreWAC:

- An ELCR (carcinogenic risk) range of $10^{-4}$ to $10^{-6}$ and an HI[1] $\leq 1$ for the first 1,000 years after closure.
- Carcinogenic risk range of $10^{-4}$ to $10^{-5}$ and HI $\leq 3$ for >1,000 years after closure. The model may be carried out to a maximum of 1,000,000 years post-closure.
- Comply with maximum concentration limits (MCLs) in waters that are current or potential sources of drinking water.

To calculate analytic PreWAC, the proposed EMDF was conceptualized as one large waste cell containing an assumed uniform concentration of a single contaminant at closure. Risk posed to the receptor was then calculated, given the uniform contaminant concentration in the cell and resulting concentration in the surface water at peak loading. Analytic PreWAC (concentration-based units) were then back-calculated by ratioing the modeled risk based on the assumed concentration and using the appropriate risk goal listed above based upon the time of peak risk and the type of risk (e.g., radioactive or hazardous) being calculated. Well water COPC concentrations were checked against MCLs, and PreWAC were adjusted if necessary to ensure that MCLs would be met. This method is repeated for each COPC, as each contaminant is assumed to occupy the cell individually. A detailed description of this method and the results obtained follows in subsequent chapters.

[1] HI is the ratio of a chemical intake to its reference dose. For a single chemical, it is the summation of intake for all routes to which an individual is exposed, divided by the chemical's reference dose. An HI value of 1.0 or less indicates that no adverse human health effects (non-cancer) are expected to occur.

# 3. PRELIMINARY WAC DEVELOPMENT AND MODELS

Information about the PreWAC development steps, modeling, and calculation methods is provided in this Chapter. An overview of the process is described in Section 3.1 and a description of the individual models used is provided in Section 3.2. Details regarding application of the models in this risk evaluation, assumptions, and site-specific parameters are covered in Chapter 4.

## 3.1 OVERVIEW OF PREWAC DEVELOPMENT

Linkage and application of the contaminant leaching/transport models and steps used to develop the PreWAC are depicted in Figure H-3.

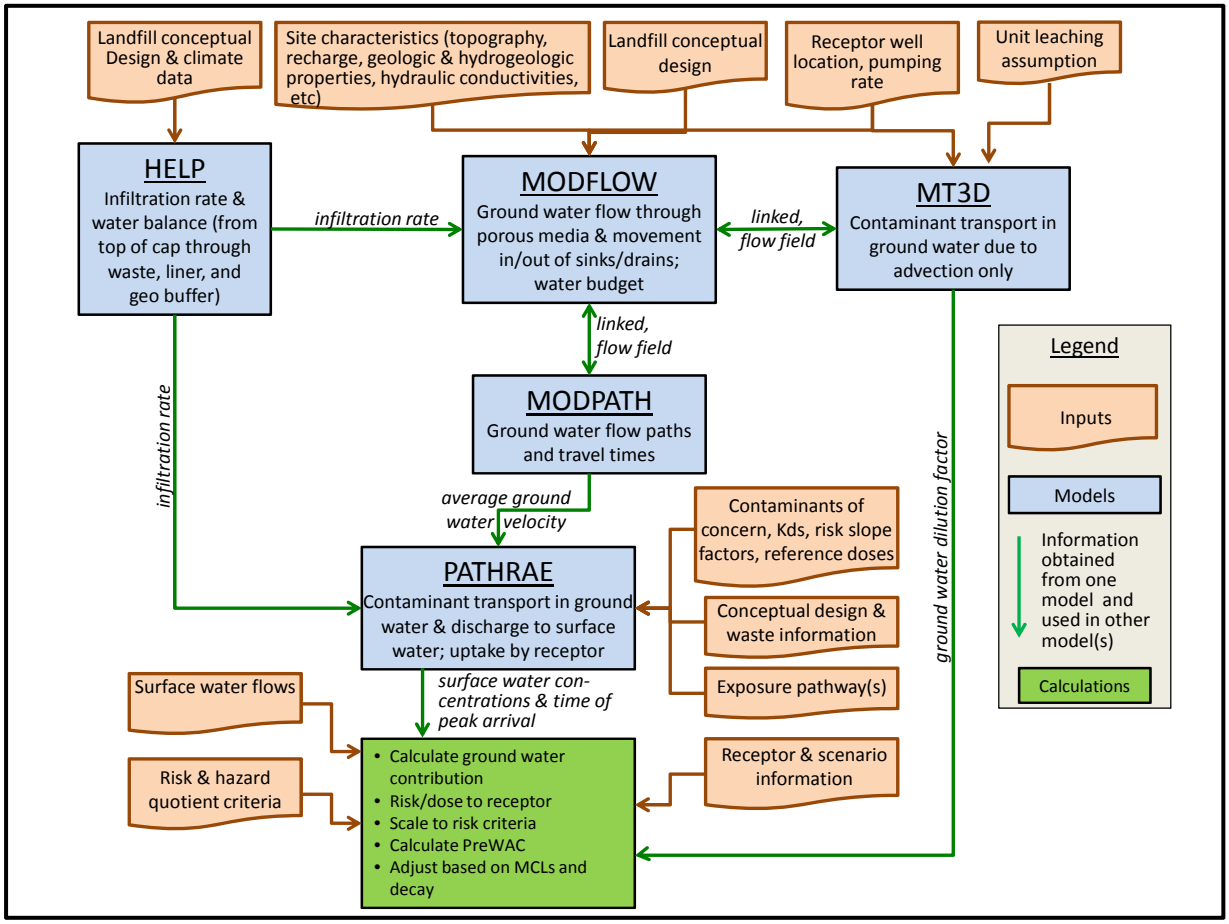



**Figure H-4. PreWAC Model Linkage and Application**

An overview of the models used, conceptual design and site features provided, and major calculations performed are as follows:

- Determination of water infiltrating the final cover, passing through the waste, liner, and geologic buffer, and entering the vadose zone and ground water was accomplished by mass balance analysis of precipitation and evapotranspiration, cap drain removal of water, and hydraulic flow using the Hydrologic Evaluation of Landfill Performance (HELP) computer code (Schroeder et al. 1994). Major inputs include the various layers of the cover and liner defined by the conceptual design. Performance of the final cover and liner system was adjusted to account for component/media degradation in calculating the steady state infiltration rate.
- Ground water flow characteristics in the disposal cell area and ground water travel time to tributaries and Bear Creek were evaluated using the three-dimensional, finite difference, time-dependent MODFLOW (McDonald and Harbaugh 1988) and MODPATH (Pollock 1989) models, respectively. Major inputs include the site characteristics (e.g., boundary conditions, hydrogeologic features and parameters, soil parameters, model domain), well location, and conceptual landfill design features.
- Ground water dilution factors (DFs) at the receptor well location (relative to an assumed constant leaching source concentration) due to advection only were established using the MT3D model (Zheng 1990). Other processes, such as contaminant specific dispersion, retardation due to absorption, and source depletion, were considered during PATHRAE modeling (Rogers and Associates Engineering 1995a and 1995b).
- All COPCs were considered (see Attachment A to this Appendix). COPCs were removed from consideration under specific assumptions; for example, radionuclides with half-lives less than five years were removed from consideration since they decay to insignificant concentrations over relatively short time frames.
- Soil solid-liquid partition coefficients ($K_d$) for each contaminant were used as input to unsaturated, one-dimensional, time-dependent modeling of source leaching from the waste and contaminant transport in the vadose zone as well as the saturated zone (see Attachment A to this Appendix). The PATHRAE code was used for these calculations.
- Discharge of ground water to tributaries and/or Bear Creek, solute mixing with tributary/stream flow, and contaminant uptake by a receptor were calculated using the PATHRAE code. Average surface water flow data were used for these calculations.
- Ground water concentrations were calculated based on the ground water DFs and surface water concentrations that were determined by the PATHRAE code.
- The PATHRAE RAD results and applicable slope factors (EPA 1989) were used to calculate carcinogenic risk for a resident farmer (receptor) using well water as a drinking supply and Bear Creek water for agricultural purposes. Likewise, cancer risk and HIs for chemicals were calculated using EPA applicable reference doses and PATHRAE HAZ results.

Analytic PreWAC concentration limits for individual radiological and chemical constituents are calculated that ensure carcinogenic risk and HI toxicity goals are met. These limits correspond to the maximum permissible concentration of each constituent that could be placed in the facility if the waste containing that single constituent were to occupy the entire disposal cell volume in a soil like matrix.

The PreWAC development process used for the proposed EMDF is similar to the process that was used for EMWMF. The exposure pathway from disposal cell to surface water was analyzed using the PATHRAE-HAZ/RAD analytical model, a revised version of the original risk performance code (PATHRAE-EPA) developed for EPA. In addition to waste volume and contaminant characteristics data, results from the other models supply input data for PATHRAE-HAZ/RAD modeling. For example HELP provides the infiltration rate through the landfill, MODFLOW provides the ground water flow field, path,

and discharge locations and rates, and MODPATH provides the average constituent travel time as determined by MODFLOW-defined flow paths/fields. The peak contaminant concentration in the well is determined by scaling the surface water concentrations/doses modeled by PATHRAE using the DFs. The well (ground water) DF ($DF_{well}$) is the ratio of the concentration of a constituent in the well water to a unit concentration in solute seepage entering the ground water beneath the disposal facility; it is calculated using MODFLOW and MT3D. The creek (surface water) $DF_{creek}$ is the ratio of annual water volumetric flux from the disposal cell to the (average annual) surface water volumetric flow rate.

The contaminant leaching/transport analysis and exposure scenario includes the following processes:

- Infiltration of (rain) water into the waste cell.
- Leaching of contaminants from the waste into the underlying vadose and ground water zones.
- Transport of contaminants from the site to the receptor well and discharge to surface water bodies.
- Uptake by the hypothetical receptor via applicable ground water and surface water exposure routes.

## 3.2 MODELS USED TO SUPPORT PREWAC DEVELOPMENT

The relevant HELP, MODFLOW/MODPATH, MT3D, and PATHRAE-HAZ/RAD models are briefly described in the following subsections. Details regarding application of the models for the site-specific risk evaluation in terms of assumptions and site-specific parameters used, and development of PreWAC are covered in Chapter 4.

### 3.2.1 HELP Model

The HELP model (Version 3.07, Schroeder et al., 1994) is used to evaluate the water budget for the proposed EMDF and estimate infiltration rates to ground water. This information is needed for ground water flow and fate and transport modeling as the precursor to risk/dose analysis using PATHRAE-HAZ/RAD and ground water modeling using MODFLOW.

HELP is a quasi two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model accepts climate, soil, and design data, and uses estimation techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, and unsaturated vertical drainage as well as leakage through soil, geomembrane, or composite liners. These input data are described in Section 2.0 of Attachment B to this Appendix. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The HELP model was developed to assist hazardous waste landfill designers and regulators in evaluating the hydrologic performance of proposed landfill designs. The program was developed to conduct water balance analyses of landfills, cover systems, and solid waste disposal and containment facilities. The model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety of landfill designs.

### 3.2.2 MODFLOW and MODPATH Models

MODFLOW (Version 88, McDonald and Harbaugh 1988) and MODPATH (Version1.0, Pollock 1989) are used to evaluate the hydrogeologic conditions and parameters at the proposed waste disposal site. The parameters estimated include ground water flow path, travel time, ground water velocity, and flux rate.

MODFLOW is a modular, block-centered finite-difference ground water flow code developed by the U.S. Geological Survey (USGS). MODFLOW is capable of simulating both transient and steady-state

saturated ground water flow in one, two, or three dimensions. MODFLOW calculates potentiometric head distribution, flow rates, velocities, and water balances throughout an aquifer system. It also includes modules simulating recharge, flow toward wells, and ground water flowing into drains and rivers. A number of different boundary conditions are available, including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, and streams or rivers. Aquifers can be simulated as unconfined, confined, or a combination of unconfined and confined. The finite-difference equations may be solved using a strongly implicit procedure, slice-successive over-relaxation, or preconditioned conjugate gradient method.

MODFLOW implicitly considers that the aquifer can be characterized as a porous media. The application of a porous media code (i.e., MODFLOW) to a fractured bedrock system, such as BCV, is termed the equivalent porous media approach. This approach assumes that the media is fractured to the extent that it behaves hydraulically as a porous media. Three dimensional representation of hydraulic properties within MODLFOW also provides flexibility to present fracture orientation and distribution. This approach is acceptable for BCV given the large scale of the model domain (948 acres) compared to the fractured nature of the underlying geologic units (on the order of centimeters to meters within BCV), and the degree of accuracy that is required to support the PreWAC analysis.

MODFLOW is widely used by the industrial, scientific, and governmental communities. The code has been rigorously tested and verified, and a variety of software tools are publicly available for graphical pre- and post-processing. Various MODFLOW models have been developed for the Oak Ridge area; these models were developed for the BCV RI/FS and EMWMF modeling and performance evaluations, and received tri-party approval under the CERCLA process. (Bailey 1988; BJC 2003, DOE 1996, 1998b, 2010).

MODPATH is a three-dimensional particle tracking program designed for use with output from steady-state simulations obtained from the MODFLOW results. MODPATH can be used to compute three-dimensional path lines, position of particles at specified points in time, discharge point coordinates, and total time of travel for each particle. MODPATH uses a semi-analytical particle tracking scheme. The method is based on the assumption that each directional velocity component varies linearly within a grid cell in its own coordinate direction. This assumption allows an analytical expression to be obtained describing the flow path within a grid cell. Given the initial position of a particle anywhere in a cell, the coordinates of any other point along its path line within the cell and the time of travel between them can be computed directly.

### 3.2.3 MT3D Model

The movement of contaminants from the waste cell to specified locations outside of the waste disposal site via ground water is simulated using MT3D (Version 1.0, Zheng, 1990), a three dimensional fate-transport model code.

MT3D is a comprehensive three-dimensional numerical simulation code that models the fate and transport of dissolved contaminants in complex ground water systems. MT3D calculates concentration distributions, concentration histories at selected points and hydraulic sinks (for example, extraction wells), and the mass of contaminants in the ground water system. The code can simulate three-dimensional transport in complex steady-state and transient flow fields and can represent anisotropic dispersion, source-sink mixing processes, first-order transformation reactions, and linear and nonlinear sorption. MT3D offers the user a choice of four solution options that make it uniquely well-suited for handling a wide range of conditions, one of which, the Method of Characteristics (MOCs) technique, is best-suited for handling advection-dominated problems.

MT3D is linked with the USGS ground water flow simulator, MODFLOW, and is designed specifically to handle advectively-dominated transport problems without the need to construct refined models

specifically for solute transport. MT3D is the world's most popular three-dimensional solute transport code and has been used successfully to model thousands of sites. MT3D is widely accepted by regulators and the ground water consulting and research communities.

### 3.2.4 PATHRAE-HAZ/RAD Model

PATHRAE-HAZ/RAD (Version 2.2d, Rogers and Associates Engineering, 1995a and 1995b), is a family of computer codes capable of assessing multiple transport pathways for hazardous/radiological contaminants that have the potential to impact human receptors. PATHRAE-HAZ/RAD was originally developed for EPA (PATHRAE-EPA) to use in preparing standards for management of LLW (Rogers and Hung, 1987). PATHRAE-HAZ/RAD can be used to estimate risks and doses to humans from possible releases and subsequent transport of contaminants through multiple pathways from land disposal units containing chemical and radioactive wastes. The code can be used to calculate risks at specified points in time and peak risks (in time) to individuals at any number of key locations inside or outside the boundaries of a disposal facility.

The PATHRAE-HAZ/RAD code is available in the public domain. The model performs similar tasks to other pathway analysis codes, such as RESRAD (Yu et al. 1993). A benchmarking comparative study by a RESRAD team concluded that the doses predicted by RESRAD and PATHRAE codes for the inhalation and ingestion pathways were in relatively good agreement (Faillace, Cheng, and Yu, 1994).

One of the advantages of the PATHRAE-HAZ/RAD family of codes is their simplicity of operation and presentation of results, while still allowing the analysis of a comprehensive set of contaminants and pathways to human receptors. This allows the easy identification of parameters important for the protection of the public from potential releases.

One pathway modeled by PATHRAE-HAZ/RAD is movement of contaminants via ground water to surface water; this is the only pathway modeled by PATHRAE in this risk evaluation. (The ground water to well pathway is evaluated using the results from MODFLOW and MT3D codes, the PATHRAE surface water results, and calculations completed outside of the code.) This movement of contaminants via ground water to surface water results from the leaching of contaminants in precipitation that infiltrates through the cap and percolates through the waste. PATHRAE models one-dimensional vertical movement through a uniform vadose zone. Once the contaminants reach the saturated zone, their horizontal movement to the point of discharge into the surface water is modeled as one-dimensional movement through a uniform medium as well. For the migration of radionuclides through the saturated zone, the in-growth of daughter radionuclides can be calculated for any of seven radioactive decay chains; however, this feature is not used in the risk evaluation and development of PreWAC since only a single contaminant occupying the landfill is evaluated. The analysis of decay products is conducted outside of the model (see Section 5.1.1.2 of this Appendix), and further PreWAC limits on parent nuclides are implemented where necessary.

Although PATHRAE-HAZ/RAD can also model movement of contaminants to a ground water well, it uses a simple one-dimensional flow assumption that would not be representative of the complex BCV ground water flow regime. Therefore, the contaminant movement in the aquifer system is modeled using the MODFLOW and MT3D codes. That output is combined with output from PATHRAE to evaluate total risk to a receptor from both surface water and ground water pathways.

# 4. DEVELOPMENT OF SITE-SPECIFIC MODELS

Development of a site-specific HELP model, site-specific ground water flow (MODFLOW/MODPATH) models, and application of the fate-transport models (MT3D and PATHRAE) for the proposed EMDF site are described, respectively, in the following Sections 4.1–4.4. Within each section, the site-specific model concept and parameters are described followed by the assumptions and bases of those assumptions for each model. Lastly, the results determined by executing each model for the risk evaluation scenarios of this RI/FS are summarized.

## 4.1 HELP MODEL APPLICATION

The landfill conceptual design, assumptions for executing the HELP model (Version 3.07, Schroeder et al. 1994), and model simulation and results for the proposed EMDF are described below.

### 4.1.1 Site-specific HELP Model Development

Site-specific input information for the HELP model is based on the conceptual design of the facility. A conceptual design of the proposed on-site waste disposal facility, developed in RI/FS Chapter 6, has been used to evaluate the facility's ability to effectively manage the volumes and types of waste (i.e., radiological and hazardous waste streams) projected to be placed in the cell. Because the facility would manage waste with RCRA, Toxic Substance Control Act of 1976, and radioactive contaminants, a number of elements associated with the various design requirements of the waste management regulations for each of these waste types are incorporated in the facility conceptual design.

The cover design of the proposed EMDF includes multiple layers designed to reduce water infiltration, minimize erosion, and prevent intrusion into the wastes. There are eight discrete layers incorporated into the cover design and eight layers incorporated into the basal liner design below the waste. Additional geotextile layers incorporated into the design to protect the geomembrane layers were not considered in the HELP model as they do not alter or retard the movement of infiltrating water. The conceptual design of these components for the proposed EMDF is consistent with the approved design for the currently operating EMWMF and with design applicable or relevant and appropriate requirements.

The cell design includes the following key components:

- The total cover thickness is 11 ft and includes a 4 ft vegetation layer (a soil/rock matrix) on its top slope, underlain by a 1 ft filter layer (graded natural materials such as sand and gravel) and a 2 ft biointrusion layer (larger rocks and boulders), which is followed by a 1 ft lateral drainage layer. The filter, biointrusion, and drainage layers will be constructed of siliceous rock that is not easily degraded. Combined, these four layers simultaneously provide a robust medium to support root systems in the upper layer, drain away water to remove the chance for deeper root penetration, and create a significant barrier to deep root development. The biointrusion layer would inhibit penetration by humans, burrowing animals, and plants. The upper portion of the cover further prevents long term erosion and protects the underlying clay barrier layers from the degrading effects of desiccation and the freeze-thaw cycle.
- The cover includes a composite barrier layer that consists of a 40 mil thick density polyethylene (HDPE) geomembrane layer (Layer 5) over a two-part 2 ft thick low-permeability clay layer (Layers 6 and 7). The two-part clay layer is comprised of a 1 ft thick compacted amended clay layer (natural clay mixed with bentonite clay) over a 1 ft thick compacted natural clay layer beneath the bio-intrusion and drainage layers, presenting a significant barrier against water infiltration. The predicted combined effects of evapotranspiration in the vegetated layer, lateral transport from the cover by the drainage layer, and the presence of the barrier layers result in negligible infiltration into the wastes. The bottom layer of the cover is installed as part of the

interim cover; it is a granular contour layer, which provides a working/contouring surface over the waste (HELP Model Layer 8).

- The waste layer is assumed to consist of contaminated soil, cement-stabilized soil-like materials, cement-solidified waste, and debris (rubble). These wastes are assumed to be placed in lifts to minimize void spaces within the waste layer. Void spaces are filled with soil or soil-like material to provide structural strength and reduce settling due to waste compaction. For modeling purposes, all waste is conservatively assumed to be soil-like (see Section 4.4 of this Appendix).
- Underneath the waste, the liner system, made up of eight layers, includes a system to collect and remove any leachate generated during waste disposal operations, any water that may infiltrate the waste before final cover construction is completed, and any transient drainage that occurs shortly after the disposal cell is capped and closed. The liner also includes a secondary leachate detection system to confirm that the cell liner system is functioning properly and to collect leachate if the primary system fails. These fully functional drainage layers will intercept all the water migrating from the waste.
- The liner design has a composite layer consisting of a geomembrane overlaying a geosynthetic clay liner layer, a composite layer consisting of a geomembrane overlaying a 3 ft low-permeability clay layer, and a 10 ft geologic buffer layer. For waste constituents, these layers present a barrier to contaminant leaching downward out of cell. They also help prevent water from intruding into the waste from beneath the cell. The fully designed and fully functional landfill system will not allow precipitation recharging to the ground water through the waste.

The liner and cover layers of the EMDF conceptual design are illustrated in Figure 6-6 in Chapter 6 of the RI/FS. Table H-1 summarizes the disposal cell layer profile and soil, waste, and geosynthetic material characteristics used in the HELP model.

As described in Section 6.2.2.4 of the RI/FS, landfill construction, operation, and long-term performance depend on maintaining the water table below the base of the landfill liner system. An underdrain is necessary for the proposed EMDF within the tributary channels and surrounding seepage areas of the footprint to provide a flow path for ground water immediately below the landfill and prevent upwelling, since tributaries are natural discharge areas for ground water.

An extensive underdrain system would be required beneath the landfill within a portion of NT-3 and where there are draws/ravines containing springs and seeps. The intent of this underdrain system is to intercept and divert upwelling ground water to prevent it from saturating the geologic buffer and liner system. The conceptual layout plan for the underdrain is shown on Figure 6-8 of this RI/FS. In addition, a geomembrane-lined drainage ditch with underlying shallow French drain would be constructed along the upper (i.e., northern) side of the landfill to intercept and divert upgradient storm water and shallow subsurface storm flow away from the landfill. The upper portion of NT-3 would be diverted to the west of the landfill. Further protection from ground water intrusion will be established by constructing the landfill base and geologic buffer above the seasonal high water table.

### 4.1.2 HELP Model Assumptions

Assumptions for the HELP model are summarized here, along with justifications for those assumptions.

1. Table H-1 summarizes the landfill layers modeled for the conceptual design final cover (eight layers), waste profile (single layer), and liner system (eight layers) for a total of 17 layers modeled. Assumed layer thicknesses, part of the conceptual design of the cover/liner systems, are given in the table. Layer types and soil texture types, which correspond to those defined in the HELP manual (Schroeder et. al. 1994), were assumed for each layer based on the layer properties, and the HELP default soil properties for the assumed layer and texture types are given in the table as well. See Attachment B of this Appendix for additional layer parameters.

2. Table H-1 gives drain slopes and lengths for drainage layers. These slopes and lengths were varied for both the liner and cap drainage layers in order to evaluate their effect on the infiltration rate based on the proposed EMDF layout. The differences in the resulting infiltration rates were negligible and demonstrated that for the EMDF site these parameters do not have a significant effect on the results of the HELP modeling. The cap drainage layer slope was varied between 5% and 25% and the length was varied between 100 ft and 400 ft. The liner drainage layer slopes were varied between 2.5% and 10% and then lengths varied between 100 ft and 400 ft.
3. The waste was assumed to be represented by a moderately compacted, loamy soil (texture type 22), see Table H-1.
4. Water moving through the waste will form leachate with an average pH of 7.3 and a range from 5.69–9.13, based on conditions at the existing EMWMF.
5. Information on growing season, average quarterly relative humidity, normal mean monthly temperatures and precipitation, maximum leaf area index, evaporative zone depth, and latitude were taken from HELP's onboard database using the default values for the Knoxville, Tennessee, area (see Attachment B of this Appendix for tabulated values).
6. Rainfall annual average (calculated by HELP): 55.38 in. corresponds to reported Oak Ridge Reservation annual average for years 2002–2013, and is slightly higher than the 30-year average for 1981–2010 of 50.91 in. because it includes 2013, which was 32% wetter than normal.
7. Performance Scenario – The performance of the conceptual design (cover and liner specifically) was assumed to change over time. Three stages were defined as follows:
   A. Stage 1: The best case, short-term performance of the cover/liner systems is assumed. All layers fully function. This stage is assumed to continue through the first 100 years following closure of the landfill. The composite barrier (the compacted and amended clay layers and geosynthetic layers) in conjunction with the overlying lateral drainage layer serve to divert infiltrating water away from the underlying waste and transport the water to the perimeter drainage system, thus minimizing infiltration into the waste. This is a very conservative assumption, supported by research that indicates the service life of HDPE geomembranes exceed 500 years and may reach over 1,000 years at temperatures of 20° C as expected in the case of the EMDF (depth below ground surface ensures temperate conditions); based on the thickness of the proposed geomembrane (40 mil) (antioxidant depletion lifetime in the membrane is extended with thickness); humid environment/moderate rainfall; and protected (depth under overburden) location of the geomembranes. (Benson 2014, Rowe et al. 2009, Needham et al. 2006, Mueller and Jakob 2003, Bonaparte, et al. 2002; Hsuan 2002; Koerner et al. 2001; Giroud 1984)
   B. Stage 2: Gradual failure of the cover/liner systems is assumed. This period is assumed to last for 100 years, extending from year 100 following closure, through year 200 following closure. A linearly increasing infiltration rate is assumed between Stage 1 and Stage 3 results.
   C. Stage 3: The worst case, long-term performance of the cover/liner systems is assumed. It is assumed that all geosynthetic materials degrade and are ineffective at 200 years and beyond. Layers are assumed to be degraded and no longer function (i.e., Layers 5, 11, 12, 13, 14, and 15 are removed from the model). Erosion of the cover is assumed to occur resulting in a decreased thickness of the top soil/rock layer. Layer 1 thickness is reduced by 20%.

**Table H-1. EMDF Conceptual Design Profile and Material Characteristics**

| System | Layer # | Material/Description | Layer Type* | Layer Thickness (in.) | Soil Texture Type** | Total Porosity (vol/vol) | Field Capacity (vol/vol) | Wilting Point (vol/vol) | Saturated Hydraulic Conductivity (cm/sec) | Drainage Length (ft) | Drain Slope (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Final Cover | 1 | Top Soil/Rock Mix (vegetative/erosion control layer) | 1 | 48 | 4 | 0.437 | 0.105 | 0.047 | 1.70E-03 | | |
| | 2 | Sand/Gravel (granular filter/drainage layer) | 1 | 12 | 3 | 0.457 | 0.083 | 0.033 | 3.10E-03 | | |
| | 3 | Large rock/rip-rap (biointrusion layer) | 1 | 24 | 1 | 0.417 | 0.045 | 0.018 | 1.00E-02 | | |
| | 4 | Gravel (lateral drainage layer) | 2 | 12 | 21 | 0.397 | 0.032 | 0.013 | 3.00E-01 | 100 | 5 |
| | 5 | HDPE -FML (geomembrane layer) | 4 | 0.08 | 35 | | | | 2.00E-13 | | |
| | 6 | Amended Compacted Clay (low permeability layer) | 3 | 12 | 0 | 0.427 | 0.418 | 0.367 | 3.50E-08 | | |
| | 7 | Cover Compacted Clay (low permeability layer) | 1 | 12 | 16 | 0.427 | 0.418 | 0.367 | 1.00E-07 | | |
| | 8 | Contour Gravel (waste surface layer) | 1 | 12 | 21 | 0.397 | 0.032 | 0.013 | 3.00E-01 | | |
| Waste | 9 | Waste (assumed to be soil-like) | 1 | 600 | 22 | 0.419 | 0.307 | 0.18 | 1.90E-05 | | |
| Liner | 10 | Protective Soil (layer protects liner) | 1 | 12 | 26 | 0.445 | 0.393 | 0.277 | 1.90E-06 | | |
| | 11 | Drainage (Leachate collection system) | 2 | 12 | 21 | 0.397 | 0.032 | 0.013 | 3.00E-01 | 100 | 2.5 |
| | 12 | HDPE-FML (geomembrane layer) | 4 | 0.08 | 35 | | | | 2.00E-13 | | |
| | 13 | Geosynthetic Clay Liner [GCL] (low permeability layer) | 3 | 0.24 | 17 | 0.75 | 0.747 | 0.4 | 3.00E-09 | | |
| | 14 | Geonet Leak Detection Layer (leak detection) | 2 | 0.3 | 20 | 0.85 | 0.01 | 0.005 | 1.00E+01 | 100 | 2.5 |
| | 15 | HDPE-FML (geomembrane layer) | 4 | 0.08 | 35 | | | | 2.00E-13 | | |
| | 16 | Compacted Clay Layer (low permeability layer) | 3 | 36 | 16 | 0.427 | 0.418 | 0.367 | 1.00E-07 | | |
| | 17 | Soil Geobuffer (barrier layer) | 1 | 120 | 26 | 0.445 | 0.393 | 0.277 | 1.90E-06 | | |

FML flexible membrane liner
GCL geosynthetic clay liner
*Layer type:
1 – vertical percolation
2 – lateral drainage
3 – barrier soil liner
4 – geomembrane layer
**Soil texture type and its characteristics are defined in HELP (Schroeder et. al. 1994)

8. Clay layers in the final cover system are below 8 ft of overburden. The clay layers are assumed to retain their hydraulic conductivity parameters based on the depth below ground surface, which ensures there is no direct exposure to freeze-thaw conditions and no desiccation; no cracking/tunneling due to roots or burrowing animals/insects; little temperature or moisture variation; and the layers are subjected to high pressures (approximately 60 kPa). Research has actually shown decreasing hydraulic conductivities with increased confining stress as is associated with significant overburden pressures (Boynton and Daniel 1985; Albrecht and Benson, 2001). This assumption is in line with what is recommended in DOE guidance concerning liner and cover performance based on the thought that degradation mechanisms affecting the compacted clay layer should be adequately addressed during the design process (SRNL 2014). While field studies have been published that demonstrate compacted clay is highly susceptible to environmental factors that can cause it to quickly degrade, those studies were performed on cover systems where the clay layer was quite shallow within the cover system, was under-protected from the environment, and lacked redundancy. Case studies cited as having cover systems that were effective at limiting infiltration had very thick surface layers over the compacted clay barrier, utilized drainage layers to help move water, and used geomembranes over the clay to create a composite barrier layer (Albrecht et. al 2006). The EMDF design contains these features.

### 4.1.3 HELP Model Results

Performance of the proposed EMDF cell cover/liner system is analyzed using the HELP model. It was assumed that performance of the system will degrade over time, simulated by three stages following closure of the EMDF. A conservative infiltration rate is determined in this way.

- Fully Functional Stage (Stage 1): All layers are assumed to be functional and every aspect of the system performs as designed, including all design features, such as HDPE liners, leachate collection system, and drainage layers. This fully functioning stage is assumed to continue for 100 years following closure. HELP Model simulation result for infiltration rate to ground water in this stage is 0.0 in. per year.
- Partially Functional Stage (Stage 2): The HDPE flexible membrane layers (FMLs) are assumed to be degraded and ineffective. The FML layers would no longer function as impermeable layers in the cover and liner systems. However, the leachate collection and removal system would still be operational. This partially functioning stage results in a gradual change of infiltration rate from the 0.0 in. per year simulated in Stage 1 to the fully degraded, maximum infiltration rate in Stage 3. This is not simulated by HELP; rather, the infiltration rate is assumed to follow a linear decrease from 0.0 to 0.43 in. per year.
- Long-term Performance Stage (Stage 3): This is a conservative worst-case scenario of the EMDF cell cover/liner system performance. All synthetic materials are assumed to be degraded and ineffective. The drainage layers in the liner systems are also assumed to be ineffective due to degradation of the synthetic material and failure of the leachate collection and removal system. As a result, the liner drainage layers would become vertical percolation layers and no water would flow out these drainage layers. The remaining soil materials would maintain their properties.

Using this long-term performance scenario made up of Stages 1-3, HELP model simulations resulted in an infiltration rate of 0.43 in. per year. This is considered a conservative estimate based on utilizing the conservative 100-year lifetime for the geosynthetic layers. Other simulations were run to check the sensitivity of this conservative case. These simulations included:

- Simulations were run in which the top layer (vegetative/erosion protection) layer thickness was reduced by 20% with no change in the infiltration rate.

- The leachate collection drainage layer (Layer 11) was assumed to fail and was removed from the model; a sensitivity run in which the leachate drainage layer remained as a layer in the model but was assumed to clog by changing the material properties resulted in insignificant change to the infiltration rate.
- Clogging of the sand/gravel layer (Layer 2) was assumed by increasing the hydraulic conductivity resulted in no significant change to the infiltration rate.
- The bio-barrier (Layer 3) transmissivity was degraded by assuming a custom layer in which parameters were adjusted (total porosity increased, field capacity decreased, wilting point decreased, and saturated hydraulic conductivity significantly increased) resulted in no significant change to the infiltration rate.

Table H-2 shows the results of HELP Model analysis for the given performance scenario. Section 2.0 of Attachment B to this Appendix provides additional detail about the HELP model.

**Table H-2. HELP Model Predicted Mass Balance and Infiltration Rates for Long-term Performance (Worst Case)**

| Cell Layer System | | | Performance – Worst Case (200 years+) | |
|---|---|---|---|---|
| **Cover System** | **Layer Performance** | Top Soil/Rock Mix (5 ft) | YES – eroded | |
| | | Sand/Gravel (1 ft) | YES | |
| | | Bio-Intrusion Layer (3 ft Rip-rap) | YES | |
| | | Drainage (1 ft) | YES | |
| | | FML | Degraded – removed | |
| | | Amended Clay | YES | |
| | | Compacted Clay | YES | |
| | | Contour Gravel | YES | |
| | **Modeled Results** | | **Mass Balance (in./yr)** | **Mass Balance (%)** |
| | | Precipitation | 54.39 | 100 |
| | | Runoff | 0.69 | 1.3 |
| | | Evapotranspiration | 30.90 | 56.8 |
| | | Drain Collection | 22.37 | 41.1 |
| | | **Flux Rate into Waste (in./yr)** | **0.42** | 0.8 |
| **Waste Zone** | | | | |
| **Liner System** | **Layer Performance** | Soil (1 ft) | YES | |
| | | Leachate Collection Drainage (1 ft) | Not Functional – removed | |
| | | FML | Degraded – removed | |
| | | GCL | Degraded – removed | |
| | | Leak Detection Drainage Geonet | Degraded – removed | |
| | | FML | Degraded – removed | |
| | | Compacted Clay (3 ft) | YES | |
| | | Geobuffer | YES | |
| | **Modeled Results** | | **Mass Balance (in./yr)** | **Mass Balance (%)** |
| | | Leachate Drain Collection | not applicable | |
| | | Leak Drain Collection | not applicable | |
| | | **Flux Rate through Clay Liner (in./yr)** | **0.43** | 0.8 |

## 4.2 GROUND WATER FLOW (MODFLOW/MODPATH) MODELS APPLICATION

To develop required key input parameters to support analytic PreWAC development and future design of a potential new disposal facility, a site-specific ground water flow model for the Upper BCV (UBCV) area has been developed for the proposed EMDF based on the Bear Creek regional ground water flow model (DOE 1997) and more recent EMWMF models (BJC 2003, DOE 1998b, and 2010). The model was developed using MODFLOW (Version 88, McDonald and Harbaugh 1988), the ground water flow portion of the code, and MODPATH (Version 1.0, Pollock 1989), the particle tracking portion of the software.

A telescopic mesh refinement (TMR) modeling approach was used to develop a refined UBCV model from the calibrated BCV flow model originally constructed by the Jacobs Environmental Management Team (DOE 1997). The TMR approach enables the user to develop a site-specific model using existing regional information and allows focus on areas of interest with increased model grid resolution and more accurate representation of site-specific features. The TMR approach utilizes the results from the calibrated regional flow model to initialize boundary conditions (constant heads) and model parameters in the TMR model. Further refinements of locations of streams and waste units were made after the site-specific flow model was constructed.

### 4.2.1 Site-specific MODFLOW/MODPATH Model Development

The UBCV model was developed in two stages. The UBCV model representing current site conditions (as of year 2012) was the first stage. The current condition model was compared to existing and current site-specific data (such as stream flow and ground water levels); model parameters were then adjusted to ensure model results corresponded to these actual measured conditions.

The current condition model forms the foundation for the EMDF future condition model that was constructed as the second stage of UBCV model development. The EMDF future condition model incorporates EMDF proposed facility conceptual design features to predict the long-term cell performance after disposal facility closure.

Thus construction of the disposal cell site-specific UBCV model consisted of the following steps:

1. Establish model domain and dimensions.

   The TMR method was used to develop the UBCV model from the calibrated BCV flow model (DOE 1997) by extracting boundary conditions, model layers, and model properties. A reduced grid cell size was used for the new model domain to improve accuracy.

2. STAGE 1: Refine model domain and parameters to produce the current condition (2012) model.

   To represent the detailed current site-specific features, the following refinements were made after the site-specific flow model domain was constructed.

   A. Refinement in the vertical direction was achieved by dividing the former Model Layer 1 into three separate layers and former Layer 2 into five separate layers to represent the current site conditions, to allow for future EMDF engineering features, and to support the risk/performance evaluation.
   B. The refined and improved site-specific parameters used in extensive calibrated EMWMF models were incorporated into the UBCV model (e.g., ground water elevations).
   C. Detailed adjustments were made to areas to smooth the transition along the model boundaries and parameter zones to represent the field conditions more precisely.
   D. Parameters representing surface water features at the site (creeks and tributaries) were incorporated into the new model to represent the current condition model.

3. STAGE 2: Create the EMDF (future condition) model.

   The future condition model was developed to provide required parameters for risk analysis and PreWAC estimations for the future on-site disposal facility.

   A. EMDF design and post-closure topography were incorporated into the future condition model to predict the flow conditions after disposal cell construction.
   B. Parameters representing the construction/engineered features for the proposed EMDF were incorporated into the future condition model (e.g., the underdrain).
   C. Future landfill performance parameters, such as long-term recharge rate through waste zone, were included.

#### 4.2.1.1 UBCV Model Domain and Discretization

The UBCV model domain is the volume of earth represented mathematically by the model. The UBCV Model covers an area of 948 acres from east of S-3 Pond to NT-6 (8,600 ft from east to west) and from the top of Chestnut Ridge to top of the Pine Ridge (4,800 ft from south to north). Figure H-5 shows the 2012 topography and UBCV (current condition) model domain. Figure H-6 shows the topography of the constructed EMDF that represents the future condition.

Model discretization refers to the assignment and alignment of the numerical cells in the model and the relationship of those cells to actual engineered and natural conditions. A uniform horizontal grid size of 10 ft × 10 ft is used for the model domain. There are a total of 4,540,800 cells in the UBCV Model, of which 3,572,049 are active in ground water flow.

The UBCV Model uses 11 model layers to reflect the vertical variation in the hydraulic properties at the site. The top of the model, Layer 1, reflects the topography for the current condition model (circa 2012) and proposed cell design topography around the EMDF for the future condition model. The first three model layers represent engineered design features, residuum saprolite and weathered bedrock zone. The top three model layers have variable thicknesses ranging from 15–25 ft. The bottom of Layer 3 corresponds approximately to the unweathered bedrock surface. Fractured bedrock is represented by Layers 4–8, each of which are 20 ft thick. Layers 9, 10, and 11 are 150 ft, 200 ft, and 300 ft thick, respectively, representing less fractured and less permeable deeper bedrock. Figure H-7 shows the vertical discretization for the future condition model along two cross sections that are shown in Figure H-6.

#### 4.2.1.2 Model Boundary Conditions

The UBCV Model has a no-flow boundary at the top of Pine Ridge to the north of the proposed facility, at the top of Chestnut Ridge to the south, and at the ground water divide between BCV and Upper East Poplar Creek to the east (Figures H-5 and H-6). These boundaries approximate the natural ground water divide. Constant head boundary conditions to the west were assumed based on a steady state simulation of the calibrated regional BCV ground water flow model. The model boundary was established at a sufficient distance from the EMDF site so as not to be affected by topographic alterations associated with disposal cell development.

The vertical base of the model is a no-flow boundary because minimal exchange of meteoric water with mineralized ground water (i.e., brine) occurs below this depth (see Section 2.3.3 in Appendix E). The model incorporates Bear Creek and its tributaries, as well as site features for the proposed EMDF, such as ditches and channels, cut and filled areas, underdrain features, and French drains. The surface drainage features are represented in the model as drain cells (see Figure H-8). Drain cells allow ground water to discharge into a surface water body. Actual stream bottom elevations were assigned in the model.

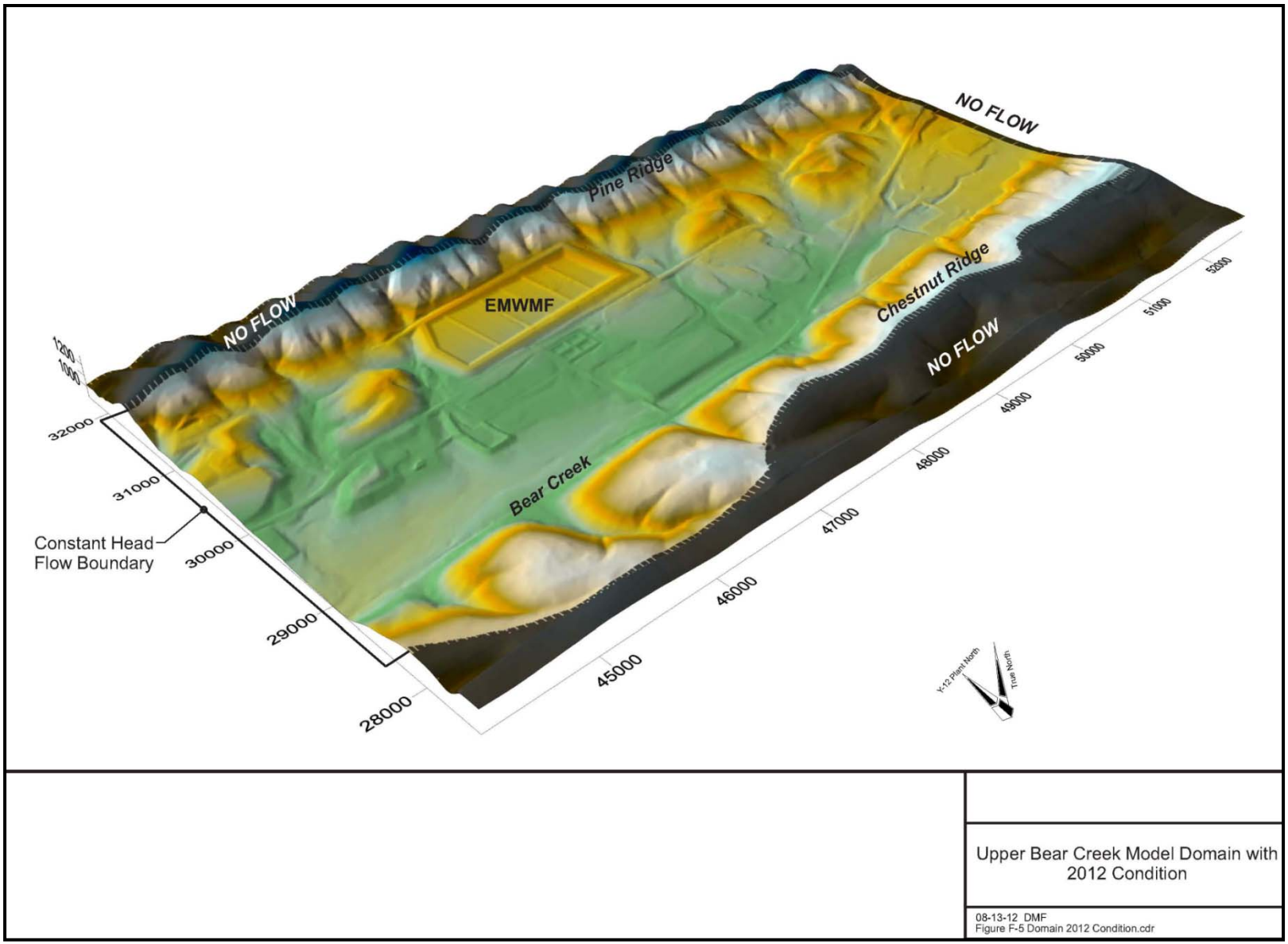



**Figure H-5. Upper Bear Creek Valley Model Domain (Current 2012 Condition)**

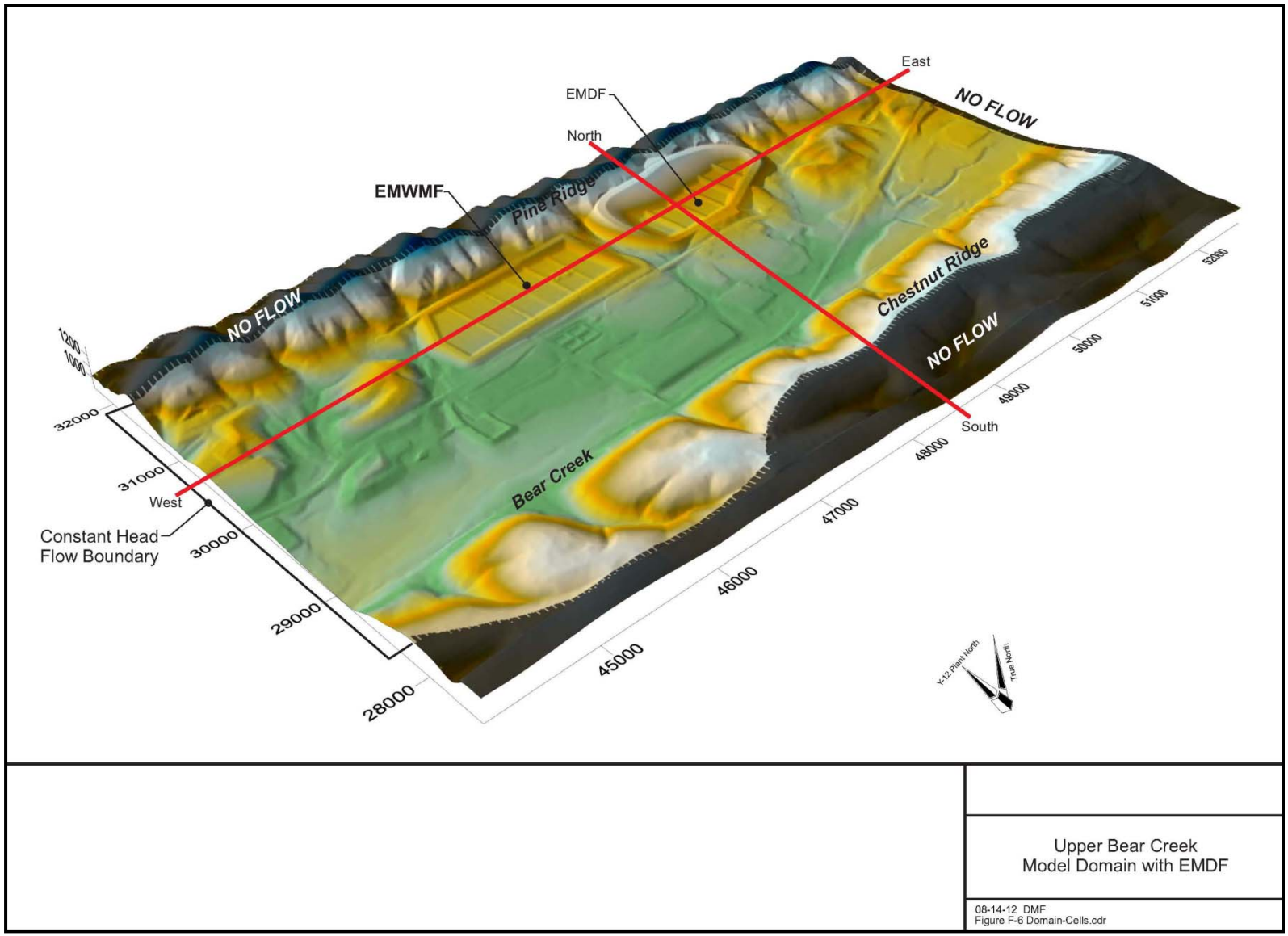



**Figure H-6. Upper Bear Creek Valley Model Domain with New Disposal Cell (EMDF Future Condition)**

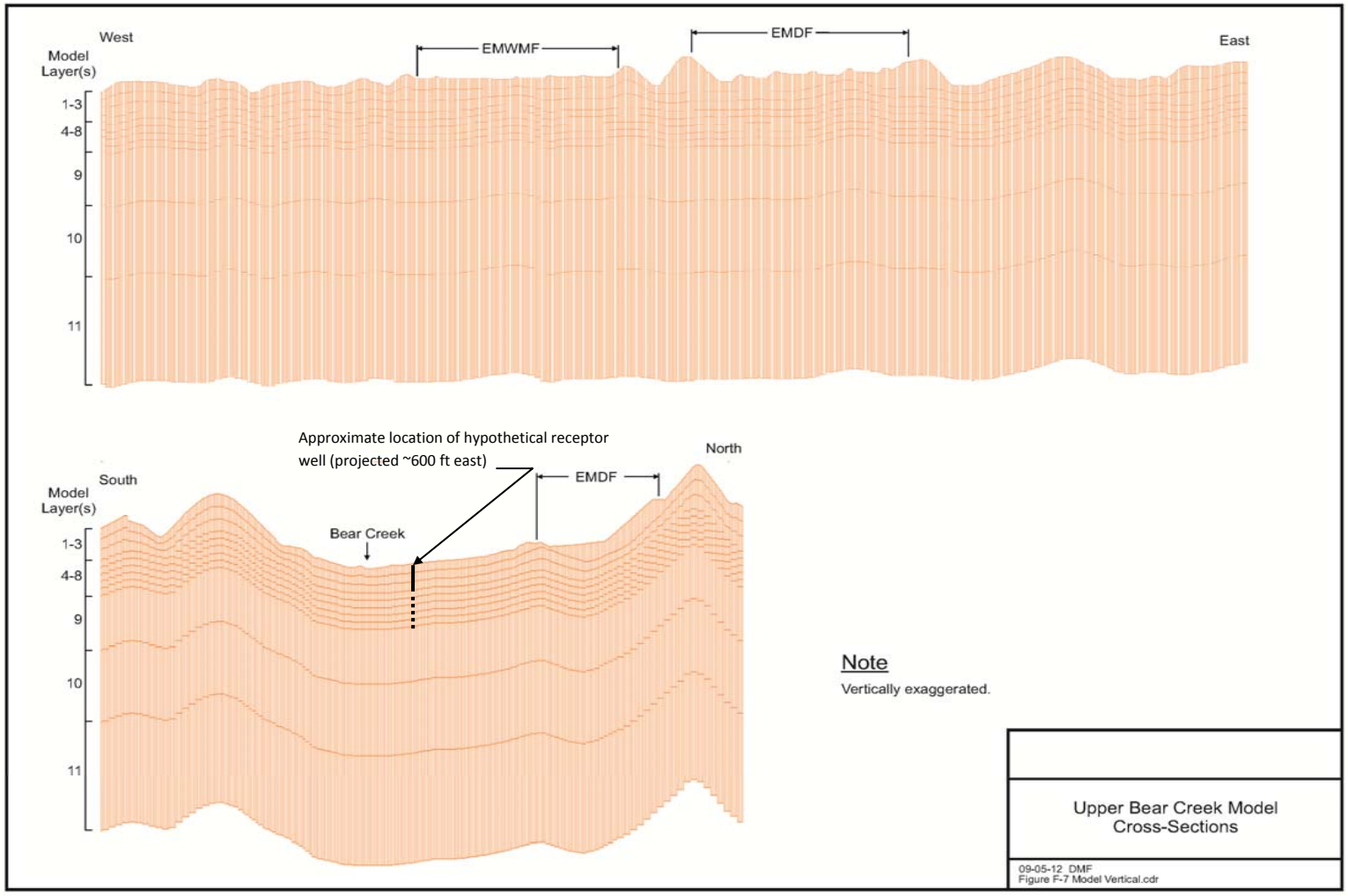



**Figure H-7. Upper Bear Creek Valley Model Cross-Sections**

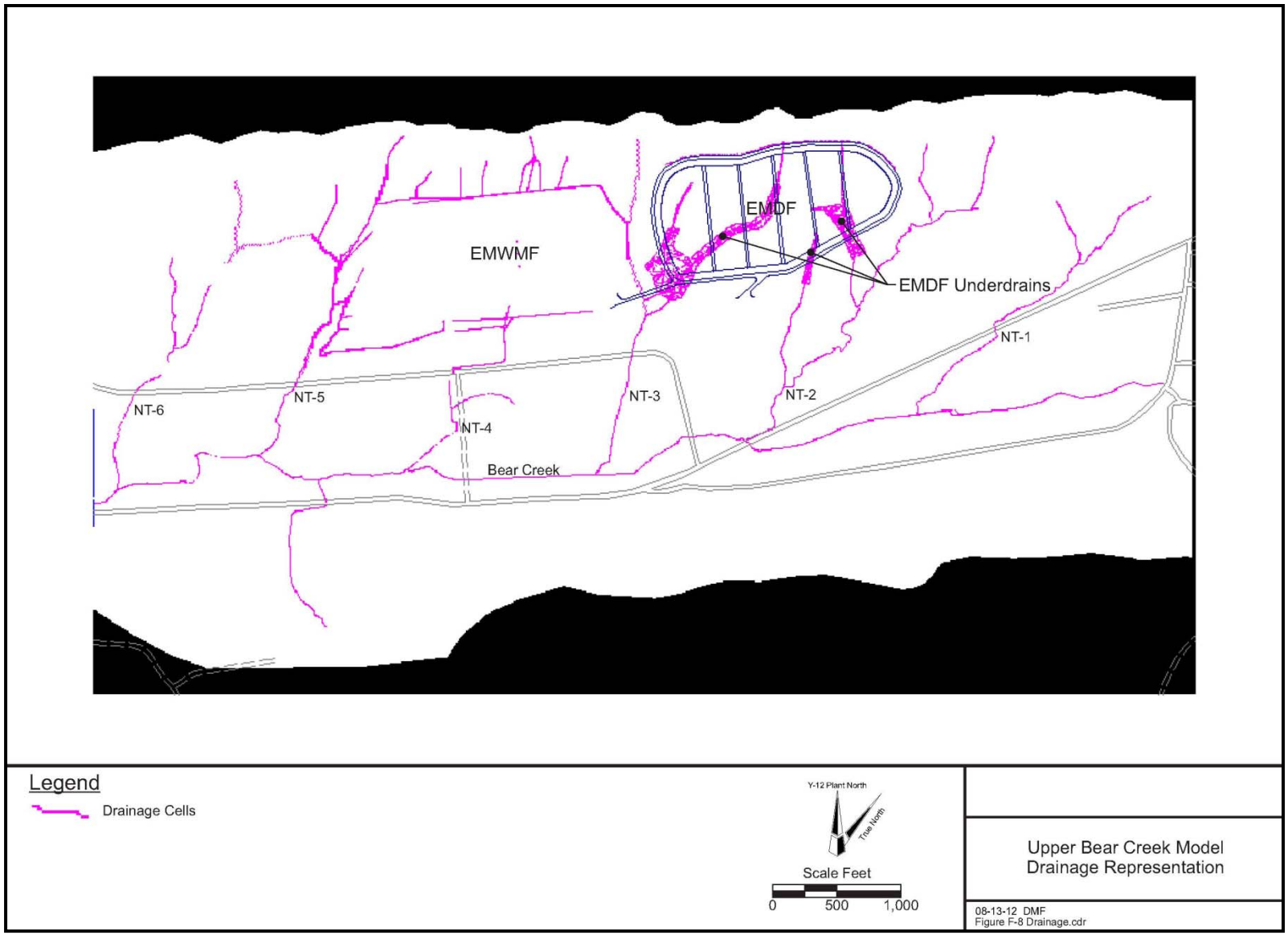



**Figure H-8. Upper Bear Creek Valley MODFLOW Model Drainage Representation**

Infiltration from precipitation is assumed to be the sole source of recharge to ground water for the site-specific UBCV Model, as the site is bounded on three sides by no-flow boundaries. Infiltration is precipitation minus runoff and evapotranspiration; and the recharge rate is a function of geologic media, surface slope, and vegetation. Several recharge rates were assigned in the model (see Figure H-9) corresponding to (1) natural recharge to the Maynardville Formation and Knox Group carbonates (2E-3 ft/day), (2) natural recharge to the Nolichucky shale (2E-3 ft/day), (3) natural recharge to the Conasauga Group shales and siltstones (1.6E-3 ft/day) and to Rome Formation sandstone (2E-3 ft/day), (4) reduced recharge through existing caps at former disposal sites (2.28E-4 ft/day), and (5) reduced recharge through the existing EMWMF and proposed EMDF disposal cells in a future closed state (9E-5 ft/day), which corresponds to the infiltration precipitation recharge rate of 0.42 in. per year as determined in the HELP Model worst case scenario described in Sections 4.1.2 and 4.1.3.

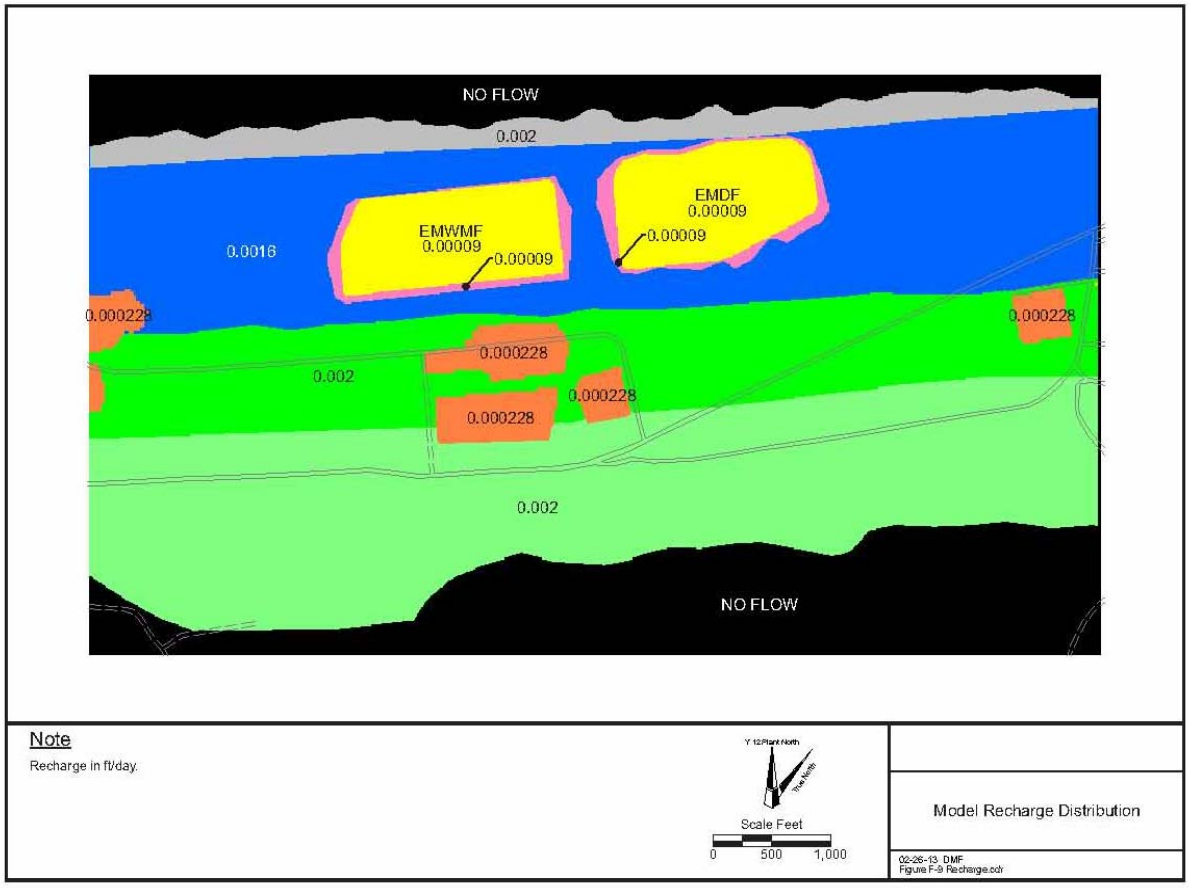



**Figure H-9. Upper Bear Creek Valley Model Recharge Distribution (ft/day)**

### 4.2.1.3 Hydraulic Conductivity Field

Six distinct hydraulic conductivity zones were used in the UBCV Model to represent the eight geologic units that exist in BCV (Knox Dolomite, Maynardville Limestone, Nolichucky Shale, Maryville-Rogersville-Rutledge formations, Pumpkin Valley shale, and Rome shale/sandstone). Anisotropy ratios (Ky versus Kx [Kz]) of 5:1 (for weathered bedrock zone) and 10:1 (for fractured bedrock zone) were used to represent the preferred fracture/bedding orientation of the geologic units. In this case, Ky represents the conductivity parallel to strike, Kx is the horizontal conductivity perpendicular

to strike, and Kz represents the vertical hydraulic conductivity. Both field data and previous modeling sensitivity analyses support the anisotropic ratios used in the model. Field data included analytical plume distribution and aquifer test data within BCV (Geraghty and Miller 1987, 1989; Law Engineering 1983; Lee, et al. 1992; Golder and Associates 1988). Extensive modeling sensitivity analyses were conducted during the Bear Creek model development reported in the Bear Creek Feasibility Study (FS) report (DOE 1997). A summary was also presented in a journal publication (Evans, et al. 1996). All these data indicated an anisotropic flow regime in the aquifer of BCV. A detailed summary of the aquifer test data is provided in the Bear Creek FS, Appendix F (DOE 1997).

Extensive modifications were made to the UBCV Model to represent future conditions and site-specific features associated with cell construction. Engineered features that were added include berms, underdrains, geologic buffer material, and the low permeability clay liner. All the engineered and reworked materials were modeled as isotropic units in the horizontal plane (i.e., hydraulic conductivity does not vary with direction).

In summary, the site is modeled as a single unconfined aquifer, with 11 vertical layers to simulate the changes in hydraulic parameters with depth, and the 45° average dip is represented by staggering hydrogeologic units with depth. Model Layers 1–3 represent the unconsolidated/weathered bedrock zone. Model Layers 4–8 represent the top bedrock interval between 50 and 150 ft. Model Layers 9–11 represent the intermediate/deep bedrock zone.

Figure H-10 shows the zones of hydraulic conductivities used to represent hydrogeologic units in Layer 1 of the UBCV Model. Figure H-11 shows the hydraulic conductivity field in a vertical south-north cross section, which illustrates the staggering of the hydrogeologic units with depth to simulate the 45° dip. Table H-3 provides a summary of model parameters for the future condition UBCV Model. All parameter values shown in Table H-3 are the same for the current condition (2012) model and the future condition model except the two parameters marked with an "*": the number of drain cells (shown under Model Boundary Conditions) and the EMDF recharge rate.

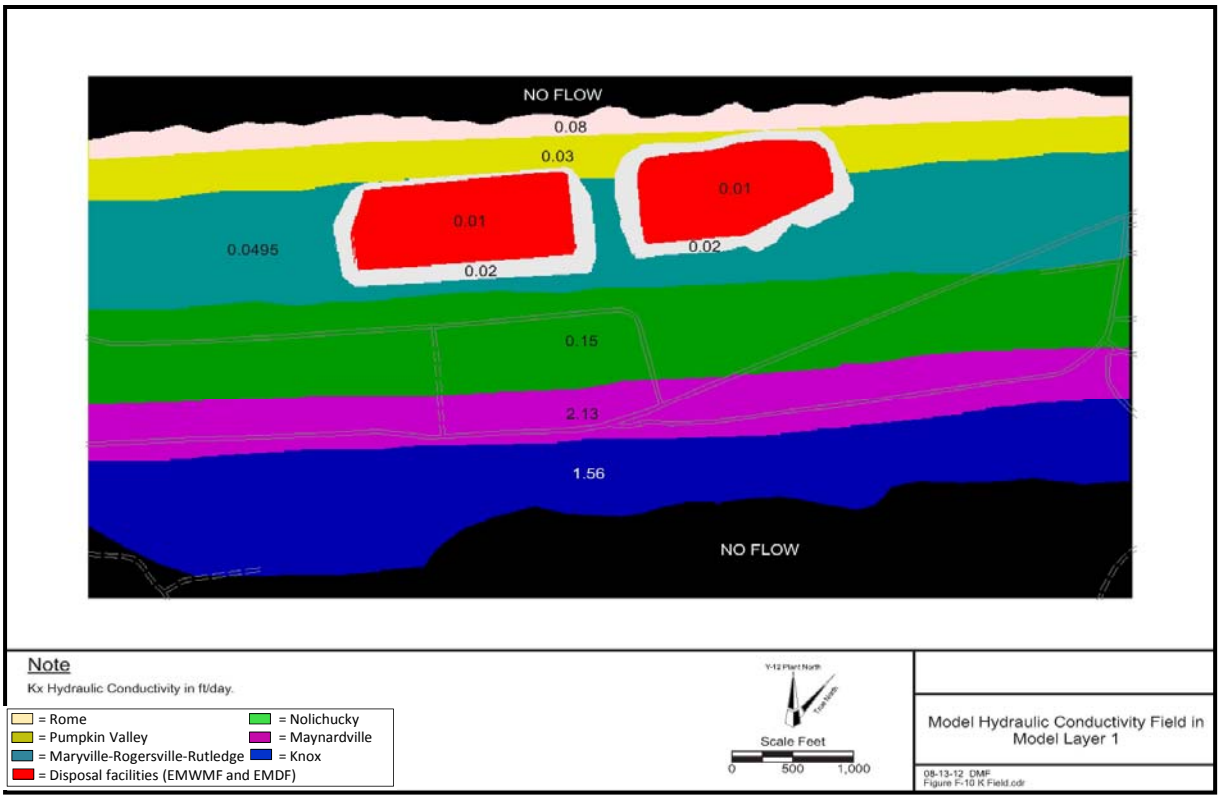



**Figure H-10. Upper Bear Creek Valley Model Hydraulic Conductivity Field in Layer 1**

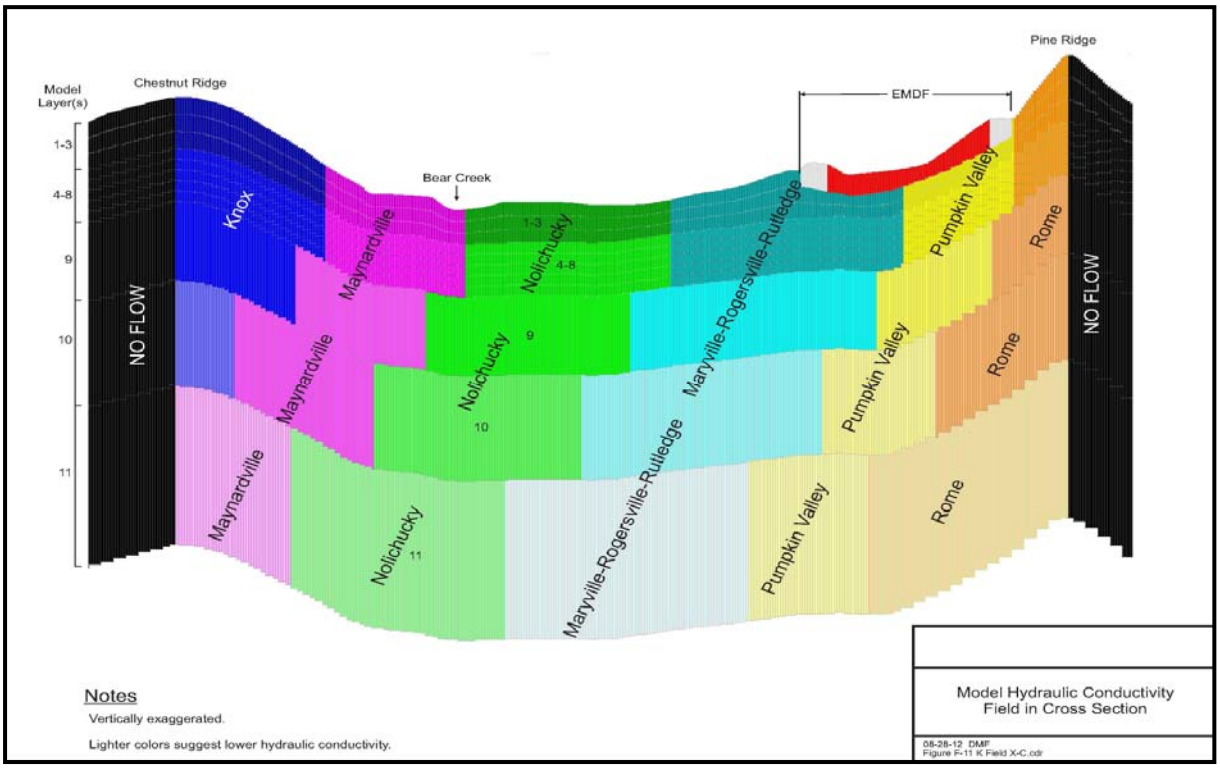



**Figure H-11. Upper Bear Creek Valley Model Hydraulic Conductivity Field in Cross Section**

**Table H-3. UBCV MODFLOW Ground Water Model Parameter Summary (Future Condition)**

| GRID INFORMATION | | |
|---|---|---|
| Number of Rows | 860 | |
| Number of Columns | 480 | |
| Number of Layers | 11 | |
| Total Cells | 4,540,800 | |
| Total Active Cells | 3,572,049 | |
| Percent Active Cells | 78.67% | |
| **GRID DIMENSIONS** | | |
| Row Spacing - Uniform Delta-Y | 10 | ft |
| Column Spacing - Uniform Delta-X | 10 | |
| **Vertical Spacing** | | |
| Layers 1–3 | Variable (10–25) | ft |
| Layers 4–8 | 20 (each) | |
| Layer 9 | 150 | |
| Layer 10 | 200 | |
| Layer 11 | 300 | |
| **COORDINATE TRANSFORMATION** | | |
| X Offset (to Y-12 Coordinate System) | 52723.33 | ft |
| Y Offset (to Y-12 Coordinate System) | 27510.47 | |
| Rotation | 90.23 | degree |
| **MODEL BOUNDARY CONDITIONS** | | |
| Constant Heads | 3,981 | # of cells |
| Rivers | 0 | |
| Drains* | 126,126 | |
| General Heads | 0 | |
| Wells | 8 | |
| No Flow | 968,751 | |
| **RECHARGE** | | |
| **Areas/Geologic Units** | **Recharge Rate** | **Units** |
| Closed Landfill/Paved Park Area | 2.28E-04 | ft/day |
| Rome | 2E-03 | |
| Maryville-Rogersville-Rutledge | 1.6E-03 | |
| Nolichucky | 2E-03 | |
| Knox | 2E-03 | |
| EMDF* and EMWMF | 9.6E-05 | |

**Table H-3. UBCV Ground Water Model Parameter Summary (Future Condition) (Continued)**

| HYDRAULIC CONDUCTIVITY[a] | | | | | |
|---|---|---|---|---|---|
| **Material or Geologic Formation** | **Model Layer(s)** | **Kx** | **Ky** | **Kz** | **Units** |
| Knox | 1−3 | 1.56E+00 | 7.80E+00 | 1.56E+00 | ft/day |
| Knox | 4−8 | 9.18E-03 | 9.18E-02 | 9.18E-03 | |
| Knox | 9 | 2.54E-03 | 2.54E-02 | 2.54E-03 | |
| Knox | 10 | 1.16E-03 | 1.16E-02 | 1.16E-03 | |
| Knox | 11 | 3.60E-04 | 3.60E-03 | 3.60E-04 | |
| Maynardville | 1– 3 | 2.13E+00 | 1.07E+01 | 2.13E+00 | |
| Maynardville | 4−8 | 1.21E-02 | 1.21E-01 | 1.21E-02 | |
| Maynardville | 9 | 3.34E-03 | 3.34E-02 | 3.34E-03 | |
| Maynardville | 10 | 1.52E-03 | 1.52E-02 | 1.52E-03 | |
| Maynardville | 11 | 4.80E-04 | 4.80E-03 | 4.80E-04 | |
| Nolichucky | 1−3 | 1.50E-01 | 7.50E-01 | 1.50E-01 | |
| Nolichucky | 4−8 | 6.81E-03 | 6.81E-02 | 6.81E-03 | |
| Nolichucky | 9 | 2.52E-03 | 2.52E-02 | 2.52E-03 | |
| Nolichucky | 10 | 6.10E-04 | 6.10E-03 | 6.10E-04 | |
| Nolichucky | 11 | 5.00E-05 | 5.00E-04 | 5.00E-05 | |
| Maryville-Rogersville-Rutledge | 1−3 | 4.95E-02 | 2.48E-01 | 4.95E-02 | |
| Maryville-Rogersville-Rutledge | 4−8 | 3.60E-03 | 3.60E-02 | 3.60E-03 | |
| Maryville-Rogersville-Rutledge | 9 | 1.35E-03 | 1.35E-02 | 1.35E-03 | |
| Maryville-Rogersville-Rutledge | 10 | 3.20E-04 | 3.20E-03 | 3.20E-04 | |
| Maryville-Rogersville-Rutledge | 11 | 4.50E-05 | 4.50E-04 | 4.50E-05 | |
| Pumpkin Valley | 1−3 | 3.00E-02 | 1.50E-01 | 3.00E-02 | |
| Pumpkin Valley | 4−8 | 4.72E-03 | 4.72E-02 | 4.72E-03 | |
| Pumpkin Valley | 9 | 1.75E-03 | 1.75E-02 | 1.75E-03 | |
| Pumpkin Valley | 10 | 4.20E-04 | 4.20E-03 | 4.20E-04 | |
| Pumpkin Valley | 11 | 5.60E-05 | 5.60E-04 | 5.60E-05 | |
| Rome | 1−3 | 8.00E-02 | 4.00E-01 | 8.00E-02 | |
| Rome | 4−8 | 5.00E-03 | 5.00E-02 | 5.00E-03 | |
| Rome | 9 | 2.00E-03 | 2.00E-02 | 2.00E-03 | |
| Rome | 10 | 5.00E-04 | 5.00E-03 | 5.00E-04 | |
| Rome | 11 | 8.00E-05 | 8.00E-04 | 8.00E-05 | |
| compacted clay | 1 | 1.00E-02 | 1.00E-02 | 1.00E-02 | |
| compacted clay berm | 1 | 2.00E-02 | 2.00E-02 | 2.00E-02 | |

***** Indicates the parameter shown for the future condition model is an addition to the current condition (2012) model parameter

[a] Hydraulic conductivities from references: DOE 1997, BJC 2003, DOE 1998b, and DOE 2010.

#### 4.2.1.4 Model Calibration

Calibration of a ground water flow model refers to the process of adjusting model input parameters (e.g., hydraulic conductivity) and boundary conditions (e.g., precipitation recharge, stream and seep conductivity) to obtain a reasonable match between observed (actual ground water levels from monitoring wells) and simulated hydrogeologic conditions. In practice, this usually involves an iterative process of adjusting hydraulic properties and/or boundary conditions assigned in the model. At all stages of the model calibration process, parameter values and boundary conditions should be constrained by hydrogeologic data collected in the field and engineering design values.

The UBCV Model was constructed using the TMR approach based on the calibrated UBCV Model, and used extensive knowledge derived from EMWMF models. An advantage of the TMR approach is that a high resolution (small-scale) model can be developed that retains the regional flow characteristics. Because the parameters and boundary conditions associated with the refined model are derived from the regional ground water flow model, additional extensive calibration of the refined model is usually not necessary. New ground water monitoring wells installed under Phase I characterization efforts, within the proposed EMDF area, have been used in UBCV Model calibration, and well head values were in general agreement with the model-predicted values.

The water balance conducted for the calibrated current condition UBCV Model compared observed and predicted ground water discharge rates. Ground water sinks (drains cells in the model) discharge to Bear Creek directly and to surface drainage features that also flow into Bear Creek eventually. The model predicted ground water discharge above the Bear Creek/NT-3 junction is 0.31 $ft^3$ per second (cfs). For comparison, the average flow rate measured at the junction location is 0.55 cfs (Appendix E, Section 2.4.3.1), which includes both base flow (ground water discharge) and surface water runoff. The water balance error for the UBCV Model was about 0.34% and is within the typically accepted limit of 1% (EPA 1996). The water balance shows that essentially all water has been mathematically accounted for, and that the MODFLOW simulation has correctly solved the governing flow equations. The comparison suggests that the UBCV Model provides very good discharge results, indicating that the hydraulic conductivity parameters (K) and recharge rates are properly represented in the model. In addition, the parameters that were used in the BCV regional model were validated previously in the BCV FS through extensive model calibration and sensitivity analysis (DOE 1997). The calibration was conducted using data from hundreds of ground water wells. Stream and seep discharge data collected by the USGS at hundreds of locations were used to constrain the model. Sensitivity analyses were run on the calibrated model to evaluate recharge rates and hydraulic conductivities, which demonstrated that the most sensitive hydraulic conductivities were those in the upper layers of the model. These validated parameters and the BCV model are the basis of the future condition model presented in this RI/FS.

### 4.2.2 MODFLOW/MODPATH Model Assumptions

Assumptions and code-supplied options used as a basis for executing the MODFLOW/MODPATH models are as follows:

- MODFLOW outputs are set as inputs to MODPATH.
- MODFLOW simulates ground water flow through a porous media using a 3D, block-centered finite-difference approach to solve the governing flow equation relating flow in the x, y, and z directions (Darcy's law), sources, sinks, and storage.
- A porous media model is applicable since fractures are very small compared to the model domain (e.g., fracture spacings on the order of centimeters to meters) as compared to a model domain of 384 ha (948 acres).

- MODFLOW simulates effects of wells, recharge, rivers, drains, evapotranspiration, and "general-head boundaries." MODFLOW calculates head and flow rate within each grid. An overall water budget is determined.
- MODPATH uses a semi-analytical particle tracking scheme to obtain the particle flow path within each finite-difference grid cell from MODFLOW output. MODPATH simulates advection movement only.
- A heterogeneous and three-dimensional anisotropic medium is assumed.
- The model domain, grid, and layers are defined as described in Section 4.2.1.1.
- Boundary conditions are as described in Section 4.2.1.2. The model incorporates Bear Creek and its tributaries, as well as site features for the proposed EMDF such as ditches and channels, cut and filled areas, underdrain features, and French drains. The surface drainage features are represented in the model as drain cells as described in Section 4.2.1.2. Drain cells allow ground water to discharge into a surface water body. Actual stream bottom elevations were assigned in the model.
- Model hydraulic parameters (including hydraulic conductivities and recharge rates) are given in Section 4.2.1.3, and are based on those developed under the regional BCV model (DOE 1997).
- Model water balance is completed on an average annual basis; therefore,6704 seasonal variations are averaged annually.

### 4.2.3 MODFLOW/MODPATH Model Results

Figures H-12 and H-13 show the future condition, model-predicted shallow and intermediate zone ground water levels, respectively, and associated flow direction and gradients predicted by MODPATH. Generally, the figures indicate that shallow ground water discharges into Bear Creek and its tributaries. However the tributaries exhibit a less pronounced influence on ground water flow in the intermediate bedrock ground water zone. Even though there is an upward gradient toward the NTs in the intermediate zone, the flow vectors indicate deeper ground water may underflow the NTs. The simulated ground water flow field is consistent with the site conceptual model, water level maps constructed based on monitoring data, and general understanding of the site presented in Appendix E.

Ground water flow paths and particle travel times from cells to surface discharge locations are determined using the MODPATH model (Pollock 1989). Figure H-14 shows the ground water flow paths and discharge locations from various cell locations. The data are used to calculate the average flow velocity of the ground water, which is used in PATHRAE modeling. For the future condition model, that predicted average ground water flow velocity is 14 ft/year.

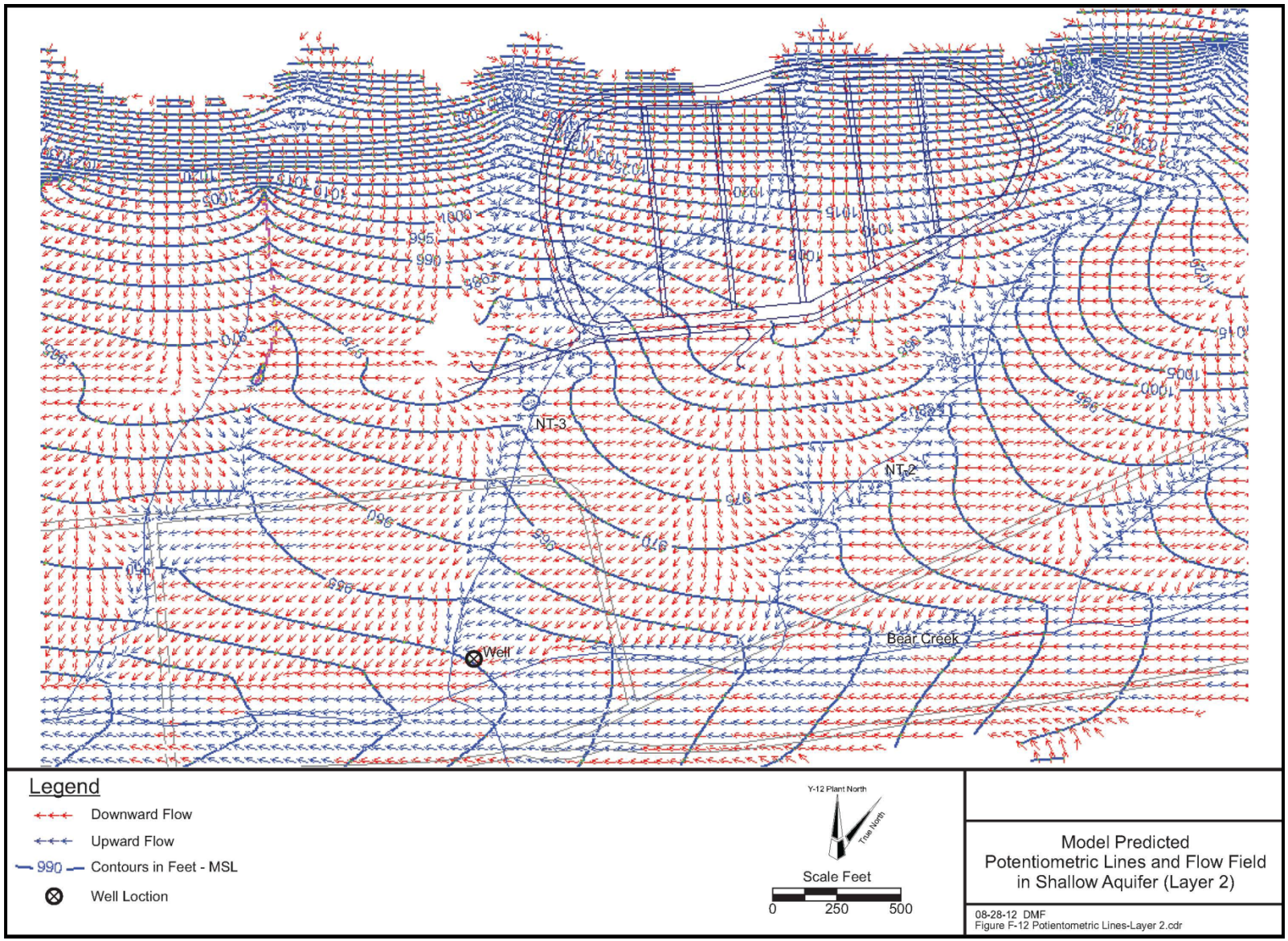



**Figure H-12. MODPATH Model Predicted Potentiometric Lines and Flow Field in the Shallow Aquifer**

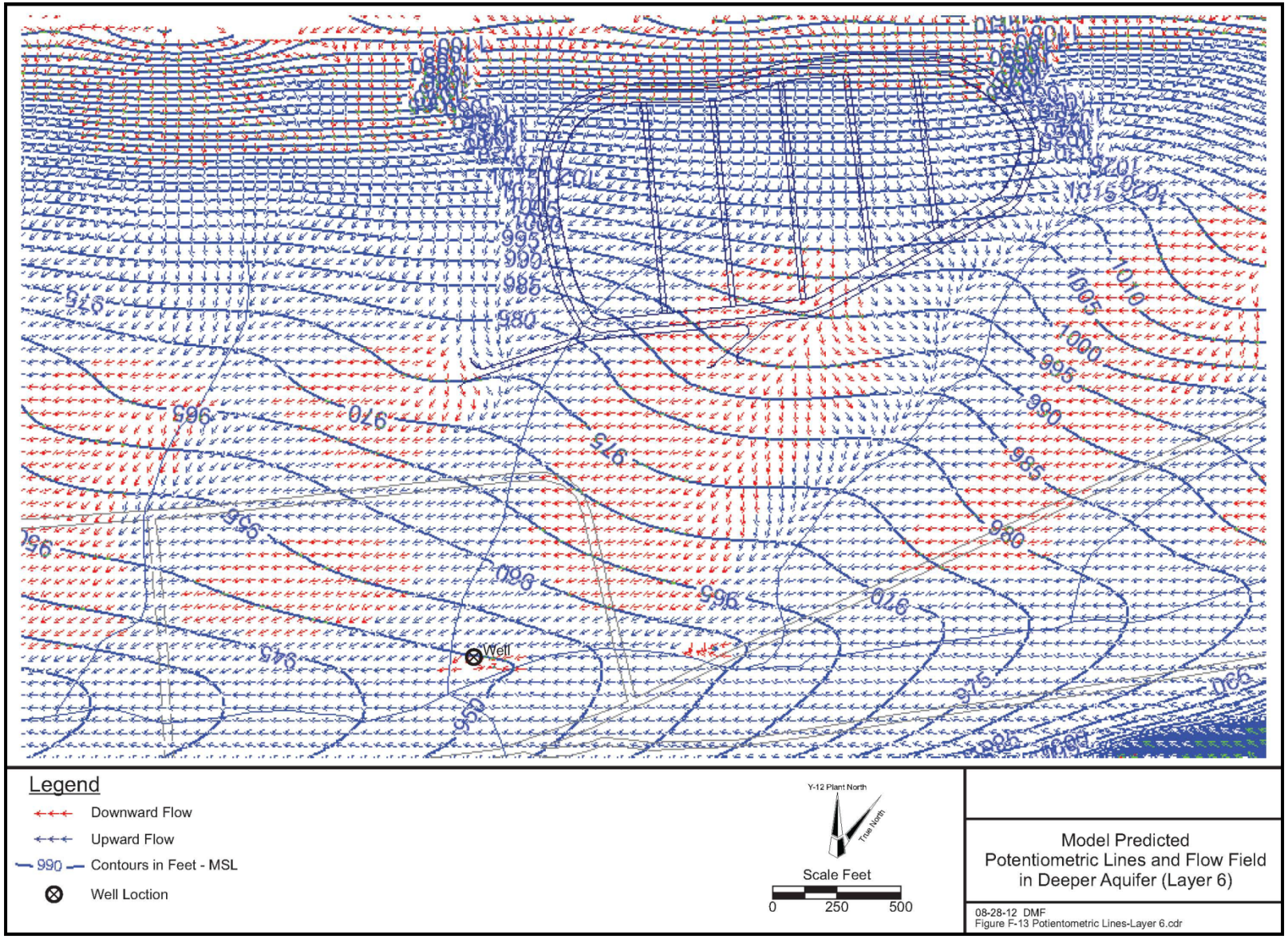



**Figure H-13. MODPATH Model Predicted Potentiometric Lines and Flow Field in the Intermediate Aquifer**

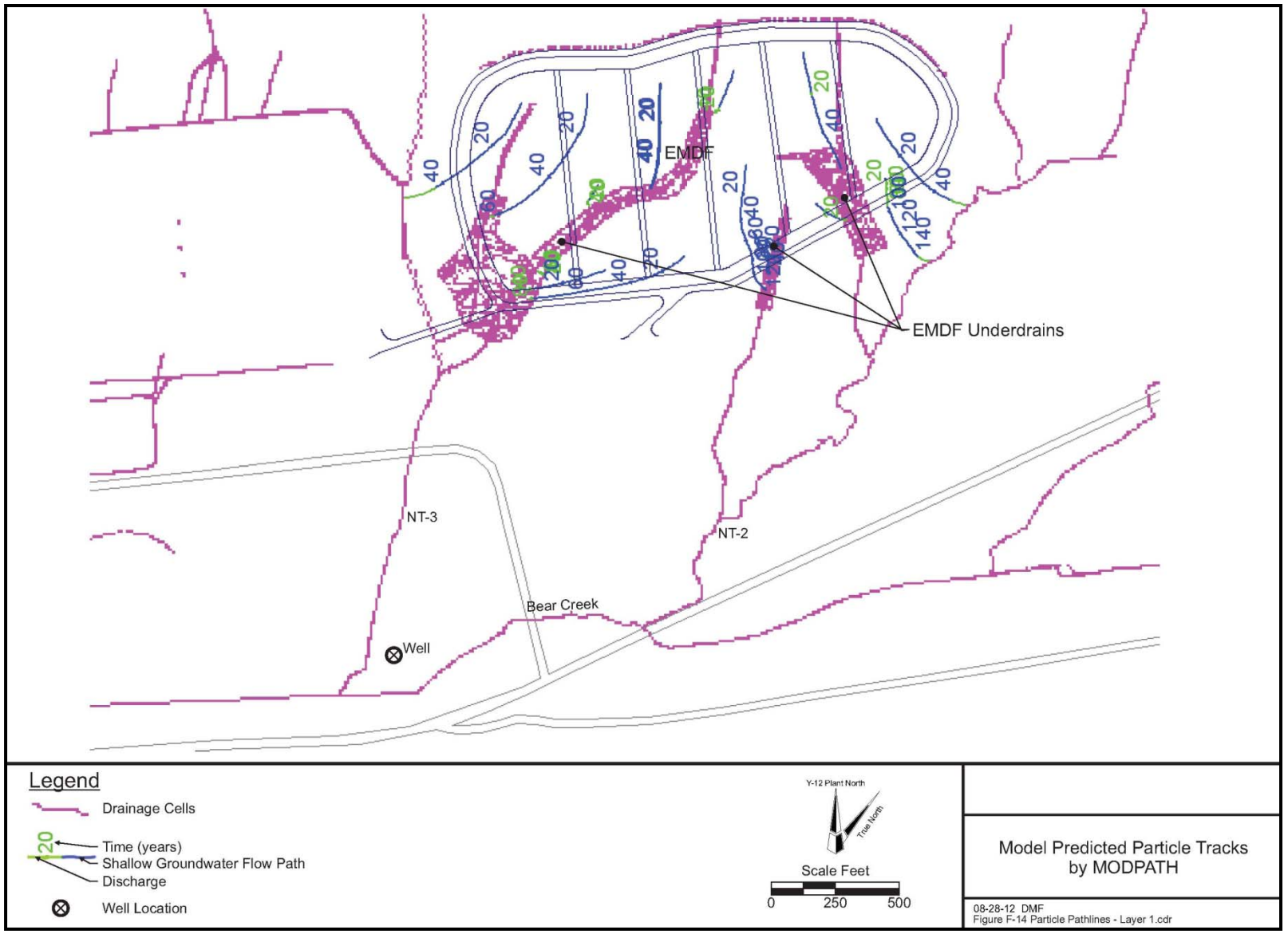



**Figure H-14. MODPATH Predicted Particle Tracks**

## 4.3 FATE-TRANSPORT (MT3D) MODEL APPLICATION

The movement of contaminants from the waste cell to various locations (e.g., to the exposure locations) outside of the waste disposal site via ground water was simulated by using MT3D (Version 1.0, Zheng, 1990), a fate-transport model code that is coupled to the ground water flow field results for the future site condition generated by MODFLOW. Based on the results of the MODFLOW simulation for the future closed EMDF scenario, MT3D is used to predict a non-specific contaminant concentration distribution for the site, specifically at the location selected for the resident farmer well, or exposure point, relative to the landfill itself.

### 4.3.1 Site-specific MT3D Model Development

Although MT3D can be used to simulate the concentration of a contaminant at various locations based on a given flow field, in this application it has been used to determine a single relative concentration at a given location compared to an assumed concentration of that contaminant source in the landfill. The flow field is supplied by the MODFLOW simulation. A constant leaching source (set equal to 1.0) from the waste disposal cell to ground water underneath the cell was assumed as input to the model (see Figure H-15). Assigning a constant leaching source is a very conservative assumption as the contaminant mass (thus leaching rate) will decrease with time due to decreasing mass in the disposal cell. Only the advection process was considered. No hydrodynamic dispersion or retardation processes were considered in the MT3D simulations. The MOC solution method was used for all the simulations to minimize the potential error from numerical dispersion. Retardation and dispersion processes are considered in the PATHRAE analysis.

The risk evaluation for the proposed EMDF assumes a scenario in which a hypothetical domestic ground water supply well is placed hydraulically down-gradient from the disposal cell. As discussed in Section 2.4, the hypothetical well analyzed is located on the BCV floor between the EMDF and Bear Creek before the intersection of down-gradient tributary NT-3 as shown in Figure H-15 at a distance of 460 m from the edge of the landfill. The well is completed in model Layers 5–8, and is assumed to have a pumping rate of 240 gallons per day, adequate to supply water to a family of four. The well is assumed to be a typical domestic water supply well that pumps water from the bedrock aquifer. The well location was selected to penetrate in the Nolichucky Shale near the more permeable Maynardville/Nolichucky formation boundary at a depth where sufficient water yield is met.

The model analyses were carried out in the following steps:

1. For the pumping well location and well scenario, a ground water flow simulation run was performed to determine the specific ground water flow field.
2. Contaminant movement in the flow field with time was simulated with MT3D. After a steady state was achieved for the contaminant plume, the maximum concentration field was established. The steady state was established by assuming a constant leaching source of 1.0 (CL= 1.0) for the duration of the model simulation. Once steady state is reached, this establishes a constant DF that is later applied to all contaminants.
3. For the well location, a concentration ratio (well to leachate [with CL = 1.0]) versus time graph was plotted to show the relative transient concentration change with pumping and relative steady state concentration maximum (e.g., minimum dilution) used with the PATHRAE analyses and calculations to produce the PreWAC.

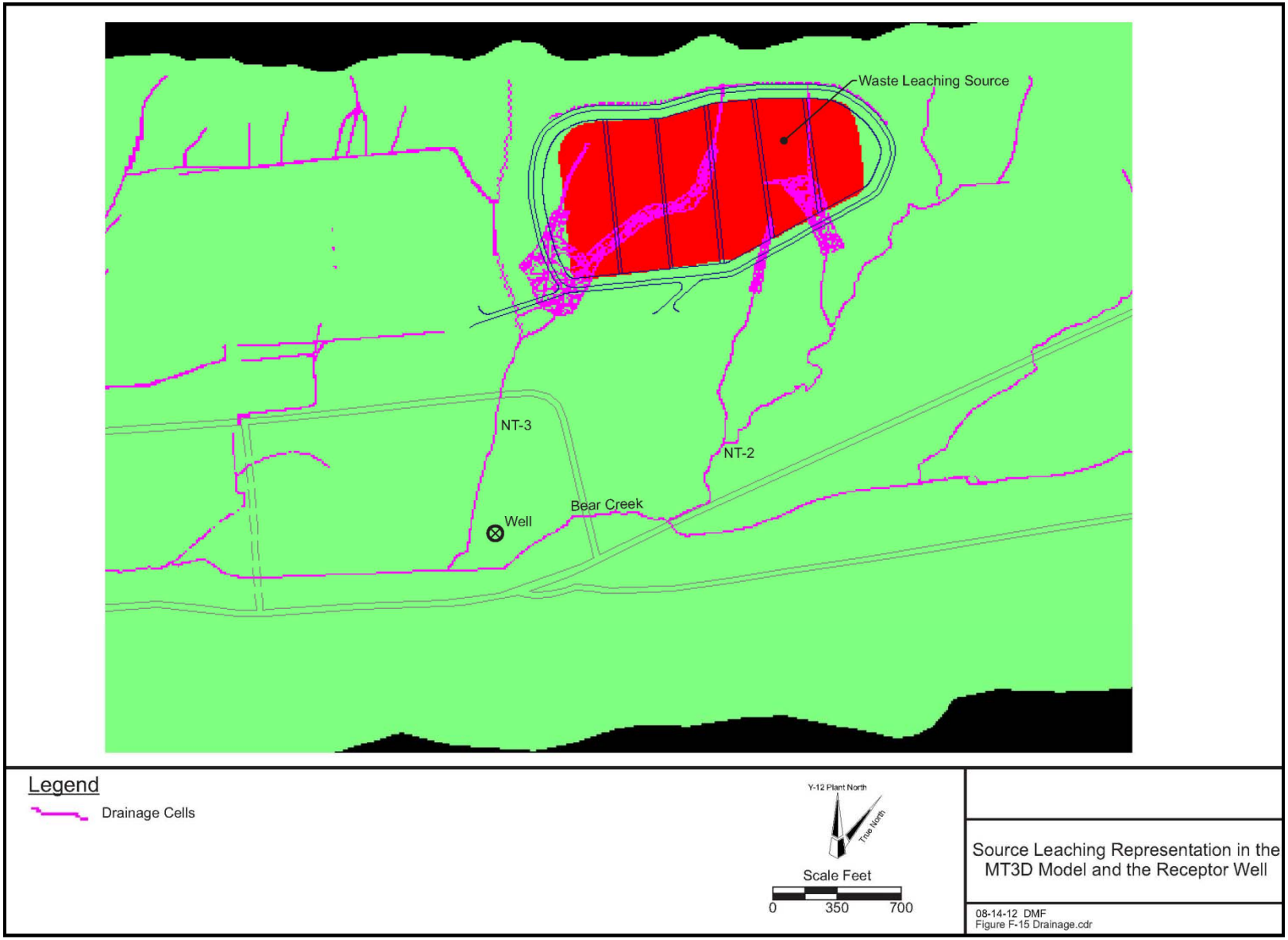



**Figure H-15. Source Leaching Representation in the MT3D Model and the Hypothetical Receptor Well Location**

### 4.3.2 MT3D Model Assumptions

Assumptions made in running the MT3D code are as follows:

1. Changes in the concentration field will not measurably affect the flow field.
2. Transport is modeled as three dimensional and transient until a steady state condition is reached.
3. Only advection is considered; other processes (dispersion and retardation) were not assumed. This is a conservative assumption because other processes will reduce the contaminant peak concentrations, as dispersion and retardation terms represent the contaminant spreading in the environment, thus flattening the peak.
4. The MOC solution method, best for advection only, was used for the simulation to minimize the potential error from numerical dispersion.
5. The well pumping rate is 240 gallon/day, based on its use by a family of four.
6. The well is cased to 70 ft. Water is drawn from model Layers 5–8, corresponding to 70–150 ft below ground surface.
7. The well was assumed to be located nearby on the BCV floor between the EMDF and Bear Creek (see Section 2.4), at a distance of 460 m from the edge of the landfill. This location is also consistent with topographical and geological features, lithostratigraphic and hydrogeological data, and ground water modeling results
8. The landfill is represented by a uniform, constant leaching source (assigned a unit leach rate of 1.0), which is assumed for the duration of the simulation. This represents a conservative approach as in reality the source will be depleted as leaching proceeds. The code is run for a single, non-specific contaminant source.
9. Steady state is reached at peak leaching, based on a constant, non-depleting contaminant source.

### 4.3.3 MT3D Model Results

Based on the results of UBCV flow simulations for the closed landfill scenario (i.e., permanent cover system in place) and the withdrawal of ground water from a supply well, the MT3D code was used to predict the contaminant concentration distribution in the site for the given well scenario. Figure H-16 shows the maximum (relative, nonspecific) contaminant concentration plume in the ground water for all model layers. The steady-state plume represents the maximum plume resulting from the constant EMDF source that is predicted to be achieved 1,500 years after facility closure. The plume in Figure H-16 shows the relative ground water concentration as fraction of the leachate concentration at the source. As predicted by the site conceptual model, most of the shallow plume discharges into surface water features (gravel-filled former tributaries, NT-3, and Bear Creek).

Figure H-17 shows the average steady state plume in model Layers 5–8, and is representative of the plume at the screened interval of the hypothetical receptor well. Figure H-18 shows the steady plume distribution in a south-north cross section. The plume maps in Figures H-16 through H-18 show the plume from the proposed disposal facility discharges into Bear Creek eventually. Model Layer 9 shows a thickened plume that is an artifact of the model layer thicknesses, and not representative of actual ground water conditions. As noted above, model Layers 1–8 are relatively thin, reflecting the fact that most ground water flow occurs in the shallow interval. Model Layers 9–11 were defined more coarsely because relatively little flow occurs in these layers. The thick contaminant plume in model Layer 9 should be interpreted as actually occurring in the upper part of the layer, not the entire layer thickness.

DFs for the residential well location were calculated based on the MT3D model results. The $DF_{well}$ values are defined as the ratios of $C_{well}$ (the peak steady-state contaminant concentration in the continuously pumped well [240 gallons per day]) to $C_L$ (the unit contaminant concentration [leachate] entering the ground water beneath the disposal facility). Figure H-19 shows the predicted concentrations in model layers at the hypothetical domestic ground water supply well location. The hypothetical receptor well is screened at depths corresponding to model Layers 5–8. The average $C_{well}/C_L$ or $DF_{well}$ extracted from the screened interval (model Layers 5–8) is also shown in Figure H-19. This calculated average ratio of the concentration at the well relative to leachate concentration from the cell, 0.000015, equals the $DF_{well}$.

The calculated DFs for the residential well location, landfill parameters, and surface water flow statistics are used along with PATHRAE surface water results to calculate the projected peak risks and doses from radioactive or hazardous constituents in the risk evaluation as discussed further in Section 4.4.3.

## 4.4 PATHRAE MODELING AND RISK/DOSE ANALYSIS

The PreWAC development methodology used for the proposed EMDF is similar to the methodology used to develop the EMWMF WAC (DOE 1998a, 1998b). The PATHRAE model is used to estimate receptor exposure for the surface water pathway. Additional calculations using output from PATHRAE and MT3D determine the overall risk and dose for the hypothetical receptor from the combined effects of contaminated ground water ingestion (via a well) and contaminated surface water use. It is assumed under the hypothetical receptor scenario that a resident farmer consumes drinking water from a well and uses Bear Creek surface water for agricultural purposes resulting in ingestion of contaminated milk, meat, and vegetation. The conceptual exposure model annotated with modeling functions and domains is shown in Figure H-20.

PATHRAE model development for the EMDF is described in Section 4.4.1; assumptions are given in Section 4.4.2. PATHRAE model output and risk/dose calculations are described in Section 4.4.3. Calculations of PreWAC are described in Chapter 5.

### 4.4.1 Site-specific PATHRAE Model Development

A single pathway is used in the PATHRAE RAD/HAZ model to predict exposure to the receptor from surface water usage. Exposure to the receptor via the ground water ingestion route is determined in calculations performed outside of the code (using the ground water flow model results). PreWAC are then developed based on the combined exposure of the receptor via surface water and ground water.

The method involves assuming a single constituent in the waste occupies the entire disposal facility volume (at an assumed concentration basis of 1 $Ci/m^3$ for radiological contaminants or 1 $kg/m^3$ for toxicological constituents)[2]. The determined risk (ELCR) or chemical exposure (HI) corresponding to the starting source term basis is then used to rescale to an allowable waste concentration (PreWAC) based on the RAO-defined ELCR or HI criteria for the 0–1,000 year and >1,000 yr time frames (see Section 2.5 of this Appendix).

[2] This assumption is necessary, since the exact contaminant concentrations and placement within the landfill will not be known until after the landfill begins operation. An assumption that contaminants are uniformly distributed is conservative because it allows leaching to be modeled in all the formations underlying the landfill, for the entire footprint.

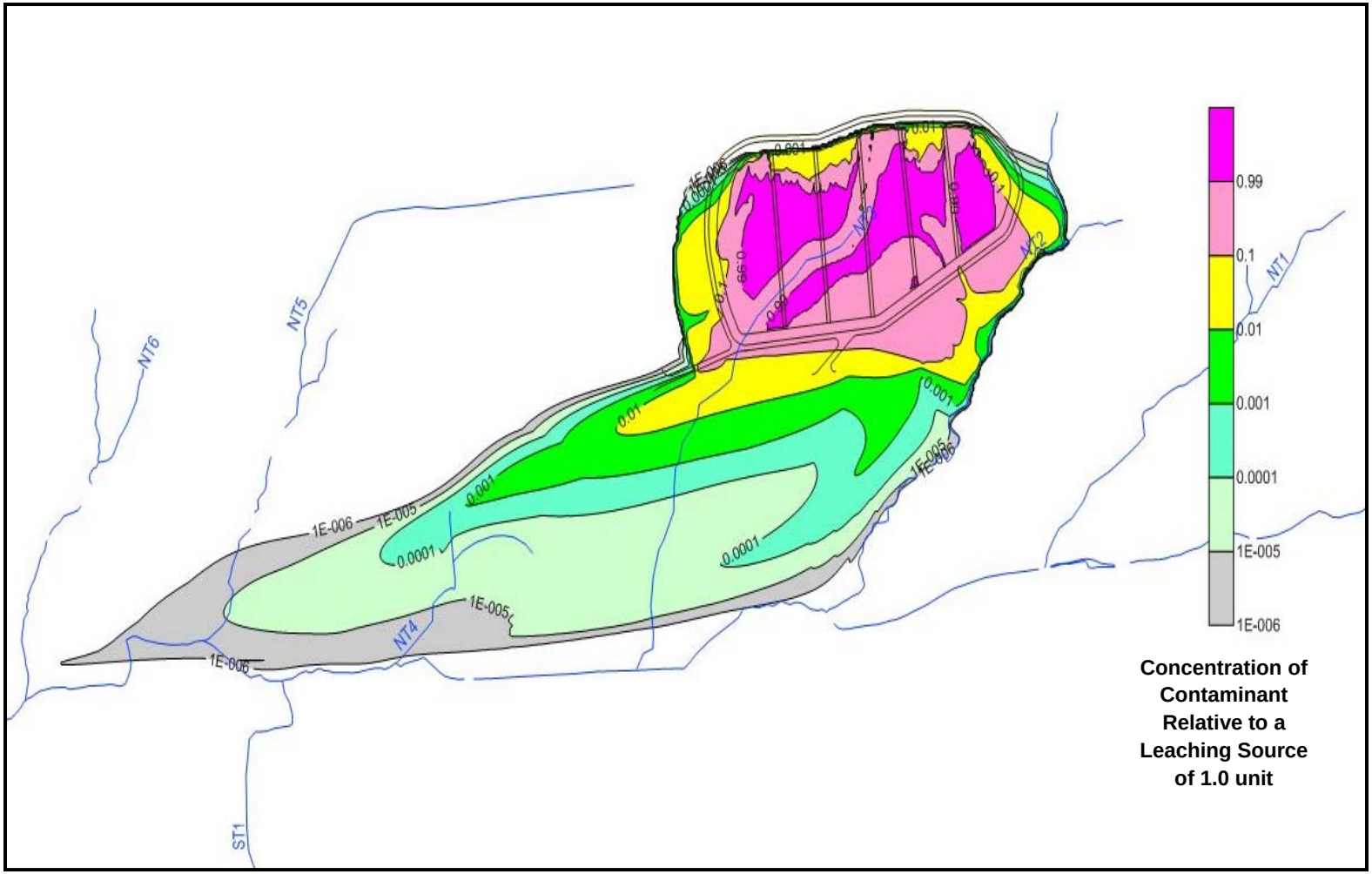
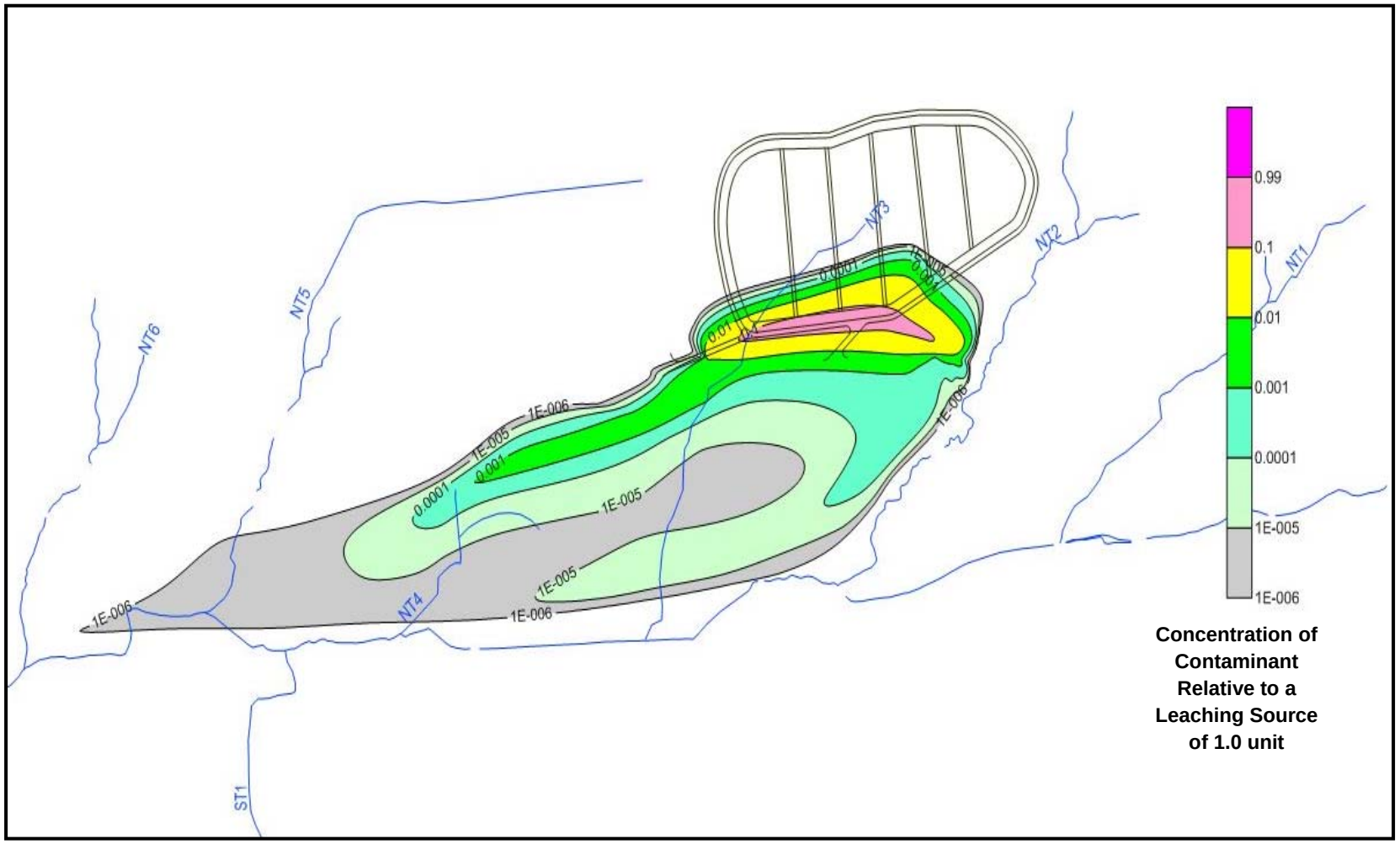
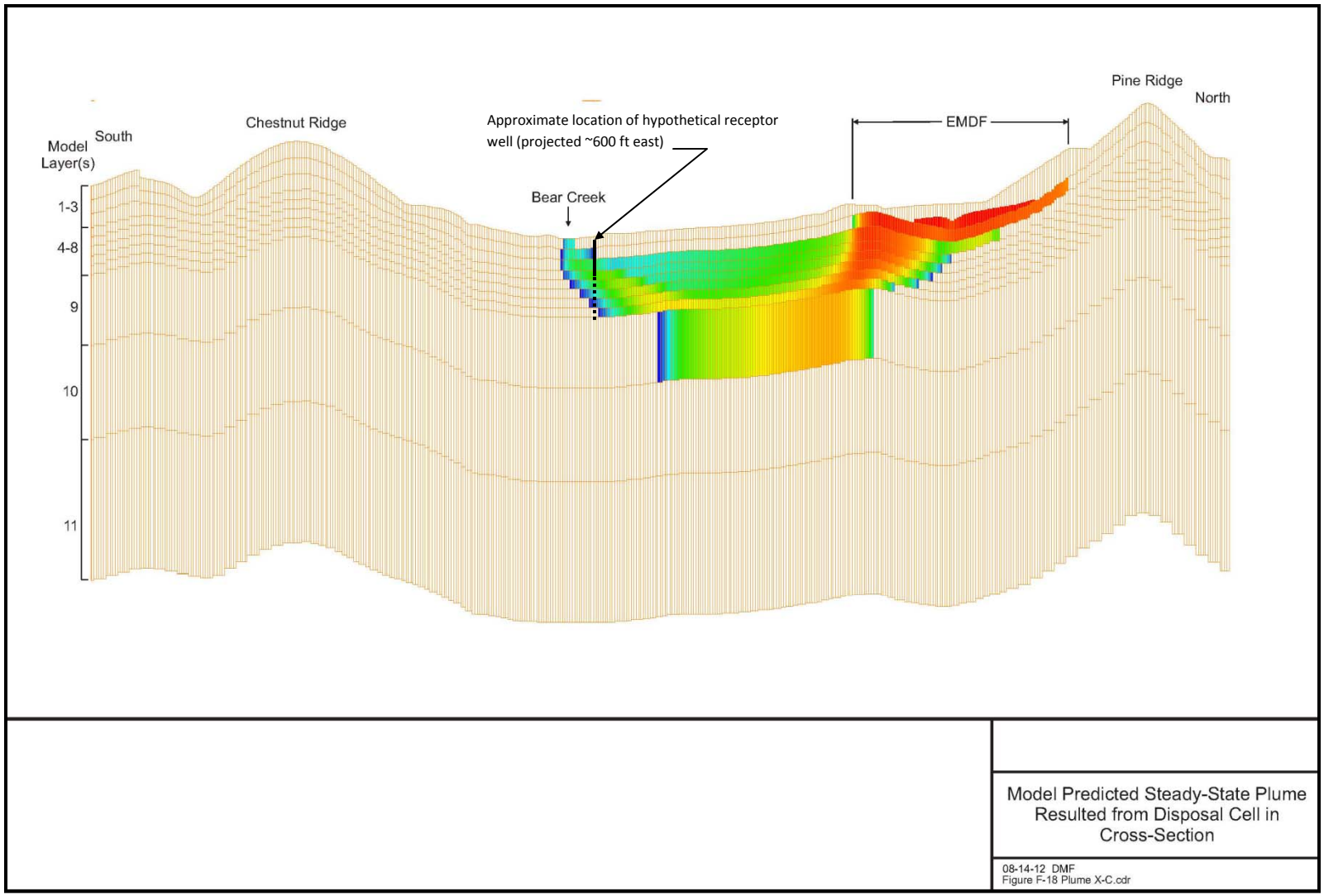



**Figure H-16. MT3D Model Predicted Plume of Maximum Contaminant Concentration in All Model Layers for EMDF**




*Plum in figure is representative of well water concentration.*

**Figure H-17. MT3D Model Predicted Plume of Average, Relative Contaminant Concentration for Model Layers 5–8**




Well is projected 600 ft east so that it may appear in this cross-section figure.

**Figure H-18. MT3D Model Predicted Steady-state Plume from the EMDF in Cross-section**

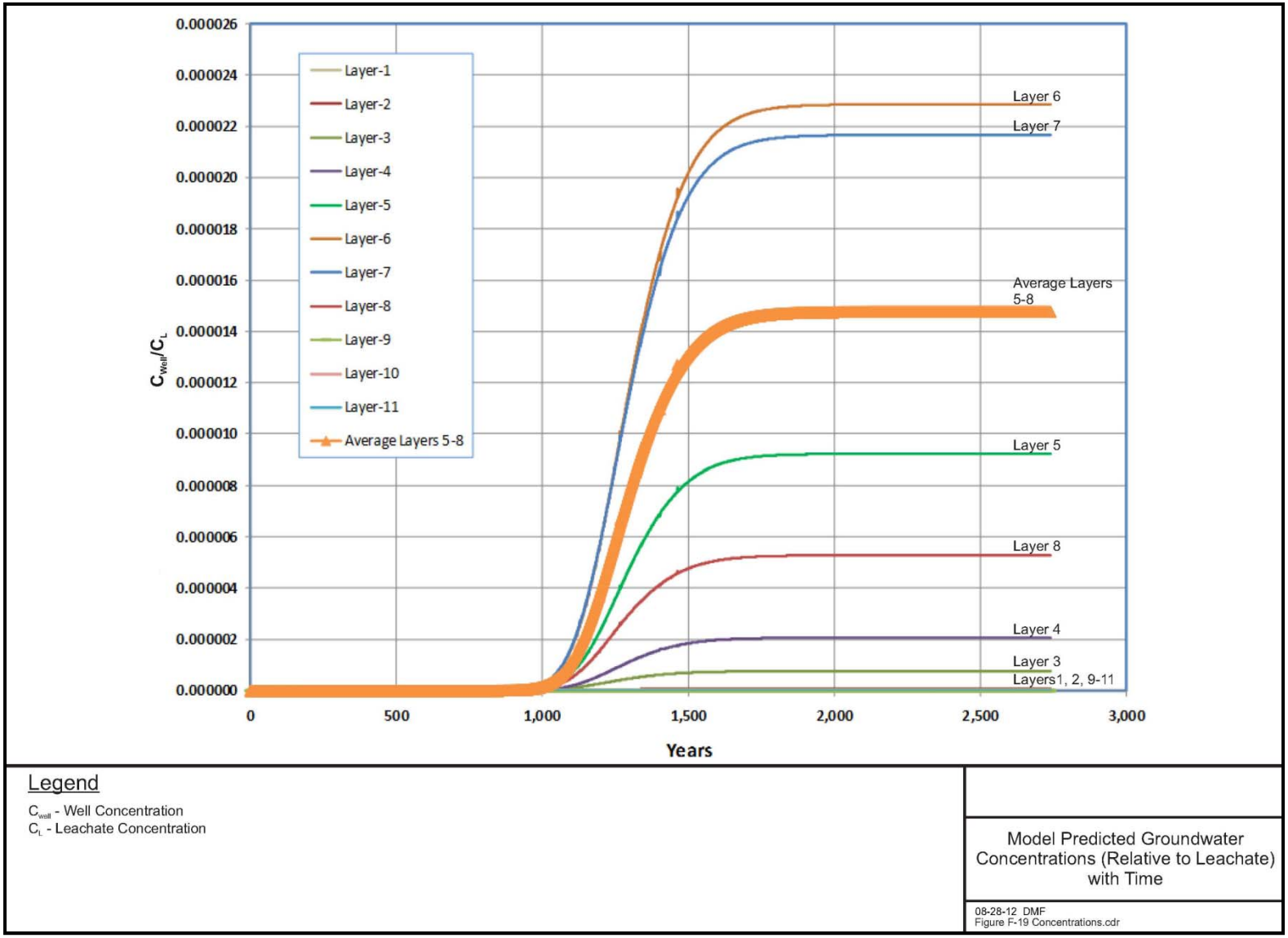



**Figure H-19. MT3D Model Predicted Ground Water Well Concentrations (Relative to Leachate) with Time**

PATHRAE is a one-dimensional fate and transport model. The code simulates contaminant migration from a contained volume (landfill) of a single uniform COPC concentration, travel of the COPC vertically through the vadose zone (via advection and dissolution in percolating precipitation/ infiltration), horizontal migration of the COPC through the saturated zone (via advection and dispersion in ground water) and discharge of the COPC to the surface water. The waste mass itself is conceptualized as a rectangular box, with the single contaminant uniformly distributed throughout the cell. The contaminant concentration in the landfill is depleted by two mechanisms: (1) decay (for radioactive contaminants; no degradation of hazardous COPCs (chemical compounds) is accounted for as they are all assumed to degrade well within 1,000 years; USGS 2006) and (2) leaching via solid-liquid partitioning. Migration of the COPC is assumed to occur from the entire base of the landfill throughout the simulation (or until the contaminant is completely depleted). Using input parameters generated from supporting hydrologeologic models, site-specific data, and conceptual design information, PATHRAE-RAD and PATHRAE-HAZ models are used to perform risk analysis. Based on the conceptual design of the EMDF (which dictates the volume of the facility, surface area of the facility, location with respect to well/surface water, and cover/waste thicknesses), and assuming a single contaminant occupies the landfill at a particular initial concentration level (set at 1 $Ci/m^3$ for radioactive species and 1 $kg/m^3$ for hazardous species), depletion of the source is modeled via decay and leaching from the waste volume. Transport of the contaminant is modeled assuming migration through the vadose zone by soil-water equilibrium partitioning followed by migration in the saturated zone also via soil-water partitioning (with an added level of conservatism introduced by decreasing the partition coefficient by a factor of 10), and a receptor (MEI) exposure to that contaminant via discharge of ground water to surface water. MEI intake via surface water is calculated using environmental food chain analysis. The exposure results from the receptor irrigating crops with contaminated surface water and ingesting them, eating livestock watered with contaminated surface water, and drinking milk from livestock watered with the contaminated surface water, all of which are considered in the food chain calculations (contaminant to vegetation/animal to receptor). Ultimately, an equivalent uptake (EU) factor is determined for each contaminant, which quantifies the equivalent annual amount of water the receptor would have to drink to equate to the uptake of the contaminant via the routes specified (e.g., eating crops/livestock watered with contaminated surface water or $EU_{sw}$), as well as the volume ingested via the well water (730 L/year), thus $EU = EU_{sw} + 730$ (L/year).

The ground water ingestion pathway is analyzed outside of the PATHRAE code, but is based on results of the PATHRAE surface water pathway analyses and other ground water model results (see Section 4.4.3, which explains these calculations further).

### 4.4.2 PATHRAE Model Assumptions

PATHRAE-HAZ/RAD input values used for modeling the proposed EMDF site include code default numbers, generic numbers obtained from literature sources, contaminant-specific parameters, conceptual design information, and measured site-specific data (such as stream flow rates). Some key parameters were calculated using additional models and site-specific information (e.g., water infiltration rates, ground water transport parameters, and contaminant release rates for various waste forms). Key parameters used in the PATHRAE model are summarized in Table H-4.

PATHRAE is run in two different modes: one for shorter times, with a decreased time step (analysis to 15,000 years). For examining isostopes with long half-lives, an increased time step is used so that peak concentrations can be determined (up to 1,000,000 years).

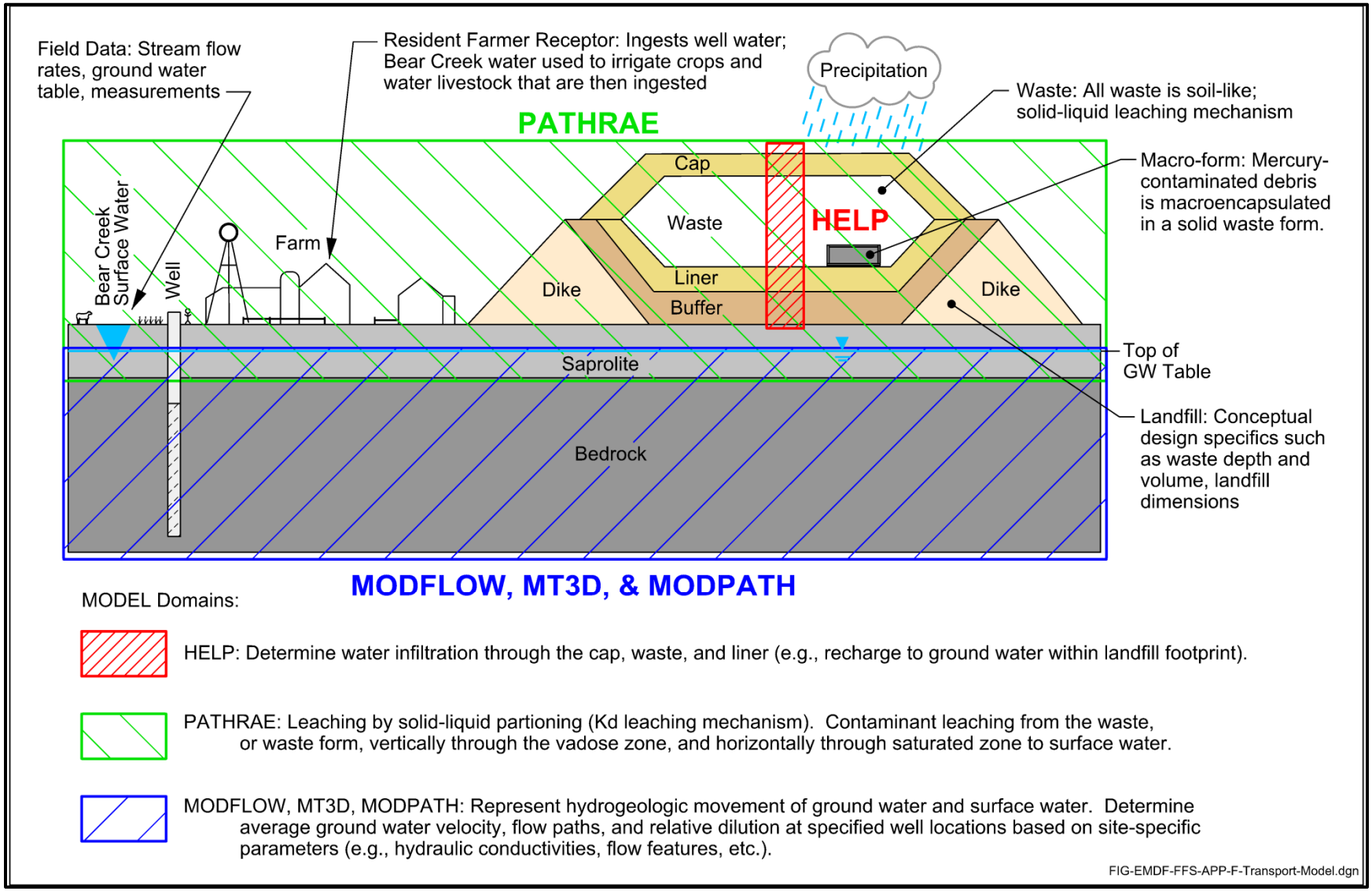



**Figure H-20. Contaminant Leaching/Transport Analysis and Exposure Conceptual Model**

**Table H-4. Key PATHRAE Parameters**

| Physical Process | Solution Methodology | Parameters Needed |
|---|---|---|
| Rate of water infiltration through final cover, waste, and liner and into vadose zone | HELP model | Site-specific climatic parameters; disposal cell conceptual design parameters (e.g., cover layers); vadose zone hydrological parameters |
| Contaminant release rates from the waste volume/footprint to the vadose zone | Partition coefficient ($K_d$) leaching mechanisms | Contaminants of concern; site-specific and generic contaminant $K_d$ factors for soils; site conceptual design |
| Material retardation characteristics (i.e., the ability of a material to retard the movement of contaminants) within and away from the disposal facility | $K_d$ equilibrium mechanisms with backfill soils, vadose zone soils, and saturated media | Site-specific and generic $K_d$ factors for soils and saturated zone media |
| Ground water transport characteristics | MODFLOW and MT3D models | Site-specific and generic hydro-geologic parameters |
| Ground water interactions with surface water | MODFLOW, MODPATH, and PATHRAE model | Surface water flow parameters and MODFLOW/MODPATH results |
| Receptor uptake of contaminant(s) by exposure routes | PATHRAE environmental food chain analysis and modeled Equivalent Uptake (EU) | Contaminant uptake parameters for the food chain, and the intake rates for human receptor consuming contaminated food and water – EPA and Nuclear Regulatory Commission (NRC) literature values; PATHRAE default values |

#### 4.4.2.1 Contaminants of Potential Concern

Potential contaminants disposed in the facility will consist of radioactive and hazardous constituents. All COPCs are considered, and an exhaustive list of radioactive contaminants was initially developed (see Attachment A of this Appendix). Isotopes that have a half-life of less than five years were not modeled under the assumption that the final cover will fully perform for 100 years following closure, and the isotopes will have decayed over 20 half-lives, thus their concentrations may be considered insignificant by the time they reach the receptor. A total of 263 isotopes were considered; 203 were not modeled for the reasons stated in Attachment A, and the remaining 60 isotopes were modeled. Likewise, an exhaustive list of hazardous contaminants was considered (see Attachment A). Data pertinent to each contaminant (e.g., slope factors, specific activities, reference doses, etc.) are given in the Attachment.

#### 4.4.2.2 Partition Coefficients

Contaminant-specific $K_d$ are key parameters in determining the leaching and transport of that contaminant in the environment, and ultimately, to the receptor. The assumed waste contaminant leaching characteristics use a simple $K_d$ release mechanism. The $K_d$ values that are used to develop the PreWAC are summarized in Attachment A. A discussion of $K_d$ is also included in the Attachment, and references for the $K_d$s used are presented. All waste being modeled (debris as well as soil) is assumed to be soil-like. Based on EMWMF leachate data (UCOR 2015) and Bear Creek soil data (NRCS 2013; DOE 1993), near slightly acidic to near neutral pH conditions are expected for the future EMDF, and solid-liquid $K_d$s determined in near neutral pH conditions would apply. The majority of projected waste to be generated is

debris; however, as shown in Fig. 2-3 in Chapter 2 of this RI/FS, the volume of clean fill and waste fill that would actually occupy the proposed 2.5 million $yd^3$ facility is roughly twice the volume of debris; therefore, a soil-like assumption is considered valid. Debris would be surrounded in the landfill by clean and waste soil fill to meet void and operational fill requirements, including a layer of soil that underlies all waste disposed in the facility to protect the liner from waste placement activities. Therefore, soil-like material characteristics (including $K_d$) are the most representative for the overall waste since the waste cell is modeled as a single unit source. Modeling of mercury-contaminated debris that is assumed to be macroencapsulated within the landfill is performed under several scenarios to examine assumption sensitivities.

#### 4.4.2.3 Waste Containing Mercury

Mercury is a major contaminant of concern for wastes that will be generated in the cleanup of the Y-12 National Security Complex (Y-12). Wastes will include mercury-contaminated debris to be generated upon demolition of a number of facilities at Y-12 and soil/sediment to be generated during remediation projects. Mercury is not classified as a carcinogen; however, it is toxic and has an associated reference dose (see Attachment A). It is called out specifically here since mercury-contaminated debris is proposed to be disposed in the On-site Disposal Alternative by macroencapsulation within the disposal cell, thus meeting land disposal restrictions (LDRs) once the macro-treatment is completed (see Appendix C). Remaining wastes containing mercury include (a) soil/sediments that fail the toxicity characteristic leaching procedure (TCLP) and thus are assumed to be treated to meet LDRs prior to being disposed in the landfill, and (b) debris and soil/sediment wastes that are not considered hazardous for mercury since they pass TCLP testing, yet may contain measureable amounts of mercury.

As mentioned previously, mercury-contaminated debris that is assumed to be treated by macroencapsulation within the landfill is examined in several modeling scenarios. Associated assumptions and results are explained further in Section 4.4.3.3.

Soil/sediments that fail TCLP are assumed to be treated by the generating project using a sulfur polymer stabilization/solidification (SPSS) method. This treatment method effectively stabilizes mercury in a form that is essentially non-leachable. A site-specific study of Y-12 soils (UCOR 2012) treated by SPSS or similar method, by three different vendors, resulted in a final waste that had a mercury $K_d$ of approximately $10^6$, validating the assumption that mercury, in this waste form, will not leach to any measurable degree.

Debris and soil/sediments that pass TCLP for mercury are not required to be treated and are not considered hazardous. However, there may be measureable amounts of mercury in the waste. The mercury in these wastes is modeled in PATHRAE-HAZ as are other COPCs, based on a soil $K_d$ leaching mechanism. The previously mentioned study (UCOR 2012) that examined the SPSS treatment method, fully characterized the mercury-contaminated soils prior to testing. A soil-liquid mercury $K_d$ based on the untreated soils was calculated based on the three vendors' test results; the average of all three tests resulted in a $K_d$ of 589 mL/g. This result validates the $K_d$ of 580 mL/g for mercury used previously in EMWMF modeling, and used here in this model as well. This is a conservative assumption, when compared to EPA's recommended default soil-water $K_d$ of 1,000 mL/g for elemental mercury (and higher for mercury II) (EPA 1997).

#### 4.4.2.4 Other PATHRAE Input Parameters

A notable difference in PATHRAE modeling and risk calculation for the proposed EMDF vs. the EMWMF WAC is the Reference Dose and Slope Factor parameters based on updated values in EPA risk guidance (EPA 2014), which are used to calculate risk/dose from ground water and surface water pathways. The Reference Dose and Slope Factors for all COPCs are given in Attachment A. Also,

site-specific parameters for the proposed EMDF conceptual design and conditions are used to arrive at PreWAC. Table H-5 summarizes the input parameters used to conduct PATHRAE analysis.

#### 4.4.2.5 Summary of PATHRAE Assumptions

A listing of assumptions for the PATHRAE code execution follows:

- A resident farmer (MEI) conceptual scenario, as described in Sections 4.4 and 4.4.1.
- MEI is a 70 kg person, a 30-year exposure is assumed.
- MEI drinks water from a well, at a rate of 2 L/day (730 L/year).
- Well location is not used in the PATHRAE-RAD/HAZ model; however, it is part of the overall hypothetical resident scenario. The well was assumed to be located nearby on the BCV floor between the EMDF and Bear Creek (see Section 2.4), at a distance of 460 m from the edge of the landfill. This location is historically supported as a likely location for a receptor and is also consistent with topographical and geological features, lithostratigraphic and hydrogeological data, and ground water modeling results
- MEI waters livestock and irrigates crops using surface water available at the main trunk of BCV, the closest main Bear Creek (surface water) location to the landfill.
- Attachment A contains a list of COPCs, and their associated parameters (e.g., $K_d$, slope factors, etc). Isotopes with half-lives less than five years are not modeled as they decay a minimum of 20 half-lives prior to assumed cap failure and infiltration (from precipitation) into the landfill.
- Conceptual design parameters are listed in Table H-5.
- Soil properties are listed in Table H-5.
- Site properties are listed in Table H-5.
- Inputs from other models (HELP, MODFLOW/MODPATH, MT3D) as listed in Table H-5.
- Waste is modeled as soil-like. Soil $K_d$s are assumed to represent the release mechanism in the waste and leaching mechanism in the vadose and saturated zones. The saturated zone $K_d$ is conservatively assumed to be $1/10^{th}$ of the vadose zone $K_d$.
- An average vadose zone thickness of 23 ft is based on results of ground water modeling of the long-term future condition, and corresponds to 5 ft of liner material, 10 ft of hydrogeologic buffer soil, and another 8 ft of backfill soils above the water table.
- Near neutral pH conditions exist in the waste zone based on EMWMF data.
- The complex ground water regime cannot be adequately modeled by PATHRAE simple one-dimensional flow assumptions and contaminant movement is instead modeled using MODFLOW/MODPATH and the MT3D code. PATHRAE simple one-dimensional flow is adequate to model ground water flow discharge to surface water only.
- The EMDF is conceptualized as one large rectangular waste cell containing a uniform concentration of a single contaminant at the initiation of the simulation, 1 $Ci/m^3$ for radioactive COPCs and 1 $kg/m^3$ for hazardous COPCs, which leach from the "base" of the landfill.
- A single radioisotope source is assumed to occupy the landfill in PATHRAE-RAD analysis; decay of that isotope is accounted for, as is leaching from the landfill thus resulting in a depleting source. Isotopes are modeled to peak concentration in surface water.
- A single hazardous contaminant source is assumed to occupy the landfill in PATHRAE-HAZ analysis; no degredation of contaminants is assumed therefore hazardous contaminants that are chemical compounds are modeled only to 1,000 years. Hazardous contaminants that are single elements are modeled to peak concentration in surface water.

**Table H-5. Parameters for Use in PATHRAE Modeling and PreWAC Calculations**

| Zone | Parameter | Source of Data | Value | Unit |
|---|---|---|---|---|
| Cover/ Surface | Cover thickness | Conceptual design | 11 | ft |
| | Porosity of surface soil | Assumption | 0.25 | vol/vol |
| Waste Zone | Waste volume | Conceptual design | 2,500,000 | $yd^3$ |
| | X (along ground water flow path) | Conceptual design | 1,596 | ft |
| | Y (cross ground water flow path) | Conceptual design | 798 | ft |
| | Disposal cell surface area | Conceptual design | 1,273,134 | $ft^2$ |
| | Waste thickness (average) | Conceptual design | 53 | ft |
| | Waste density | Assumption | 1,600 | $kg/m^3$ |
| | Recharge rate to ground water from waste zone | HELP Model result | 0.43 | In./yr |
| | Amount of water percolating through the waste cell | Calculated using HELP results & Conceptual design parameters | 0.00135 | cfs |
| Vadose Zone | Depth to ground water (from bottom of waste) | Model predicted water table & Conceptual design parameters | 23 | ft |
| | Bulk soil density | Assumption | 1,600 | $kg/m^3$ |
| | Porosity of vadose zone | Assumption | 0.25 | vol/vol |
| | Saturated hydraulic conductivity of vadose zone | Assumption (based on BCV field data) | 1.00E-06 | cm/s |
| Ground Water | Bedrock density | Assumption | 1,800 | $kg/m^3$ |
| | Soil/Weathered bedrock porosity | Assumption | 0.2 | vol/vol |
| | Bedrock porosity | Assumption | 0.05 | vol/vol |
| | Longitudinal dispersivity in bedrock aquifer | Assumption | 6 | meter |
| | Transverse dispersion coefficient in bedrock aquifer | Assumption | 0 | $m^2/yr$ |
| | Horizontal ground water velocity (calculated using particle tracking trajectories) | MODPATH Model result | 14 | ft/yr |
| Surface Water | Stream flow rate at compliance point (Junction NT-3 and Bear Creek) | Field data | 0.55 | cfs |
| | Surface water Dilution Factor | Calculated, volumetric flow through waste/volumetric flow at SW location | 0.00245 | unitless |
| | Distance from nearest edge of waste to surface water compliance location | Conceptual design | 1,570 (479) | ft (m) |
| Ground Water Well | Distance from nearest edge of waste to ground water well location | Conceptual design | 1,500 (460) | ft (m) |
| | Ground water well DF at specified location | MT3D Model result at given well location | 0.000015 | unitless |

- No isotopic in-growth is accounted for; this is because only a single contaminant is examined at one time, and only in terms of calculating a PreWAC limit for that radioactive species in the landfill as a whole. The source of the isotope (whether it is present due to decay or placed in the landfill during operations) need not be considered. Nuclide in-growth is, however, considered outside of the model, and analytic PreWAC have been adjusted as necessary to account for daughter product in-growth (see Section 5.1.1.2).
- Advection, retardation, and dispersion are considered in PATHRAE analysis.

### 4.4.3 PATHRAE Model Results

PATHRAE-RAD and PATHRAE-HAZ, which model, respectively, radioactive and hazardous constituent fate and transport, are used to calculate the peak time of arrival and peak concentration of each COPC at the surface water receptor location. For each contaminant that peaks within a 1,000,000 year timeframe, the peak concentration of the contaminant in the creek is determined.

The PATHRAE model also determines the equivalent annual water consumption per year for the creek water for each nuclide based on the surface water exposure routes (via crops and livestock), as stated in Section 2.3. PATHRAE uses EU factors (defined in Section 4.4.1) to represent and quantify the annual amount of nuclide (in terms of water volume) consumed by an individual from all pathways (EU includes the volume of well water ingested as well as volume ingested via surface water pathway) (EPA 1987). As a reminder of the definition given in Section 4.4.1, EU is the total equivalent annual drinking water consumption in liters that would give the same annual nuclide uptake as would occur from the consumption of contaminated vegetation, meat, and milk ($EU_{sw}$) and water (730 L/year). Thus, the specific routes by which contaminants are ingested and the quantities of the contaminated foods ingested are accounted for in the EU factor.

The input and output text files for the PATHRAE model runs (PATHRAE-RAD and PATHRAE-HAZ) are included in Attachment B to this Appendix. The input files contain all the input parameters in tabulated form, many of which are also summarized in Attachment A.

The calculated DFs for the creek and residential well (see Section 4.3.3) were used for scaling the constituent concentrations in the creek to corresponding well concentrations. The DF calculations are as follows:

- $DF_{well}$: The well (ground water) dilution factor, $DF_{well}$, is the steady state well concentration (maximum concentration, $C_{well}$) obtained while pumping, ratioed to a unit seepage from the disposal cell ($C_{LF}$), or $C_{well}/C_{LF}$ as shown previously in Figure H-19, where $C_{LF}=C_L=1$. As discussed in Section 4.3.3, the $DF_{well}$ is obtained from the MT3D model simulation, and is dependent on the location of the well within the conceptual model. The steady state was established by assuming a constant leaching source from the landfill ($C_L$ = 1 for ground water modeling) for the duration of the MT3D model simulation. This establishes a constant DF ratio ($DF_{well}$ = 0.000015 for the given well location) that is used in further calculations.
- $DF_{creek}$: The creek (surface water) dilution factor, $DF_{creek}$, is equivalent to the volumetric water flux from the disposal cell (0.00135 cfs – per Table H-5) divided by the average creek water volumetric flow rate measured at a weir location on Bear Creek (BCK- 11.54) near the hypothetical farmer's surface water irrigation intake at the junction of Bear Creek and NT-3. ($DF_{creek}$ = 0.00135/0.55 = 0.00245). Again, similar to the well DF, $DF_{creek}$ may be expressed in terms of concentrations, $DF_{creek}=C_{creek}/C_{LF}$.

These two equations are written in terms of $C_{LF}$ and set equal to each other, to solve for the contaminant concentration in the well due to a unit waste concentration: $C_{well} = (DF_{well}/DF_{creek}) \times C_{creek}$ (where $C_{creek}$ is the peak contaminant concentration in the surface water that is calculated by the PATHRAE model).

Risk is determined as a function of pathway (ground water/well and surface water/creek), then summed to get the peak effective risk:

$$PR_{eff} = PR_{well} + PR_{creek}$$

- $PR_{eff}$ = Peak effective risk (total risk from all pathways)
- $PR_{well}$ = Peak risk from ground water pathway (ingesting well water)
- $PR_{creek}$ = Peak risk from surface water pathway (ingesting crops and livestock/milk that were irrigated/watered with surface water from creek)

#### 4.4.3.1 PATHRAE-RAD Results

The peak risk due to surface water pathway and the peak risk due to the ground water pathway defined above must be calculated. Equations are written for these two risks:

$$PR_{creek} = C_{creek} \cdot EU_{sw} \cdot SF \cdot 30$$

$C_{creek}$ = Peak concentration in the surface water given by PATHRAE-RAD, [pCi/L]
$EU_{sw}$ = Equivalent uptake of surface water given by PATHRAE-RAD, [L/yr]
$SF$ = Slope factor (isotope specific, from EPA 2012), [ELCR/pCi]
$30$ = Exposure time, [yr]

and

$$PR_{well} = C_{well} \cdot 730 \cdot SF \cdot 30$$

$C_{well}$ = Peak concentration in the pumped well water, [pCi/L]
$730$ = Volume of well water ingested, [L/yr]

Combining the above risks to get the peak effective risk ($PR_{eff} = PR_{well} + PR_{creek}$), and substituting $C_{well} = (DF_{well}/DF_{creek}) \times C_{creek}$ gives:

$$PR_{eff} = C_{creek} \cdot [730 \cdot \frac{DF_{well}}{DF_{creek}} + EU_{sw}] \cdot SF \cdot 30$$

Thus, the peak effective risk or ELCR is determined, for each COPC, based on the defined hypothetical scenario. The peak effective risks calculated using the PATHRAE-RAD results and equations listed above for EMDF, based on a COPC initial source of 1 Ci/m$^3$, are given in Table H-6 for the radioactive COPCs.

#### 4.4.3.2 PATHRAE-HAZ Results

Similar calculations are carried out for hazardous COPCs that are also considered carcinogenic, and modeled using PATHRAE-HAZ. The variables are marked with a prime to indicate hazardous contaminants as opposed to radioactive contaminants. The most significant differences are the SFs, units, and conversion factors.

The peak risk due to the surface water pathway (creek) and the peak risk due to the ground water pathway (well) must be calculated. Equations are written for these two risks:

$$PR'_{creek} = C'_{creek} \cdot EU'_{sw} \cdot SF' \cdot \frac{30}{1{,}788{,}500}$$

$C'_{creek}$ = Peak concentration in the surface water given by PATHRAE-HAZ, [mg/L]
$EU'_{sw}$ = Equivalent uptake of surface water given by PATHRAE-HAZ, [L/yr]
$SF'$ = Slope factor (contaminant specific, from EPA 2012), [ELCR/(mg/kg-d)]
*30* = Exposure time, [yr]
*1,788,500* = 70 kg human × 365 day/yr × 70 yr life, [kg-d]

and

$$PR'_{well} = C'_{well} \cdot 730 \cdot SF' \cdot \frac{30}{1{,}788{,}500}$$

$C'_{well}$ = Peak concentration in the pumped well water, [mg/L]
*730* = Volume of well water ingested, [L/yr]

Combining the above risks to get the peak effective risk, and substituting $C'_{well} = (DF_{well}/DF_{creek}) \cdot C'_{creek}$ gives:

$$PR'_{eff} = C'_{creek} \cdot [730 \cdot \frac{DF_{well}}{DF_{creek}} + EU'_{sw}] \cdot SF' \cdot \frac{30}{1{,}788{,}500}$$

Thus the peak effective risk or ELCR is determined, for each hazardous COPC, at the specified well location.

The peak creek dose ($PD'_{creek}$, [mg/kg-day]) is calculated in much the same way, for hazardous COPCs:

$$PD'_{eff} = \frac{C'_{creek} \cdot \left[730 \cdot \frac{DF_{well}}{DF_{creek}} + EU'_{sw}\right]}{70\ kg \cdot 365\frac{day}{yr}}$$

The peak effective risks and doses, based on unit source terms and calculated using the PATHRAE-HAZ results and equations listed above, are given in Table H-7 for the hazardous COPCs. As these results (Table H-7) and the results for radioactive COPCs (Table H-6) are based on a single contaminant with an initial unit source term concentration in the landfill, they must be scaled to the appropriate RAO risk/HI limits to determine PreWAC limits. Calculations and PreWAC results are discussed in Chapter 5.

#### 4.4.3.3 Mercury Modeling Sensitivity

Sensitivity model runs were conducted for mercury, since mercury-contaminated debris will be in a macroencapsulated form(s) within the landfill. The controlling release mechanism of mercury in the macro-form (e.g., the $K_d$ in the waste) and potential localized placement within the cells were analyzed. The initial source concentration for mercury was kept at the assumed 1 kg/m$^3$ (corresponds to 625 ppm).

Macro-forms are expected to be placed on the landfill floor, and measure 30 ft × 30 ft × 10 ft. Multiple forms are assumed to be placed in Cells 1–4 only. Thus the landfill footprint was adjusted to be

representative of all macro forms (landfill dimensions 1,170 ft × 810 ft – 4 Cells) and waste height was set at 10 ft. This first run was made with only the adjusted source size. $K_d$ values were kept the same as for soil-like waste (e.g., $K_d$ = 580 ml/g for waste and vadose zones, saturated zone $1/10^{th}$ or 58 ml/g). This would be representative of a macro-form in which the flowable fill were enhanced (e.g., sulfur) to retard leaching of mercury. There was no change to the previous results for mercury leaching from soil-like waste, given in Table H-7. That is, the mercury did not peak in the surface water within the 1,000,000 year timeframe analyzed; therefore no PreWAC limit was required.

A lower $K_d$ in the source zone (waste) was next assumed, to represent a macroencapsulation form that might not contain specific enhancements for mercury retention. A $K_d$ value $1/10^{th}$ of the soil $K_d$ for mercury was applied (58 ml/g from 580 ml/g). The reduced source size (representative of the waste forms) was used. Results were the same; the mercury did not peak in the surface water within the 1,000,000 year timeframe analyzed, and no PreWAC limit was required. Note that changing the initial source concentration of mercury will not change the results given above, since no peak was obtained in the analyzed timeframe. Concentration changes would only affect the height of the peak (not timing).

A final model run was made in which the mercury $K_d$ in the waste form was reduced to a low 5.8 ml/g. Results were the same as for the other runs; the mercury did not peak in the surface water within the 1,000,000 year timeframe analyzed, and no PreWAC limit was required. As a further investigation, using a $K_d$ of 58 ml/g for the waste form, the $K_d$ of the vadose zone was reduced from 580 to 58 ml/g. This resulted in a mercury concentration in the surface water that required a PreWAC limit. This run was completed only to check the response of the model; a $K_d$ of 58 for mercury in a soil environment such as the vadose zone is not realistic. A $K_d$ of 580 ml/g is a reasonable assumption for the vadose zone, as discussed in Section 4.4.2.3. These results do indicate, however, that $K_d$ in the vadose zone is the controlling factor.

**Table H-6. PATHRAE-RAD Results and Peak Effective Risk for Radionuclide COPCs Determined on the Basis of 1Ci/m$^3$ COPC Source**

| Nuclide COPC | Peak Conc. in Bear Creek, $PC_{creek}$ (pCi/L) | Total Equivalent Uptake, EU (L/year) | Peak Effective Risk*, $PR_{eff}$ (ELCR) | Peak Time (Year) |
|---|---|---|---|---|
| Ac-227 | | | | > 15,000 |
| Ag-108m | | | | > 15,000 |
| Al-26 | | | | > 1E+06 |
| Am-241 | | | | > 15,000 |
| Am-243 | 1.15E+01 | 7.303E+02 | 1.57E-07 | 86,647 |
| Ba-133 | | | | > 15,000 |
| Bi-207 | | | | > 1E+06 |
| C-14 | 9.16E+05 | 9.564E+02 | 9.82E-03 | 2,971 |
| Cf-249 | | | | > 15,000 |
| Cf-250 | | | | > 15,000 |
| Cf-251 | 5.99E-25 | 7.300E+02 | 9.62E-33 | 85,380 |
| Cl-36 | 4.03E+06 | 1.150E+03 | 1.69E-01 | 1,208 |
| Cm-243 | | | | > 15,000 |
| Cm-244 | | | | > 15,000 |
| Cm-245 | 3.36E+01 | 7.301E+02 | 4.43E-07 | 86,709 |
| Cm-246 | 1.21E-01 | 7.301E+02 | 1.57E-09 | 86,435 |
| Cm-247 | 4.07E+04 | 7.301E+02 | 5.09E-04 | 88,999 |
| Cm-248 | 3.41E+04 | 7.301E+02 | 1.95E-03 | 88,010 |
| Co-60 | | | | > 1E+06 |
| Cs-135 | | | | > 1E+06 |
| Cs-137 | | | | > 1E+06 |
| Eu-150 | | | | > 1E+06 |
| Eu-152 | | | | > 1E+06 |
| Eu-154 | | | | > 1E+06 |
| H-3 | 5.56E-17 | 1.166E+03 | 3.72E-26 | 913 |

*For those COPCs for which the Peak Arrival Time is given as > 15,000 (only first run required) or > 1E+06 (half-life requires second run, for longer periods), the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor. See Section 5.3 for a discussion of results.*

**Table H-6. PATHRAE-RAD Results and Peak Effective Risk for Radionuclide COPCs Determined on the Basis of 1 Ci/m$^3$ COPC Source (Continued)**

| Nuclide COPC | Peak Conc. in Bear Creek $PC_{creek}$ (pCi/L) | Total Equivalent Uptake, EU (L/year) | Peak Effective Risk* $PR_{eff}$ (ELCR) | Peak Time (Year) |
|---|---|---|---|---|
| I-129 | 3.94E+05 | 8.293E+02 | 1.85E-01 | 9,992 |
| K-40 | 5.44E+04 | 8.712E+02 | 5.86E-03 | 79,264 |
| Nb-93m | | | | > 15,000 |
| Nb-94 | 9.97E+00 | 7.300E+02 | 9.50E-09 | 215,891 |
| Ni-59 | | | | > 1E+06 |
| Ni-63 | | | | > 1E+06 |
| Np-237 | 3.97E+04 | 7.348E+02 | 6.58E-04 | 88,505 |
| Pa-231 | 5.03E-05 | 7.538E+02 | 7.24E-12 | 857,602 |
| Pb-210 | | | | > 15,000 |
| Pd-107 | | | | > 1E+06 |
| Pu-238 | | | | > 15,000 |
| Pu-239 | 3.30E+03 | 7.305E+02 | 6.13E-05 | 87,138 |
| Pu-240 | 4.04E+00 | 7.305E+02 | 7.51E-08 | 86,594 |
| Pu-241 | | | | > 15,000 |
| Pu-242 | 3.47E+04 | 7.305E+02 | 6.11E-04 | 88,010 |
| Pu-244 | 4.08E+04 | 7.305E+02 | 8.09E-04 | 89,658 |
| Ra-226 | | | | > 1E+06 |
| Ra-228 | | | | > 1E+06 |
| Se-79 | 5.36E+00 | 7.300E+02 | 4.55E-09 | 646,818 |
| Si-32 | | | | > 15,000 |
| Sm-151 | | | | > 1E+06 |
| Sn-121m | | | | > 15,000 |
| Sn-126 | 3.61E+03 | 7.300E+02 | 1.14E-05 | 217,448 |
| Sr-90 | | | | > 15,000 |
| Tc-99 | 9.77E+05 | 7.371E+02 | 9.02E-04 | 3937 |
| Th-229 | | | | > 1E+06 |
| Th-230 | | | | > 1E+06 |
| Th-232 | | | | > 1E+06 |
| U-232 | | | | > 15,000 |
| U-233 | 2.03E+04 | 7.356E+02 | 4.24E-04 | 109,473 |
| U-234 | 2.40E+04 | 7.356E+02 | 4.93E-04 | 109,679 |
| U-235 | 3.27E+04 | 7.356E+02 | 6.61E-04 | 131,697 |
| U-236 | 3.26E+04 | 7.356E+02 | 6.31E-04 | 111,119 |
| U-238 | 3.27E+04 | 7.356E+02 | 6.08E-04 | 131,697 |
| Zr-93 | 3.11E+04 | 7.300E+02 | 4.12E-06 | 110,296 |

*For those COPCs for which the Peak Arrival Time is given as > 15,000 (only first run required) or > 1E+06 (half-life requires second run, for longer periods), the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor. See Section 5.3 for a discussion of results.*

**Table H-7. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous COPCs Determined on the Basis of 1 kg/m$^3$ COPC Source**

| COPC | Peak Conc. in Bear Creek $PC'_{creek}$ (mg/L) | Peak Time ** (Year) | Total Equivalent Uptake EU´ (L/year) | Peak Effective Risk $PR'_{eff}$ (ELCR) | Peak Effective Dose $PD'_{eff}$ (mg/kg-day) |
|---|---|---|---|---|---|
| Antimony | 8.56E-02 | 50,302 | 7.332E+02 | | 2.45E-05 |
| Arsenic | 5.62E-02 | 76,518 | 7.434E+02 | 2.47E-05 | 3.86E-05 |
| Barium | 2.97E-02 | 144,680 | 7.372E+02 | | 1.31E-05 |
| Beryllium | | > 1E+06 | | | |
| Boron | 5.20E-01 | 8,356 | 7.474E+02 | | 4.37E-04 |
| Cadmium | 2.18E-02 | 197,112 | 7.426E+02 | | 1.42E-05 |
| Chromium VI | 1.61E-01 | 26,707 | 7.713E+02 | 6.13E-05 | 2.87E-04 |
| Chromium III | 1.61E-01 | 26,707 | 7.787E+02 | | 3.34E-04 |
| Copper | 4.66E-02 | 92,248 | 7.942E+02 | | 1.25E-04 |
| Lead | 1.64E-02 | 262,652 | 7.369E+02 | | 7.04E-06 |
| Manganese | 8.19E-03 | 524,813 | 7.355E+02 | | 3.08E-06 |
| Mercury *** | | > 1E+06 | | | |
| Molybdenum | 8.14E-02 | 52,923 | 7.498E+02 | | 7.61E-05 |
| Nickel | 2.52E-02 | 170,896 | 7.703E+02 | | 4.37E-05 |
| Selenium | 1.08E-01 | 39,815 | 1.312E+03 | | 2.48E-03 |
| Silver | 1.94E-01 | 22,251 | 8.880E+02 | | 1.23E-03 |
| Strontium | 1.20E-01 | 34,511 | 7.941E+02 | | 3.20E-04 |
| Tin | 6.17E-01 | 7,045 | 7.907E+02 | | 1.57E-03 |
| U-233 | 2.03E-02 | 109,369 | 7.371E+02 | | 8.88E-06 |
| U-234 | 2.39E-02 | 109,575 | 7.371E+02 | | 1.05E-05 |
| U-235 | 3.27E-02 | 131,572 | 7.371E+02 | | 1.43E-05 |
| U-236 | 3.26E-02 | 111,014 | 7.371E+02 | | 1.43E-05 |
| U-238 | 3.27E-02 | 131,572 | 7.371E+02 | | 1.43E-05 |
| Vanadium | 1.64E-02 | 262,652 | 7.457E+02 | | 1.27E-05 |
| Zinc | 2.64E-02 | 163,031 | 1.242E+03 | | 5.32E-04 |
| 2,4-D | 1.79E+00 | 774 | 7.328E+02 | | 4.83E-04 |
| 2,4,5-T[Silvex] | | > 1,000 | | | |
| Acenaphthene | | > 1,000 | | | |
| Acenaphthylene | | > 1,000 | | | |
| Acetone | 8.19E+00 | 722 | 7.328E+02 | | 2.21E-03 |
| Acetonitrile | 1.04E+01 | 693 | 7.329E+02 | | 2.84E-03 |
| Acetophenone | 6.60E+00 | 880 | 7.328E+02 | | 1.78E-03 |
| Acrolein | 1.03E+01 | 648 | 7.329E+02 | | 2.82E-03 |
| Acrylonitrile | 1.02E+01 | 704 | 7.328E+02 | 6.36E-04 | 2.75E-03 |
| Aldrin | | > 1,000 | | | |
| Aroclor-1221 | | > 1,000 | | | |
| Aroclor-1232 | | > 1,000 | | | |
| Benzene | | > 1,000 | | | |
| Benzoic Acid | 8.93E+00 | 692 | 7.328E+02 | | 2.41E-03 |

** For COPCs for which Peak Time exceeds 1,000 or 1E+06, COPC does not reach the surface water in a measurable concentration [e.g., for chemical compounds their Peak Time of arrival exceeds 1,000 yr and COPC is degraded] and therefore presents no risk to the receptor. See Section 5.3 for a discussion of results.

*** Mercury sensitivity runs completed; results are discussed in Section 4.4.3.3. No PreWAC limits were obtained.

**Table H-7. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous Contaminants Determined on the Basis of 1 kg/m$^3$ COPC Source (Continued)**

| COPC | Peak Conc. In Bear Creek $PC'_{creek}$ (mg/L) | Peak Time (Year) ** | Total Equivalent Uptake EU′ (L/year) | Peak Effective Risk $PR'_{eff}$ (ELCR) | Peak Effective Dose $PD'_{eff}$ (mg/kg-day) |
|---|---|---|---|---|---|
| Benzyl Alcohol | 8.74E+00 | 688 | 7.328E+02 | | 2.36E-03 |
| Benzidine | | > 1,000 | | | |
| alpha-BHC | | > 1,000 | | | |
| beta-BHC | | > 1,000 | | | |
| delta-BHC | | > 1,000 | | | |
| Bromodichloromethane | 7.96E+00 | 623 | 7.328E+02 | | 4.72E-05 |
| Bromoform | | > 1,000 | | | |
| Bromomethane | 8.89E+00 | 678 | 7.328E+02 | | 8.36E-04 |
| Butylbenzene | | > 1,000 | | | |
| Carbazole | | > 1,000 | | | |
| Carbon disulfide | 3.10E+00 | 913 | 7.328E+02 | | 3.58E-04 |
| Carbon tetrachloride | | > 1,000 | | | |
| Chlordane | | > 1,000 | | | |
| Chlorobenzene | | > 1,000 | | | |
| Chloroform | | > 1,000 | | | |
| Chloromethane [Methyl Chloride] | 8.87E+00 | 679 | 7.328E+02 | | 1.31E-03 |
| o-Chlorotoluene | | > 1,000 | | | |
| m-Cresol | 6.51E+00 | 890 | 7.328E+02 | | 4.72E-05 |
| o-Cresol | | 1,162 | | | |
| p-Cresol | 6.60E+00 | 879 | 7.328E+02 | 1.17E-07 | 1.14E-06 |
| Cumene [Isopropylbenzene] | | > 1,000 | | | |
| Cyanide | | > 1,000 | | | |
| DDD | | > 1,000 | | | |
| DDE | | > 1,000 | | | |
| Di-n-butylphthalate | 1.05E+01 | 688 | 8.061E+02 | 5.36E-05 | 1.49E-03 |
| Dibenz(a,h)anthracene | | > 1,000 | | | |
| Dibenzofuran | | > 1,000 | | | |
| Dibromochloromethane | | > 1,000 | | | |
| 1,2-Dichlorobenzene | | > 1,000 | | | |
| 1,3-Dichlorobenzene | | > 1,000 | | | |
| 1,4-Dichlorobenzene | | > 1,000 | | | |
| 1,2,-cis-Dichloroethylene | | > 1,000 | | | |
| 1,2-trans-Dichloroethylene | 7.06E+00 | 828 | 7.328E+02 | 1.32E-03 | 1.93E-04 |
| Dichlorodifluoromethane | 7.35E-01 | 738 | 7.328E+02 | | 7.64E-04 |
| 1,2-Dichloropropane | 6.55E+00 | 885 | 7.328E+02 | | 1.61E-04 |
| Dieldrin | | > 1,000 | | | |
| Diethylphthalate | | > 1,000 | | | |
| 1,2-Dimethylbenzene | | > 1,000 | | | |
| 2,4-Dimethylphenol | | > 1,000 | | | |
| Dimethylphthalate | 7.12E+00 | 823 | 7.328E+02 | 5.70E-05 | 2.14E-03 |
| 2,4 Dinitrotoluene | 7.09E-01 | 910 | 7.328E+02 | 2.40E-07 | 7.08E-05 |
| 2,6 Dinitrotoluene | 9.24E-01 | 853 | 7.328E+02 | 1.60E-04 | 2.49E-04 |

** For COPCs for which Peak Time exceeds 1,000 or 1E+06, COPC does not reach the surface water in a measurable concentration [e.g., for chemical compounds their Peak Time of arrival exceeds 1,000 yr and COPC is degraded] and therefore presents no risk to the receptor. See Section 5.3 for a discussion of results.

*** Mercury sensitivity runs completed; results are discussed in Section 4.4.3.3. No PreWAC limits were obtained.

**Table H-7. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous Contaminants Determined on the Basis of 1 kg/m$^3$ COPC Source (Continued)**

| COPC | Peak Conc. In Bear Creek $PC'_{creek}$ (mg/L) | Peak Time (Year) ** | Total Equivalent Uptake EU′ (L/year) | Peak Effective Risk $PR'_{eff}$ (ELCR) | Peak Effective Dose $PD'_{eff}$ (mg/kg-day) |
|---|---|---|---|---|---|
| Endosulfan & metabolites | | > 1,000 | | | |
| Endrin | | > 1,000 | | | |
| Endrin Aldehyde | | > 1,000 | | | |
| Endrin Ketone | | > 1,000 | | | |
| Ethylbenzene | | > 1,000 | | | |
| Ethylchloride | 8.05E+00 | 739 | 7.328E+02 | | 2.17E-03 |
| Heptachlor | | > 1,000 | | | |
| Heptachlor Epoxide | | > 1,000 | | | |
| Hexachlorobenzene | | > 1,000 | | | |
| Hexachloroethane | | > 1,000 | | | |
| n-Hexane | | > 1,000 | | | |
| 1-Hexanol | 9.00E+00 | 671 | 7.328E+02 | | 2.43E-03 |
| 2-Hexanone | 9.00E+00 | 671 | 7.328E+02 | | 2.43E-03 |
| Isophorone | | > 1,000 | | | |
| Lindane | | > 1,000 | | | |
| Methanol | 1.04E+01 | 695 | 7.330E+02 | | 2.87E-03 |
| Dichloromethane | | > 1,000 | | | |
| Methylcyclohexane | 3.68E-02 | 589 | 7.329E+02 | | 1.00E-05 |
| Methyl Isobutyl Ketone | 1.02E+01 | 604 | 7.328E+02 | | 2.74E-03 |
| Methyl Methacrylate | 9.30E+00 | 652 | 7.328E+02 | | 2.51E-03 |
| 1-Methyl-4-(1-methylethyl)-benzene | | > 1,000 | | | |
| 2-Methylnapthalene | | > 1,000 | | | |
| (1-Methylpropyl)-benzene | | > 1,000 | | | |
| Naphthalene | | > 1,000 | | | |
| 4-Nitrobenzenamine [4-Nitroaniline] | | > 1,000 | | | |
| Nitrobenzene | 5.49E+00 | 995 | 7.328E+02 | | 1.48E-03 |
| 2-Nitrophenol | | > 1,000 | | | |
| 4-Nitrophenol | | > 1,000 | | | |
| N-nitrosodipropylamine | | > 1,000 | | | |
| N-Nitrosodiphenylamine | | > 1,000 | | | |
| Phenol | | > 1,000 | | | |
| Propylbenzene | | > 1,000 | | | |
| Propylene glycol | 1.04E+01 | 695 | 7.334E+02 | | 3.03E-03 |
| Pyridine | 9.64E+00 | 633 | 7.328E+02 | | 2.60E-03 |
| Styrene | | > 1,000 | | | |
| 1,1,1,2-Tetrachloroethane | | > 1,000 | | | |
| 1,1,2,2-Tetrachloroethane | | > 1,000 | | | |
| Tetrachloroethylene | | > 1,000 | | | |
| 2,3,4,6-Tetrachlorophenol | | > 1,000 | | | |

** For COPCs for which Peak Time exceeds 1,000 or 1E+06, COPC does not reach the surface water in a measurable concentration [e.g., for chemical compounds their Peak Time of arrival exceeds 1,000 yr and COPC is degraded] and therefore presents no risk to the receptor. See Section 5.3 for a discussion of results.

*** Mercury sensitivity runs completed; results are discussed in Section 4.4.3.3. No PreWAC limits were obtained.

**Table H-7. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous Contaminants Determined on the Basis of 1 kg/m$^3$ COPC Source (Continued)**

| COPC | Peak Conc. In Bear Creek $PC'_{creek}$ (mg/L) | Peak Time (Year) ** | Total Equivalent Uptake EU′ (L/year) | Peak Effective Risk $PR'_{eff}$ (ELCR) | Peak Effective Dose $PD'_{eff}$ (mg/kg-day) |
|---|---|---|---|---|---|
| Toluene | | > 1,000 | | | |
| 1,2,4-Trichlorobenzene | | > 1,000 | | | |
| Trichloroethylene | | > 1,000 | | | |
| Trichlorofluoromethane | | > 1,000 | | | |
| 2,4,6-Trichlorophenol | | > 1,000 | | | |
| 1,2,3-Trichloropropane | | > 1,000 | | | |
| Trimethylbenzene [isomers] | | > 1,000 | | | |
| 1,2,4-Trimethylbenzene | | > 1,000 | | | |
| 1,3,5-Trimethylbenzene | | > 1,000 | | | |
| Vinyl Chloride | | > 1,000 | | | |
| Xylene [isomer mix] | | > 1,000 | | | |

** For COPCs for which Peak Time exceeds 1,000 or 1E+06, COPC does not reach the surface water in a measurable concentration [e.g., for chemical compounds their Peak Time of arrival exceeds 1,000 yr and COPC is degraded] and therefore presents no risk to the receptor. See Section 5.3 for a discussion of results.

*** Mercury sensitivity runs completed; results are discussed in Section 4.4.3.3. No PreWAC limits were obtained.

# 5. ANALYTIC PRELIMINARY WASTE ACCEPTANCE CRITERIA

Analytic PreWAC are determined for a future on-site facility based on meeting the RAOs (see Section 2.5). The RAOs set carcinogenic risk goals and non-carcinogenic dose goals for direct protection of human health. Additionally, water resource protection is accomplished as specified in the RAOs through compliance with chemical specific Applicable or Relevant and Appropriate Regulations and/or MCLs in water used as drinking water (well water). The calculations and discussions that follow derive PreWAC that meet these objectives.

## 5.1 CARCINOGENIC PREWAC CALCULATIONS

PreWAC limits are calculated for carcinogenic contaminants (all radioactive COPCs and hazardous COPCs that are carcinogenic) based on the results of PATHRAE-RAD/HAZ modeling. HI PreWAC for hazardous COPCs are calculated as well by PATHRAE-HAZ, and are discussed in Section 5.2. As a reminder, the RAOs for the aggregate radiological and chemical impacts to the hypothetical receptor from all waste disposed in the proposed EMDF are used for development of the analytic PreWAC:

- An ELCR (carcinogenic risk) range of $10^{-4}$ to $10^{-6}$ and an HI $\leq 1$ for the first 1,000 years after closure (all COPCs).
- Carcinogenic risk range of $10^{-4}$ to $10^{-5}$ and HI $\leq 3$ for >1,000 years to peak for radionuclides and hazardous elemental COPCs (most hazardous COPCs that are not elemental [e.g., typically organic compounds] will not persist past 1,000 years in their original form).
- Prevent releases of future-generated CERCLA waste, or waste constituents that do not meet ARARs for environmental media. This is accomplished through compliance with chemical specific ARARs, MCLs in waters that are current or potential sources of drinking water considering site-specific background levels, or risk-based levels for chemicals without ARARs.

### 5.1.1 Carcinogenic Preliminary Waste Acceptance Criteria for Radioactive Contaminants of Potential Concern

The model runs are, as discussed previously, based on an assumed uniform concentration of a single contaminant completely filling the landfill (e.g., 1 Ci/m$^3$). The calculated $PR_{eff}$ (total effective risk due to this single radioactive COPC, results given in Table H-6) thus represents risk at this assumed concentration. A ratio is set up to scale this assumed concentration and risk to the RAO risk goal (set as the mid-point, $10^{-5}$ for contaminants that peak < 1,000 years to allow for deviation in either direction given that these are preliminary findings, thus corresponding to $10^{-4}$ for those that peak after 1,000 years), which allows calculation of the PreWAC limit for each radioactive COPC.

An example calculation for Tc-99 is given here with $PR_{eff}$ equal to 9.02E-04 (from Table H-6). "*X*" would be the calculated PreWAC limit based on $10^{-4}$ ELCR since Tc-99 surface water concentration peaks well after 1,000 years (see Table H-6):

$$\frac{1\,\frac{Ci}{m^3}}{9.02\times10^{-4}\;ELCR} = \frac{X\,\frac{Ci}{m^3}}{10^{-4}\;ELCR}$$

*X* requires conversion to the typical units of pCi/g using an assumed in-place waste density. For this example, *X* is determined to be 0.1109 Ci/m$^3$. Converting based on an in-place waste density of 1,600 kg/m$^3$ along with other unit conversions, the Tc-99 PreWAC limit is calculated as 6.93E+04 pCi/g. PreWAC limits for radionuclide COPCs calculated by this method, based on Table H-6 PATHRAE results, are given in Table H-8.

#### 5.1.1.1 Adjustments to PreWAC Based on MCLs

These PreWAC numbers must then be compared to the specific activity (SA) of the COPC (PreWAC limit cannot physically exceed the SA), and predicted ground water (well water) peak concentrations compared to the MCLs, to arrive at "adjusted" PreWAC limits that meet all RAOs. MCLs are given in 40 Code of Federal Regulations (CFR) 141.66. Radionuclide MCLs are calculated based on DOE Standard-1196-2011 Derived Concentration Standards (DOE 2011). The adjusted PreWAC are given in the last column. If the SA is exceeded, the PreWAC limit is set to the SA. If the MCL is exceeded, the PreWAC is recalculated based on a more restrictive risk goal. As an example, the Am-243 PreWAC limit (contaminant peaks after 1,000 years) is calculated based on a $10^{-4}$ risk goal. However, when the predicted well water peak concentration was compared to the MCL, the MCL was exceeded. Thus the PreWAC limit was recalculated based on a risk goal of $10^{-5}$, resulting in a final PreWAC limit of 3.97E+07 for Am-243, which ensures the ground water peak concentration meets MCLs. A total of 12 COPCs did not require adjustment of PreWAC, the remaining 14 did require adjustments. Highlighted COPCs and PreWAC in Table H-8 indicate those in which the PreWAC were set to the SA or re-calculated to achieve the MCL.

#### 5.1.1.2 Adjustments to PreWAC Based on Isotopic Decay

Radioactive decay chains in which decay products (daughters) have PreWAC limits were analyzed for cases where the parent isotope may require either establishment of a PreWAC limit (if no limit was determined by the fate-transport modeling of that isotope), or a more stringent limit (if the isotope has an initial fate-transport calculated PreWAC limit). The analysis thus assures that decay of a parent will not result in a daughter concentration exceeding its PreWAC limit. Several decay paths were determined to require this analysis including the following parent → daughter pairs:

- Am-241 → Np-237
- Cm-248 → Pu-244
- Pu-240 → U-236
- Pu-239 → U-235
- Cf-249 →Cm-245
- Cm-344→ Pu-240
- Pu-241 → Am-241
- Pu-238 → U-234
- Pu-242 → U-238
- U-238 → U-234

**Table H-8. EMDF Analytic PreWAC for Radionuclides**

| Nuclide COPC | Carcinogenic PreWAC (pCi/g) | | | Nuclide COPC | Carcinogenic PreWAC (pCi/g) | | |
|---|---|---|---|---|---|---|---|
| | Peak ≤ 1,000 Yr | Peak > 1,000 Yr | Adjusted PreWAC* | | Peak ≤ 1,000 Yr | Peak > 1,000 Yr | Adjusted PreWAC* |
| Ac-227 | | ** | | Ni-63 | | ** | |
| Ag-108m | | ** | | Np-237 | | 9.49E+04 | 9.49E+04 |
| Al-26 | | ** | | Pa-231[1] | | 8.63E+12 | 4.7E+10 |
| Am-241[3] | | ** | 4.62E+08 | Pb-210 | | ** | |
| Am-243[2] | | 3.97E+08 | 3.97E+07 | Pd-107 | | ** | |
| Ba-133 | | ** | | Pu-238[3] | | ** | 1.29E+05 |
| Bi-207 | | ** | | Pu-239[2] | | 1.02E+06 | 1.02E+05 |
| C-14 | | 6.37E+03 | 6.37E+03 | Pu-240[2] | | 8.33E+08 | 8.33E+07 |
| Cf-249[3] | | ** | 3.46E+08 | Pu-241[3] | | ** | 4.62E+08 |
| Cf-250 | | ** | | Pu-242[2] | | 1.02E+05 | 1.02E+04 |
| Cf-251[1] | | 6.49E+41 | 1.6E+12 | Pu-244[2] | | 7.73E+04 | 7.73E+03 |
| Cl-36 | | 3.69E+02 | 3.69E+02 | Ra-226 | | ** | |
| Cm-243 | | ** | | Ra-228 | | ** | |
| Cm-244[3] | | ** | 8.47E+07 | Se-79[2] | | 1.37E+10 | 1.37E+09 |
| Cm-245[2] | | 1.41E+08 | 1.41E+07 | Si-32 | | ** | |
| Cm-246[2] | | 3.99E+10 | 3.99E+09 | Sm-151 | | ** | |
| Cm-247[2] | | 1.23E+05 | 1.23E+04 | Sn-121m | | ** | |
| Cm-248[2] | | 3.21E+04 | 3.21E+03 | Sn-126 | | 5.47E+06 | 5.47E+06 |
| Co-60 | | ** | | Sr-90 | | ** | |
| Cs-135 | | ** | | Tc-99 | | 6.93E+04 | 6.93E+04 |
| Cs-137 | | ** | | Th-229 | | ** | |
| Eu-150 | | ** | | Th-230 | | ** | |
| Eu-152 | | ** | | Th-232 | | ** | |
| Eu-154 | | ** | | U-232 | | ** | |
| H-3[1] | 1.68E+26 | | 9.7E+15 | U-233 | | 1.48E+05 | 1.48E+05 |
| I-129 | | 3.39E+02 | 3.39E+02 | U-234 | | 1.27E+05 | 1.27E+05 |
| K-40 | | 1.07E+04 | 1.07E+04 | U-235 | | 9.45E+04 | 9.45E+04 |
| Nb-93m | | ** | | U-236 | | 9.90E+04 | 9.90E+04 |
| Nb-94 | | 6.58E+09 | 6.58E+09 | U-238 | | 1.03E+05 | 1.03E+05 |
| Ni-59 | | ** | | Zr-93[2] | | 1.52E+07 | 1.52E+06 |

* PreWAC in this column are corrected if necessary by (1) setting PreWAC to the SA, if SA was exceeded; (2) to meet MCLs in well water at the hypothetical receptor location through a reduction in the risk goal by a factor of 10; or (3) to account for in-growth of daughter isotopes (isotopic decay).

** Little to no migration of the radionuclide into surface water either because the COPC exhibits a high $K_d$ (e.g., does not leach from soil) or because the half-life is short (e.g., less than 50 years).

[1] These COPCs original PreWAC exceeded the SA. Therefore, the adjusted PreWAC was set equal to the SA.

[2] These COPCs original PreWAC resulted in MCLs being exceeded in well water. The target ELCR was reduced by a factor of 10, resulting in a lower PreWAC limit.

[3] These COPCs have adjusted PreWAC limits that account for isotopic decay.

Table H-9 is a summary of data required for the analysis, and calculated limits to be compared to the parent isotope fate-transport PreWAC limit. The analysis is based on calculating a parent concentration limit assuming 100% of the parent decays to the daughter isotope, if the parent decays a minimum of seven half-lives within 1E+06 years (fractional decay was taken into account if less than seven half-lives pass). If the calculated limit is less than the existing (or unlimited) PreWAC for that parent isotope, the calculated limit will replace the isotope's PreWAC limit. If the calculated limit exceeds the parent isotope's fate-transport PreWAC limit, no further adjustments are necessary.

As a result of these calculations, five isotopes were identified that originally had no PreWAC limit, but, once decayed, challenge the daughter PreWAC limits. Therefore, the parent isotope is assigned an adjusted PreWAC limit. Table H-9 shows the results of these calculations, and the adjusted PreWAC limits are highlighted. These values were also given in Table H-8.

**Table H-9. Isotopic Decay Pairs Considered for Further Adjustments to PreWAC**

| Decay Path Considered | Parent Initial PreWAC (pCi/g) | Daughter PreWAC Limit (pCi/g) | Daughter Specific Activity (Ci/g) | Parent Specific Activity (Ci/g) | Adjusted PreWAC for Parent (pCi/g) |
|---|---|---|---|---|---|
| Am-241 decays to Np-237 | no limit | 9.49E+04 | 7.10E-04 | 3.40E+00 | 4.62E+08 |
| Cm-248* decays to Pu-244 | 3.21E+03 | 7.73E+03 | 1.80E-05 | 4.20E-03 | 2.10E+06 |
| Pu-240 decays to U-236 | 8.33E+07 | 9.90E+04 | 6.50E-05 | 2.30E-01 | 3.56E+08 |
| Pu-239 decays to U-235 | 1.02E+05 | 9.45E+04 | 2.20E-06 | 6.20E-02 | 2.71E+09 |
| Cf-249 decays to Cm-245 | no limit | 1.41E+07 | 1.70E-01 | 4.10E+00 | 3.46E+08 |
| Cm-244 decays to Pu-240 | no limit | 8.33E+07 | 2.30E-01 | 8.10E+01 | 8.47E+07 |
| Pu-241 decays to Am-241 | no limit | 4.62E+08 | 3.40E+00 | 1.00E+02 | 4.62E+08 |
| Pu-238 decays to U-234 | no limit | 1.27E+05 | 6.20E-03 | 1.70E+01 | 1.29E+05 |
| Pu-242* decays to U-238 | 1.02E+04 | 1.03E+05 | 3.40E-07 | 3.90E-03 | 1.20E+05 |
| U-238* decays to U-234 | 1.03E+05 | 1.27E+05 | 6.20E-03 | 3.40E-07 | no limit |

*Parent isotope does not decay more than seven half-lives in the time frame considered (1E+06 year). This is taken into account in calculations.

### 5.1.2 Carcinogenic PreWAC for Hazardous COPCs

PreWAC limits for carcinogenic hazardous COPCs are calculated in the same manner as described above for radioactive COPCs limits. However, in this case *X´* requires conversion to the typical units of mg/kg for a non-radioactive COPC, using the in-place waste density. Acrylonitrile is used as an example (see Table H-7 where the ELCR for this contaminant is listed):

$$\frac{1\,\frac{kg}{m^3}}{6.36\times10^{-4}\;ELCR}=\frac{X'\,\frac{kg}{m^3}}{10^{-5}\;ELCR}$$

*X'* requires conversion to the typical units of mg/kg using an assumed in-place waste density and unit conversions. For this example, *X'* is determined to be 0.01572 kg/m$^3$, and converting based on an in-place waste density of 1,600 kg/m$^3$ along with other unit conversions, the acrylonitrile carcinogenic PreWAC limit is calculated as 9.82 mg/kg. Carcinogenic PreWAC limits for hazardous COPCs calculated by this method, based on Table H-7 PATHRAE results, are given in Table H-10. As with radionuclide PreWAC, hazardous COPC carcinogenic PreWAC are compared to physical limits (e.g., cannot physically exceed 1E+6 mg/kg), and predicted ground water (well) concentrations may not exceed MCLs. In the case of hazardous COPCs whose concentrations in well water (drinking water) exceed MCLs, an adjusted PreWAC is calculated based on meeting the MCL in the ground water (at the well) as opposed to adjusting the HI goal. Table H-10 provides the adjusted PreWAC as well.

## 5.2 HAZARDOUS (HAZARD INDEX) PRELIMINARY WASTE ACCEPTANCE CRITERIA CALCULATIONS

Toxicological effects of hazardous COPCs (HI) are quantified based on allowable daily intake limits. The goal for protecting human health is an HI of 1 for contaminants that peak prior to 1,000 years, and an HI of 3 for those contaminants that peak after 1,000 years (elemental COPCs only). HI PreWAC for hazardous COPCs are determined on this basis, using the same relationships as are setup for carcinogenic PreWAC calculations. Using antimony as an example, the contaminant peaks at >1,000 years (see Table H-7 where a Peak Effective Dose of 2.45E-05 is given; dividing by the reference dose for antimony [4.00E-04] (given in Attachment A) this corresponds to an HI of 16.3). Using the HI results from the modeling based on a C´$_L$ of 1.0 kg/m$^3$ and setting up a ratio to calculate the HI PreWAC based on meeting an HI of 3:

$$\frac{1\,\frac{kg}{m^3}}{16.3\;HI}=\frac{X'\,\frac{kg}{m^3}}{3\;HI}$$

where X´ requires conversion to the typical units of mg/kg using an assumed in-place waste density. For this example, the antimony HI PreWAC is calculated as 3.07E+04 mg/kg. Table H-10 lists the HI PreWAC for all hazardous COPCs. As with radionuclide PreWAC, hazardous HI PreWAC are compared to physical limits (e.g., cannot physically exceed 1E+6 mg/kg), and predicted ground water (well) concentrations may not exceed MCLs (40 CFR 141.61 and 40 CFR 141.62), requiring PreWAC to be back-calculated based on meeting the MCLs in ground water (at the well). The adjusted HI PreWAC are provided in the table.

In this way, the carcinogenic and HI PreWAC that meet target risk goals are calculated for each hazardous contaminant in EMDF based on the PATHRAE-HAZ simulations under the assumption that a single contaminant at an assumed concentration occupies the landfill. For hazardous COPCs, the MCLs are met in the ground water (well water), and this drives the back-calculation of adjusted PreWAC in cases where those MCLs are exceeded. Note that, for those cases that require adjustments to PreWAC to meet MCLs, carcinogenic and HI PreWAC for the COPC are the same.

**Table H-10. EMDF Analytic PreWAC for Hazardous Constituents**

*Key: Yellow = PreWAC adjusted to meet MCLs;*
*Purple = PreWAC exceeds 1E+06 (no limit applied);*
*Green = no peak (COPC does not peak in receptor surface water, in time frame analyzed 1E+06 years)*

| COPC | Carcinogenic and HI PreWAC* | | | | | |
|---|---|---|---|---|---|---|
| | Carcinogenic (mg/kg) ≤ 1000 Yr | HI (mg/kg) ≤ 1000 Yr | Carcinogenic (mg/kg) > 1000 Yr | HI (mg/kg) > 1000 Yr | Adjusted Carcinogenic (mg/kg) | Adjusted HI (mg/kg) |
| Antimony | | | | 3.07E+04 | | 7.82E+03 |
| Arsenic | | | 2.53E+03 | 1.46E+04 | 2.53E+03 | 1.46E+04 |
| Barium | | | | 2.85E+07 | | |
| Beryllium | | | | | | no peak |
| Boron | | | | 8.58E+05 | | 8.58E+05 |
| Cadmium | | | | 6.58E+04 | | 2.56E+04 |
| Chromium VI | | | 1.02E+03 | 1.96E+04 | 1.02E+03 | 1.96E+04 |
| Chromium III | | | | 5.62E+06 | | 6.93E+04 |
| Chromium Total | | | | | | |
| Copper | | | | 6.02E+05 | | 6.02E+05 |
| Lead | | | | 3.73E+05 | | 1.02E+05 |
| Manganese | | | | 8.53E+07 | | |
| Mercury | | | | | | no peak |
| Molybdenum | | | | 1.23E+05 | | 1.23E+05 |
| Nickel | | | | 8.57E+05 | | 4.43E+05 |
| Selenium | | | | 3.77E+03 | | 3.77E+03 |
| Silver | | | | 7.62E+03 | | 1.84E+03 |
| Strontium | | | | 3.51E+06 | | |
| Tin | | | | 7.19E+05 | | 7.19E+05 |
| U-233 | | | | 6.33E+05 | *see RAD | 1.65E+05 |
| U-234 | | | | 5.37E+05 | *see RAD | 1.40E+05 |
| U-235 | | | | 3.93E+05 | *see RAD | 1.02E+05 |
| U-236 | | | | 3.94E+05 | *see RAD | 1.03E+05 |
| U-238 | | | | 3.93E+05 | *see RAD | 1.02E+05 |
| Vanadium | | | | 7.39E+05 | | 7.39E+05 |
| Zinc | | | | 1.06E+06 | | 5.07E+05 |
| 2,4-D | | 1.29E+04 | | | | 4.36E+03 |
| 2,4,5-T[Silvex] | | | | ** | | |
| Acenaphthene | | | | ** | | |
| Acenaphthylene | | | | ** | | |
| Acetone | | 2.55E+05 | | | | 2.55E+05 |
| Acetonitrile | | 1.32E+03 | | | 9.82E+00 | 1.32E+03 |
| Acetophenone | | 3.52E+04 | | | | 3.52E+04 |
| Acrolein | | 1.11E+02 | | | | 6.50E+01 |
| Acrylonitrile | 9.82E+00 | 9.08E+03 | | | 5.58E+00 | 5.58E+00 |
| Aldrin | | | ** | ** | | |
| Aroclor-1221 | | | ** | | | |
| Aroclor-1232 | | | ** | | | |
| Benzene | | | ** | ** | | |
| Benzoic acid | | 1.04E+06 | | | | No limit |
| Benzyl alcohol | | 2.65E+04 | | | | 2.65E+04 |
| Benzidine | | | ** | ** | | |
| alpha-BHC | | | ** | ** | | |

**Table H-10. EMDF Analytic PreWAC for Hazardous Constituents (Continued)**

| COPC | Carcinogenic and HI PreWAC* | | | | | |
|---|---|---|---|---|---|---|
| | Carcinogenic (mg/kg) ≤ 1000 Yr | HI (mg/kg) ≤ 1000 Yr | Carcinogenic (mg/kg) > 1000 Yr | HI (mg/kg) > 1000 Yr | Adjusted Carcinogenic (mg/kg) | Adjusted HI (mg/kg) |
| beta-BHC | | | ** | | | |
| delta-BHC | | | ** | | | |
| Bromodichloromethane | 1.10E+02 | 5.83E+03 | | | 1.10E+02 | 5.83E+03 |
| Bromoform | | | ** | ** | | |
| Bromomethane | | 3.65E+02 | | | | 3.65E+02 |
| Butylbenzene | | | | ** | | |
| Carbazole | | | ** | | | |
| Carbon disulfide | | 7.48E+04 | | | | 7.48E+04 |
| Carbon tetrachloride | | | ** | ** | | |
| Chlordane | | | ** | ** | | |
| Chlorobenzene | | | | ** | | |
| Chloroform | | | ** | ** | | |
| Chloromethane [Methyl chloride] | 4.69E+02 | | | | 4.69E+02 | |
| o-Chlorotoluene | | | | ** | | |
| m-Cresol | | 1.78E+04 | | | | 1.78E+04 |
| o-Cresol | | | | ** | | |
| p-Cresol | | 3.52E+04 | | | | 3.52E+04 |
| Cumene [Isopropylbenzene] | | | | ** | | |
| Cyanide | | | | ** | | |
| DDD | | | ** | | | |
| DDE | | | ** | | | |
| Di-n-butylphthalate | | 1.90E+03 | | | | 1.90E+03 |
| Dibenz(a,h)anthracene | | | | | | |
| Dibenzofuran | | | | ** | | |
| Dibromochloromethane | | | ** | ** | | |
| 1,2-Dichlorobenzene | | | | ** | | |
| 1,3-Dichlorobenzene | | | | ** | | |
| 1,4-Dichlorobenzene | | | ** | ** | | |
| 1,2,-cis-Dichloroethylene | | | | ** | | |
| 1,2-trans-Dichloroethylene | | 6.55E+03 | | | | 1.58E+03 |
| Dichlorodifluoromethane | | 6.30E+05 | | | | 6.30E+05 |
| 1,2-Dichloropropane | 2.29E+02 | 3.18E+04 | | | 8.52E+01 | 8.52E+01 |
| Dieldrin | | | ** | ** | | |
| Diethylphthalate | | | | ** | | |
| 1,2-Dimethylbenzene | | | | ** | | |
| 2,4-Dimethylphenol | | | | ** | | |
| Dimethylphthalate | | 3.26E+06 | | | | |
| 2,4 Dinitrotoluene | 2.46E+02 | 6.55E+03 | | | 1.73E+02 | 1.73E+02 |
| 2,6 Dinitrotoluene | 3.90E+01 | 1.00E+04 | | | | |
| Endosulfan plus metabolites | | | | ** | | |
| Endrin | | | | ** | | |
| Endrin aldehyde | | | | ** | | |
| Endrin ketone | | | | ** | | |
| Ethylbenzene | | | ** | ** | | |
| Ethylchloride | | | | | | |
| Heptachlor | | | ** | ** | | |
| Heptachlor epoxide | | | ** | ** | | |
| Hexachlorobenzene | | | ** | ** | | |

**Table H-10. EMDF Analytic PreWAC for Hazardous Constituents (Continued)**

| COPC | Carcinogenic and HI PreWAC* | | | | | |
|---|---|---|---|---|---|---|
| | Carcinogenic (mg/kg) ≤ 1000 Yr | HI (mg/kg) ≤ 1000 Yr | Carcinogenic (mg/kg) > 1000 Yr | HI (mg/kg) > 1000 Yr | Adjusted Carcinogenic (mg/kg) | Adjusted HI (mg/kg) |
| Hexachloroethane | | | ** | ** | | |
| n-Hexane | | | | ** | | |
| 1-Hexanol | | 1.03E+04 | | | | 1.03E+04 |
| 2-Hexanone | | 1.29E+03 | | | | 1.29E+03 |
| Isophorone | | | ** | ** | | |
| Lindane | | | ** | ** | | |
| Methanol | | 4.35E+05 | | | | 4.35E+05 |
| Methylene Chloride | | | | | | |
| Methylcyclohexane | | 3.75E+06 | | | | No limit |
| Methyl Isobutyl Ketone | | 1.82E+04 | | | | 1.82E+04 |
| Methyl Methacrylate | | 3.49E+05 | | | | 3.49E+05 |
| 1-Methyl-4-(1-methylethyl)-benzene | | | | ** | | |
| 2-Methylnapthalene | | | | ** | | |
| (1-Methylpropyl)benzene | | | | ** | | |
| Naphthalene | | | | ** | | |
| 4-Nitrobenzenamine [4-Nitroaniline] | | | ** | ** | | |
| Nitrobenzene | | 8.47E+02 | | | | 3.46E+02 |
| 2-Nitrophenol | | | | ** | | |
| 4-Nitrophenol | | | | ** | | |
| N-nitroso-di-n-propylamine | | | ** | | | |
| N-Nitrosodiphenylamine | | | ** | | | |
| Phenol | | | | ** | | |
| Propylbenzene | | | | ** | | |
| Propylene glycol | | 4.12E+06 | | | | No limit |
| Pyridine | | 2.40E+02 | | | | 2.40E+02 |
| Styrene | | | | ** | | |
| 1,1,1,2-Tetrachloroethane | | | ** | ** | | |
| 1,1,2,2-Tetrachloroethane | | | ** | ** | | |
| Tetrachloroethene | | | ** | ** | | |
| 2,3,4,6-Tetrachlorophenol | | | | ** | | |
| Toluene | | | | ** | | |
| 1,2,4-Trichlorobenzene | | | ** | ** | | |
| Trichloroethene | | | ** | ** | | |
| Trichlorofluoromethane | | | | ** | | |
| 2,4,6-Trichlorophenol | | | ** | ** | | |
| 1,2,3-Trichloropropane | | | ** | ** | | |
| Trimethylbenzene [isomer mix] | | | | | | |
| 1,2,4-Trimethylbenzene | | | | | | |
| 1,3,5-Trimethylbenzene | | | | ** | | |
| Vinyl Chloride | | | ** | ** | | |
| Xylene [mixture of isomers] | | | | ** | | |

*Carcinogenic and HI PreWAC for hazardous organic COPCs are calculated for those contaminants that peak at the receptor surface water location before 1,000 years. Those that peak after 1,000 years (denoted by **) are not reported. For COPCs that did not meet MCLs in ground water (well water) at the fate-transport calculated PreWAC, the PreWAC were back-calculated and adjusted (denoted by shaded cells) based on meeting MCLs.

## 5.3 DISCUSSION OF PREWAC RESULTS

Analytic WAC limits represent the maximum allowable concentration of a single contaminant within the landfill as a whole. The PreWAC are developed based on individual contaminants occupying the landfill, and therefore wastes that have multiple contaminants must have the SOF rule applied to determine their acceptability. The application of the SOF to individual waste streams or the landfill as a whole is beyond the scope of the RI/FS, but will be addressed in a future primary document, the WAC Attainment Plan. For purposes of this RI/FS, the application of the PreWAC is to the landfill waste upon closure. The final analytic WAC, along with other physical, administrative, and ASA-derived WAC, will dictate the acceptance of waste into the landfill. Based on this preliminary analysis of only the analytic PreWAC, the on-site disposal facility can accept a majority of the anticipated waste without resulting in unacceptable risk.

A 1,000 year compliance period is modeled, based on requirements in DOE M 435.1 (DOE 1999b). This time is selected to encompass the processes and migration of radionuclides most likely to contribute to the risk/dose to a receptor. Longer times of performance are not used to assess compliance because of the inherently large uncertainties in extrapolating such calculations over long time frames. That said, uncertainty/sensitivity analyses appropriately compel modeling of long-lived isotopes out to peak concentrations. In this case, the model is run for much longer periods of time, with an increased time step. In demonstrating compliance with risk goals, CERCLA does not specify a period of compliance to be adhered to, so the 1,000 year period is adopted for hazardous COPCs as well. Hazardous compounds are not modeled past 1,000 years, due to their expected degradation in the environment well within that 1,000-year time frame. Hazardous elements/metals (e.g., silver, mercury) are modeled to the maximum impact on the receptor (e.g., their peak concentration), but with goals that are adjusted to account for the uncertainties in modeling these long time frames (e.g., the HI goal is adjusted to 3 for time exceeding 1,000 years).

An original extensive list of radionuclides (see Attachment A) was considered as COPCs, and those isotopes with half-lives under five years were removed from consideration since during the course of landfill operation and shortly after closure they would undergo decay and result in insignificant risk to a receptor; these isotopes were not modeled. Several other isotopes were removed from consideration because there is no information that indicates a source of that isotope in the future waste. This left a list of 60 isotopes to be modeled. Modeling resulted in the following conclusions:

- Isotopes with half-lives up to about 500 years, regardless of the $K_d$ [mL/g], result in insignificant concentrations at receptor locations, as demonstrated by modeling results. This group of isotopes includes, most notably, Sr-90 and Cs-137 (expected to be present in future EMDF waste), among 24 others. See Figures H-21 and H-22 that show the relative contaminant decrease in concentration in the landfill itself, due largely to radioactive decay of the contaminants as opposed to their leaching/mobility. Figure H-22 also shows decay-only curves for isotopes illustrated, showing the relatively large decrease in the landfill due to decay, and relatively small decrease due to leaching. The Sr-90 decay-only curve is illustrated in Figure H-21 as well.
- A number of isotopes that did not result in significant risk to the receptor (e.g., did not display a peak concentration in the time frame up to 1,000,000 years) included those with significantly high $K_d$s (e.g., above 2000 mL/g) and relatively long half-lives; eight isotopes fit this category (see Figure H-23). Figure H-24 illustrates that a high Kd results in very limited mobility; reduction of the COPC in the landfill (in this case, Ni-59) is due mostly to the radioactive decay of the contaminant.

- The remaining 26 isotopes include highly mobile COPCs with longer half-lives or moderately mobile COPCs with shorter to moderate half-lives. These COPCs were determined to pose a risk to the receptor such that analytical PreWAC limits were defined (as given in Table H-8). Figure H-25 illustrates the difference in the decay-only curve versus relative concentration in the landfill due to decay and leaching for Tc-99, which is indicative of COPCs with PreWAC.

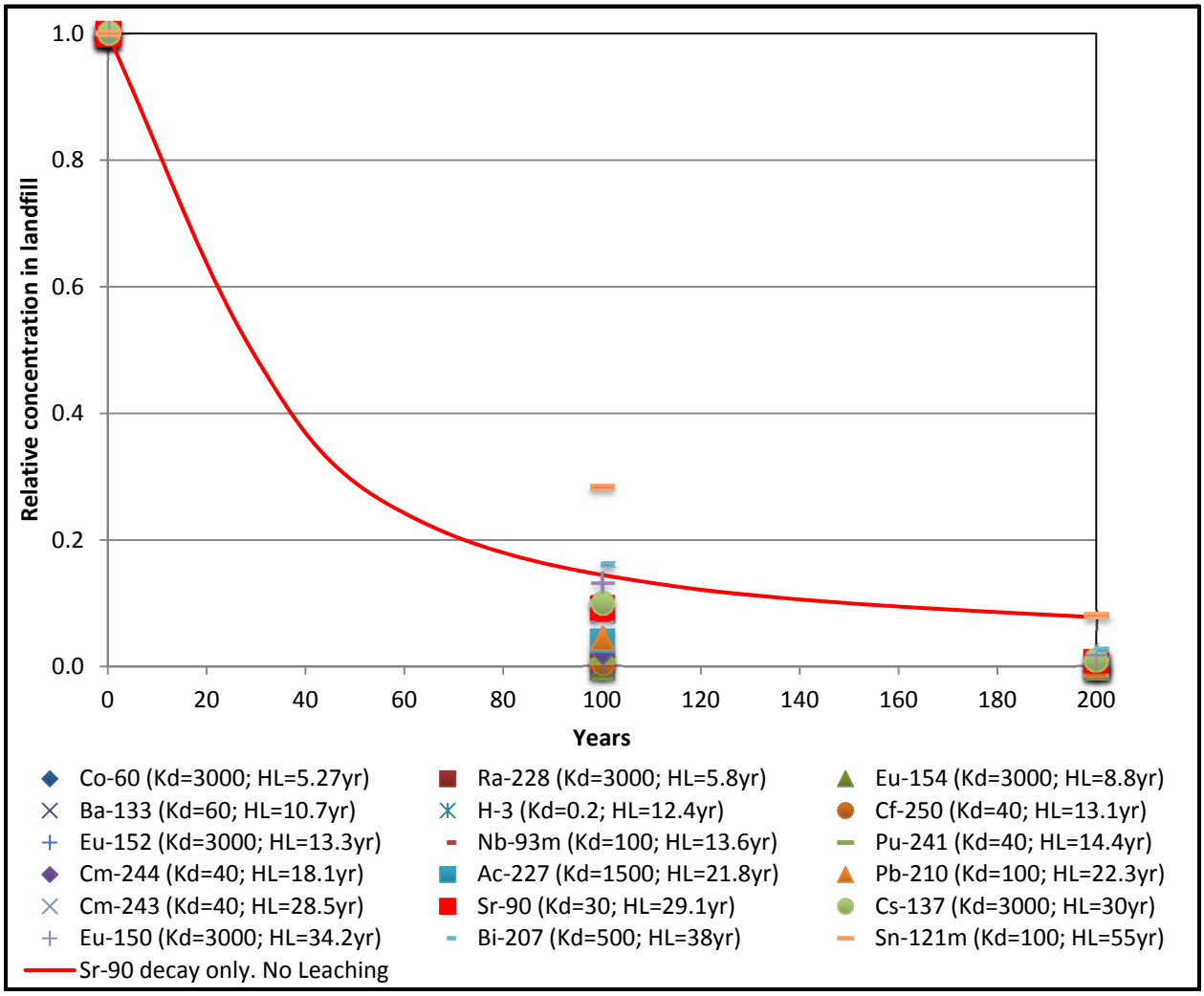
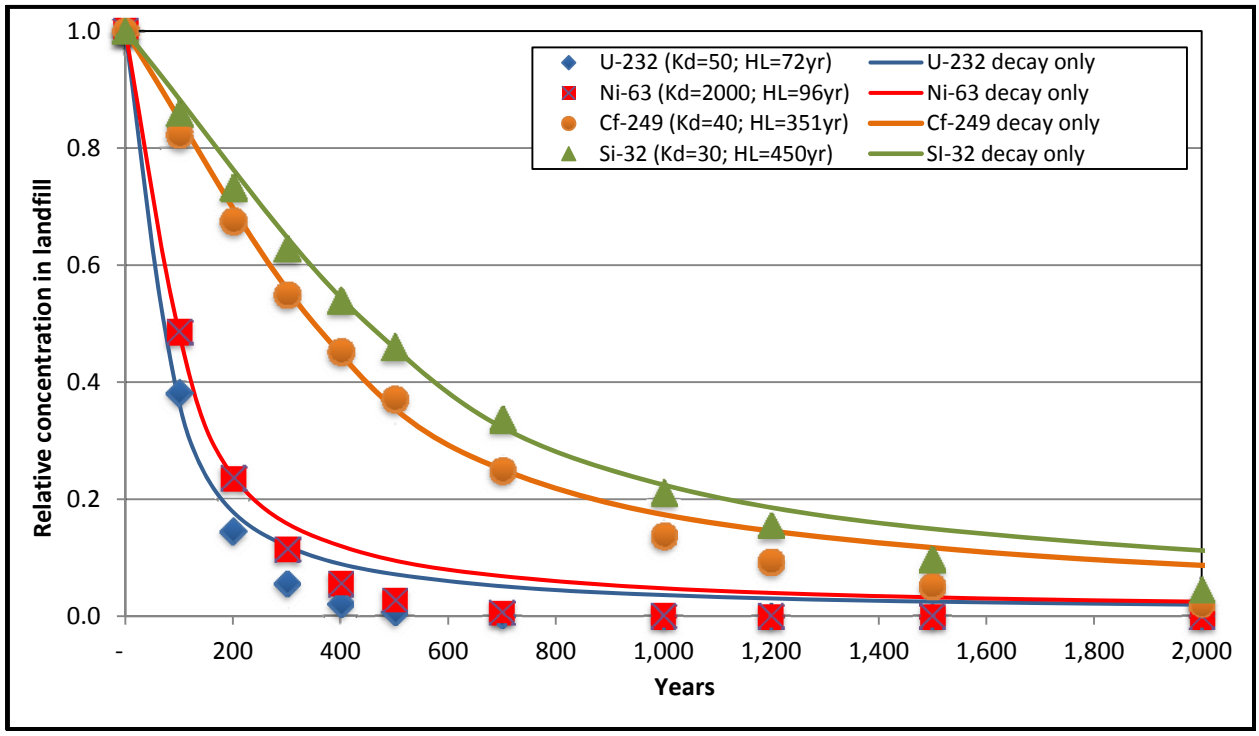



**Figure H-21. Relative Concentration in Landfill of Radioactive COPCs with Half-lives under 55 Years**




*Differences in isotope decay curves vs data points, which represent decay and leaching of isotope, illustrate how these shorter half-lives account for the majority of the decrease of isotope concentration in the landfill.*

**Figure H-22. Relative Concentration in Landfill of Radioactive COPCs with Half-lives under 500 Years**

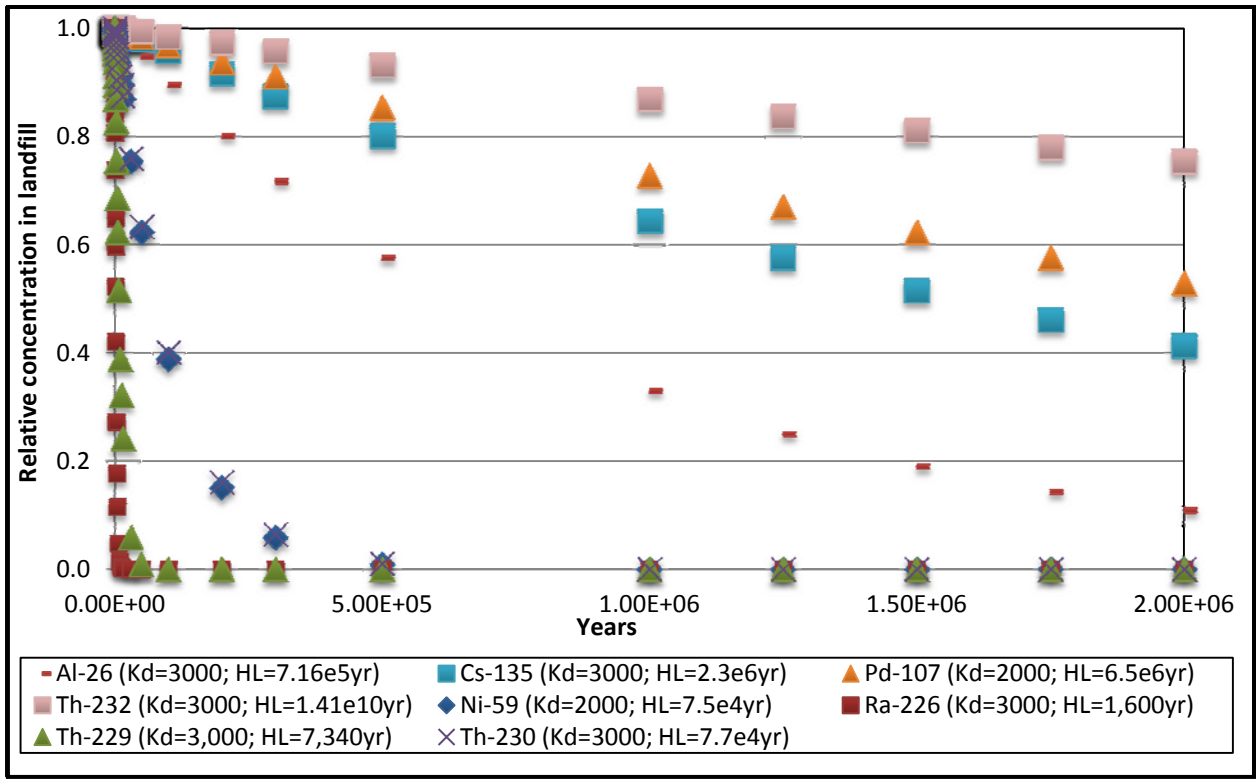
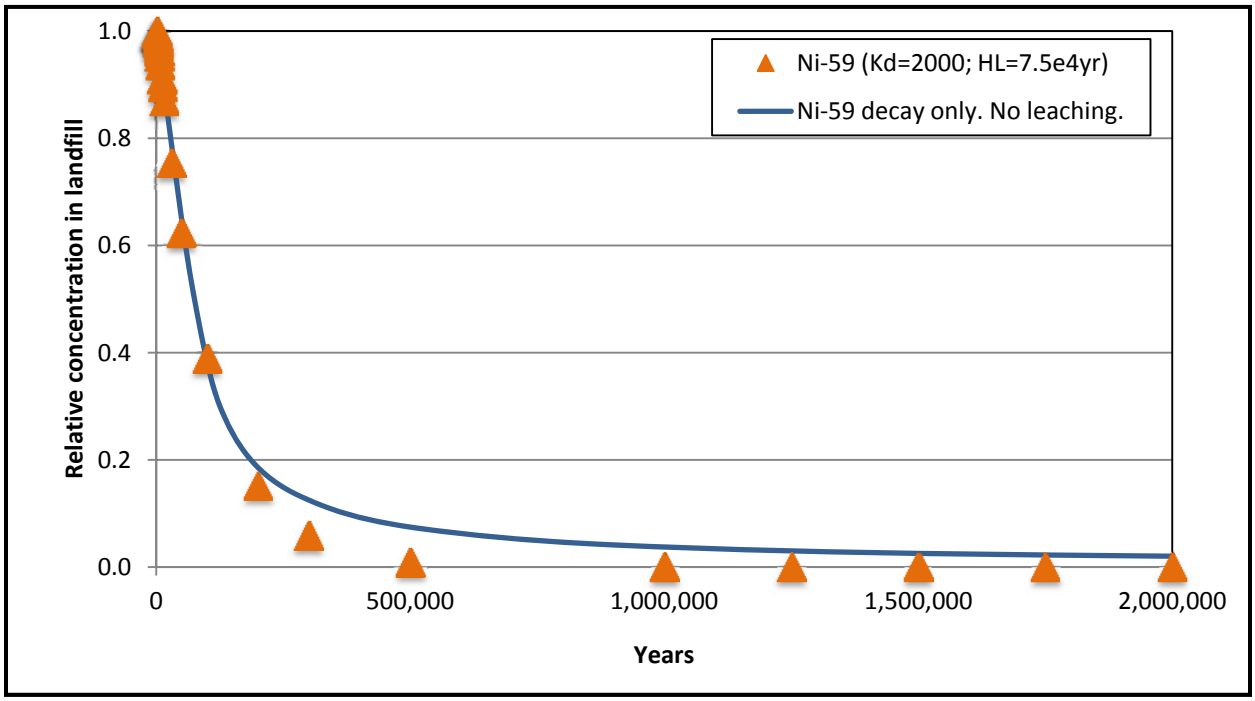



**Figure H-23. Relative Concentration in Landfill of Radioactive COPCs with High Partition Coefficients**




*Difference in curve vs data points accounts for leaching of Ni-59 from the landfill. This illustrates how relatively little leaching is seen for a COPC with a high $K_d$.*

**Figure H-24. Relative Concentration of Ni-59 in Landfill due to Decay+Leaching versus Decay Only**

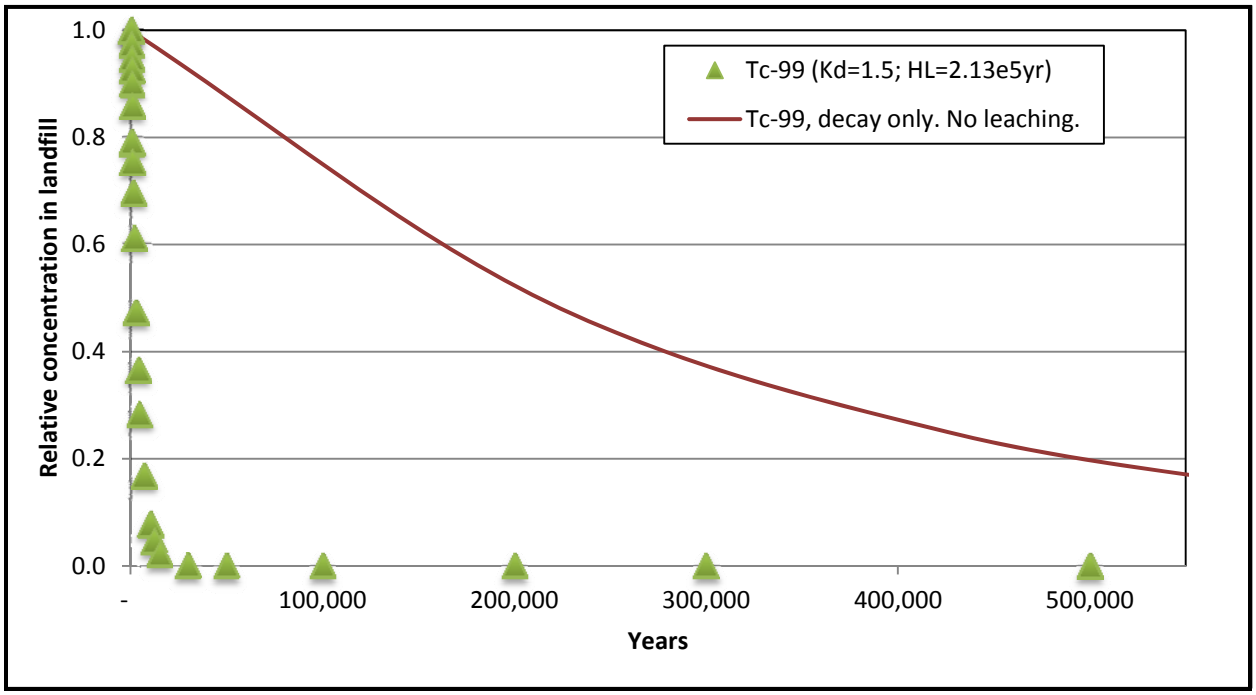



**Figure H-25. Relative Concentration of Tc-99 in Landfill due to Decay+Leaching versus Decay Only**

The analytic PreWAC limits calculated for radioactive constituents were given in Table H-8. Many radionuclides modeled, as noted in the table, did not result in significant risk and thus a defined limit, either because of their lack of mobility in the environment (a result of relatively high $K_d$), and/or because of their rapid decay (a result of a short half-life). Beyond the fate and transport modeling for individual COPCs that set PreWAC limits, further analyses (comparison to SAs, MCLs, and isotopic decay) were carried out that resulted in adjustments to many PreWAC limits (to result in limit reductions only), as explained in Sections 5.1.1.1 and 5.1.1.2.

Several conservative assumptions were made for PreWAC development. Those conservative assumptions provide a defense-in-depth approach in the modeling, and are summarized here:

- Isotopes are modeled to peak. Modeling is not truncated at 1,000 years. Many isotopes' peak time of arrival at the receptor are tens of thousands of years out.
- Cap and liner geosynthetics are assumed to fully function for only 100 years. This is conservative according to literature sources (Rowe, et al. 2009, 2005), which indicate lifetimes over 500 years may be expected for comparable environments (e.g., depth of overburden).
- A constant leaching source is assumed for ground water modeling. This is conservative since a depleting source would result ultimately in lower concentrations of contaminants.
- A constant, average and unchanging footprint is assumed for the landfill in fate and transport modeling with a uniform depleting source (note this is different from the constant leaching source assumed for the ground water modeling). Realistically, the contaminant-contributing footprint of the landfill will shrink over time, as the outer edges of the landfill (source) become depleted more quickly (less source due to shape of landfill) resulting in a decreasing footprint available for leaching.
- Partition coefficients in the saturated zone are assumed to be a factor of 10 lower than the partition coefficients in the vadose and waste zones.
- All waste is assumed to be soil or a soil-like matrix with one $K_d$ value for each radiological and chemical constituent within the waste (see Section 5.1). For concrete and process equipment, the effective leach rate that the material actually exhibits can be lower than indicated by the $K_d$ value since contaminant release occurs only at the surface by direct contact with percolating water due to the lack of porosity of the waste form. Use of a soil-like waste form to represent all waste forms is a conservative assumption in that it assumes all the waste is uniformly distributed and available to leaching as soon as cell performance evaluation begins.

There are uncertainties in the PreWAC analysis due to data gaps in site-specific information and the conceptual stage of the disposal facility design at the proposed EMDF site; however, the numerous conservative assumptions off-set these uncertainties. Furthermore, simplifying assumptions such as the use of a porous ground water flow model, introduce uncertainty. It is recognized that the scale of the model allows this simplification, due to the overall dimensions of the modeled area. Phase I characterization has allowed confirmation of the assumed high ground water tables used in the conceptual design. However, as the site selection and design process proceeds, additional site-specific data obtained through further site investigation and hydrogeological/ geotechnical analyses, as well as engineering design changes (e.g., disposal facility location, excavation depth, configuration, depth to water from the bottom of the waste, and waste thickness) can be used to optimize the disposal facility design for the actual site conditions, better define input parameters, and reduce uncertainties. Similar to the EMWMF design process, any additional data and design changes that could significantly impact the PreWAC analyses would be re-evaluated to confirm that the EMDF WAC is still protective for radionuclide and chemical constituents.

## 5.4 COMPARISON TO ENVIORNMENTAL MANAGEMENT WASTE MANAGEMENT FACILITY ANALYTIC WASTE ACCEPTANCE CRITERIA

Table H-11 compares the analytic PreWAC developed for EMDF with the EMWMF analytic WAC. As shown in the table, the analytic PreWAC for EMDF are generally 10 to 100 times higher than the analytic WAC for EMWMF. However, many more isotopes are assigned PreWAC for the proposed EMDF compared to the EMWMF analytic WAC.

The higher analytic PreWAC for the EMDF relative to EMWMF are mainly the result of one significant difference – the distance from the disposal cell to the receptor location and thus the $DF_{well}$. The EMWMF analytic PreWAC were developed based on an initial conceptual design of a cell located closer to Bear Creek than the actual constructed footprint. The actual EMWMF facility was constructed farther upslope on Pine Ridge at a greater distance from Bear Creek and the hypothetical receptor near NT-5 (see Figure H-26); however, PreWAC calculated for EMWMF based on the original distance were not re-calculated based on a final, revised distance to the receptor, and thus they remain quite restrictive. The distance between the original EMWMF cell conceptual design and the hypothetical receptor location used to develop the EMWMF PreWAC is significantly shorter than the distance between the as-built EMWMF and the hypothetical receptor location, yet the final analytical WAC for the EMWMF were not recalculated, but were left at the conservatively lower limits originally determined. Minor differences in conceptual design, site-specific data (water table depth, creek flow rates), and contaminant constants (e.g., slope factors) also contribute to differences in EMDF PreWAC compared to EMWMF analytic WAC.

The shorter distance from the EMWMF conceptual design cell to the hypothetical receptor location results in higher concentrations in the creek. It also greatly impacts the ground water DF. For example, the EMWMF analytic WAC was developed using a $DF_{well}$ of 0.0027. Subsequent analyses using the revised EMWMF design and as-built construction yielded a $DF_{well}$ in the $10^{-4}$ range (0.00057 for the six-cell design). This lower $DF_{well}$ resulted in lower risks and doses that would support a lower analytic WAC than the approved EMWMF analytic WAC; however, no request to lower the approved EWMMF WAC was made to reflect the design change.

For comparison, the $DF_{well}$ for the proposed EMDF is 0.000015 or 180 times lower than the $DF_{well}$ used to develop the EMWMF WAC. As shown in Section 5.2, the well concentration ($C_{well}$) is directly proportional to the DF and indirectly proportional to the analytic PreWAC value. As a result, a lower $DF_{well}$ results in a lower $C_{well}$ and a higher analytic PreWAC value.

PreWAC calculated for the proposed EMDF are based on a receptor scenario that places the receptor at a greater distance from the landfill than EMWMF analytic WAC are based on, resulting in less stringent PreWAC for those COPCs that have analytic WAC limits for EMWMF. However, many isotopes now have limits for the proposed EMDF that were not assigned analytic WAC limits for EMWMF, as demonstrated in this document.

Another contributing factor to a higher PreWAC is the underdrain system and the impact of backfilled existing channels within the proposed EMDF footprint. Disposal cell design requires that the bottom of the disposal cell liner system and top of the water table be separated by a hydraulic break, which must function even during wet periods. Lessons learned from the EMWMF construction and operation (BJC 2003) guided the conceptual design of the EMDF underdrain.

A hydraulic break will be created by excavating and filling the major existing stream channels within the landfill footprint with highly conductive gravel/cobble sized material. A thinner blanket drain would extend beyond this trench drain to conduct high water seepage to the trench drain. These backfilled existing channels would behave hydraulically as underdrains to allow shallow ground water to move laterally to discharge to surface water outside the landfill. The underdrain system should also help maintain a lower water table under much of the landfill. The underdrain system would act as a preferred

migration pathway for contaminant movement under some conditions. While contaminant leachate could percolate into the ground water system and migrate downgradient in the ground water zone, some leachate would be captured in the underdrain system and discharge into the surface water, resulting in lower contaminant concentrations in ground water and a higher PreWAC.

The analysis completed in this RI/FS demonstrates that an analytic PreWAC for the EMDF that is higher than the EMWMF WAC would meet applicable risk criteria and be protective. Based on these results, it can be concluded that most future CERCLA waste to be generated after EMWMF reaches maximum capacity would be able to be disposed at the proposed EMDF. It is acknowledged that the analytic PreWAC identified in this RI/FS are a preliminary data set provided to show viability of land disposal at the proposed site, and is subject to change based on final design and further analyses. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC (administrative, analytic, ASA-derived, and physical) for a new facility will require approval by all FFA parties and will be documented in the future primary document, WAC Attainment Plan.

**Table H-11. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC**

| COPC | Carcinogenic (pCi/g or mg/mg) | | HI PreWAC (pCi/g or mg/kg) | |
|---|---|---|---|---|
| | EMWMF WAC | Proposed EMDF PreWAC | EMWMF WAC | Proposed EMDF PreWAC |
| **RADIONUCLIDES, [pCi/g]** | | | | |
| Ac-227 | | | Not applicable | |
| Ag-108m | | | | |
| Al-26 | | | | |
| Am-241 | 2.00E+21 | 4.62E+08 | | |
| Am-243 | | 3.97E+07 | | |
| Ba-133 | | | | |
| Bi-207 | | | | |
| C-14 | 1.65E+02 | 6.37E+03 | | |
| Cf-249 | | 3.46E+08 | | |
| Cf-250 | | | | |
| Cf-251 | | 1.6E+12 | | |
| Cl-36 | | 3.69E+02 | | |
| Cm-243 | | | | |
| Cm-244 | | 8.47E+07 | | |
| Cm-245 | | 1.41E+07 | | |
| Cm-246 | | 3.99E+09 | | |
| Cm-247 | | 1.23E+04 | | |
| Cm-248 | | 3.21E+03 | | |
| Co-60 | | | | |
| Cs-135 | | | | |
| Cs-137 | | | | |
| Eu-150 | | | | |
| Eu-152 | | | | |
| Eu-154 | | | | |
| H-3 | 1.50E+05 | 9.7E+15 | | |
| I-129 | 1.30E+01 | 3.39E+02 | | |
| K-40 | | 1.07E+04 | | |
| Nb-93m | | | | |
| Nb-94 | | 6.58E+09 | | |
| Ni-59 | | | | |
| Ni-63 | | | | |
| Np-237 | 3.20E+02 | 9.49E+04 | | |
| Pa-231 | | 4.7E+10 | | |
| Pb-210 | | | | |
| Pd-107 | | | | |
| Pu-238 | | 1.29E+05 | | |
| Pu-239 | 7.20E+02 | 1.02E+05 | | |

**Table H-11. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)**

| COPC | Carcinogenic (pCi/g - rads or mg/mg - haz) | | HI PreWAC (pCi/g - rads or mg/kg - haz) | |
|---|---|---|---|---|
| | EMWMF WAC | Proposed EMDF PreWAC | EMWMF WAC | Proposed EMDF PreWAC |
| **RADIONUCLIDES (continued), [pCi/g]** | | | | |
| Pu-240 | 5.80E+03 | 8.33E+07 | Not applicable | |
| Pu-241 | | 4.62E+08 | | |
| Pu-242 | | 1.02E+04 | | |
| Pu-244 | | 7.73E+03 | | |
| Ra-226 | | | | |
| Ra-228 | | | | |
| Se-79 | | 1.37E+09 | | |
| Si-32 | | | | |
| Sm-151 | | | | |
| Sn-121m | | | | |
| Sn-126 | | 5.47E+06 | | |
| Sr-90 | | | | |
| Tc-99 | 1.72E+02 | 6.93E+04 | | |
| Th-229 | | | | |
| Th-230 | | | | |
| Th-232 | | | | |
| U-232 | | | | |
| U-233 | 1.70E+03 | 1.48E+05 | 4.50E+07 | 1.60E+09 |
| U-234 | 1.70E+03 | 1.27E+05 | 2.80E+07 | 8.69E+08 |
| U-235 | 1.50E+03 | 9.45E+04 | 9.50E+03 | 2.25E+05 |
| U-236 | 1.70E+03 | 9.90E+04 | 2.80E+05 | 6.68E+06 |
| U-238 | 1.20E+03 | 1.03E+05 | 1.50E+03 | 3.48E+04 |
| Zr-93 | | 1.52E+06 | | |
| **INORGANICS – ELEMENTS, [mg/kg]** | | | | |
| Antimony | | | 1.60E+02 | 7.82E+03 |
| Arsenic | | 2.53E+03 | | 1.46E+04 |
| Barium | | | 1.50E+05 | |
| Beryllium | | | | no peak |
| Boron | | | | 8.58E+05 |
| Cadmium | | | | 2.56E+04 |
| Chromium VI | | 1.02E+03 | | 1.96E+04 |
| Chromium III | | | | 6.93E+04 |
| Chromium (Total) | | | 1.40E+05 | |
| Copper | | | | 6.02E+05 |
| Lead | | | 1.50E+03 | 1.02E+05 |
| Manganese | | | | |
| Mercury | | | | no peak |

**Table H-11. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)**

| COPC | Carcinogenic (pCi/g - rads or mg/mg - haz) | | HI PreWAC (pCi/g - rads or mg/kg - haz) | |
|---|---|---|---|---|
| | EMWMF WAC | Proposed EMDF PreWAC | EMWMF WAC | Proposed EMDF PreWAC |
| Molybdenum | | | | 1.23E+05 |
| Nickel | | | | 4.43E+05 |
| **INORGANICS – ELEMENTS (continued), [mg/kg]** | | | | |
| Selenium | | | 1.60E+03 | 3.77E+03 |
| Silver | | | | 1.84E+03 |
| Strontium | | | 3.00E+05 | |
| Tin | | | 2.20E+03 | 7.19E+05 |
| Vanadium | | | 2.50E+04 | 7.39E+05 |
| Zinc | | | | 5.07E+05 |
| **ORGANICS, [mg/kg]** | | | | |
| 2,4-D | | | | 4.36E+03 |
| 2,4,5-T[Silvex] | | | | |
| Acenaphthene | | | 3.90E+05 | |
| Acenaphthylene | | | | |
| Acetone | | | 2.70E+02 | 2.55E+05 |
| Acetonitrile | | 9.82E+00 | | 1.32E+03 |
| Acetophenone | | | | 3.52E+04 |
| Acrolein | | | | 6.50E+01 |
| Acrylonitrile | | 5.58E+00 | | 5.58E+00 |
| Aldrin | | | | |
| Aroclor-1221 | | | | |
| Aroclor-1232 | | | | |
| Benzene | 2.00E+02 | | | |
| Benzoic Acid | | | | |
| Benzyl Alcohol | | | | 2.65E+04 |
| Benzidine | | | | |
| alpha-BHC | | | | |
| beta-BHC | | | | |
| delta-BHC | | | | |
| Bromodichloromethane | | 1.10E+02 | | 5.83E+03 |
| Bromoform | | | | |
| Bromomethane | | | | 3.65E+02 |
| Butylbenzene | | | | |
| Carbazole | | | | |
| Carbon disulfide | | | | 7.48E+04 |
| Carbon tetrachloride | 5.60E+01 | | 6.60E+01 | |
| Chlordane | | | | |
| Chlorobenzene | | | | |
| Chloroform | 4.00E+01 | | 1.00E+02 | |
| Chloromethane [Methyl Chloride] | | 4.69E+02 | | |
| o-Chlorotoluene | | | | |
| m-Cresol | | | | 1.78E+04 |

**Table H-11. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)**

| COPC | Carcinogenic (pCi/g - rads or mg/mg - haz) | | HI PreWAC (pCi/g - rads or mg/kg - haz) | |
|---|---|---|---|---|
| | EMWMF WAC | Proposed EMDF PreWAC | EMWMF WAC | Proposed EMDF PreWAC |
| o-Cresol | | | | |
| p-Cresol | | | | 3.52E+04 |
| **ORGANICS (continued), [mg/kg]** | | | | |
| Cumene [Isopropylbenzene] | | | | |
| Cyanide | | | | |
| DDD | | | | |
| DDE | | | | |
| Di-n-butylphthalate | | | 1.90E+02 | |
| Dibromochloromethane | | | | |
| 1,2-Dichlorobenzene | | | | |
| 1,3-Dichlorobenzene | | | | |
| 1,4-Dichlorobenzene | | | | |
| 1,2,-cis-Dichloroethylene | | | | |
| 1,2-trans-Dichloroethylene | | | | 1.58E+03 |
| Dichlorodifluoromethane | | | | 6.30E+05 |
| 1,2-Dichloropropane | | 8.52E+01 | | 8.52E+01 |
| Dieldrin | 7.10E+00 | | 6.00E+01 | |
| Diethylphthalate | | | | |
| 1,2-Dimethylbenzene | | | | |
| 2,4-Dimethylphenol | | | | |
| Dimethylphthalate | | | | |
| 2,4 Dinitrotoluene | | 1.73E+02 | | 1.73E+02 |
| 2,6 Dinitrotoluene | | | | |
| Endosulfan plus metabolites | | | | |
| Endrin | | | | |
| Endrin Aldehyde | | | | |
| Endrin Ketone | | | | |
| Ethylbenzene | | | | |
| Ethylchloride | | | | |
| Heptachlor | | | | |
| Heptachlor epoxide | | | | |
| Hexachlorobenzene | | | | |
| Hexachloroethane | | | | |
| n-Hexane | | | | |
| 1-Hexanol | | | | 1.03E+04 |
| 2-Hexanone | | | | 1.29E+03 |
| Isophorone | 6.10E+03 | | 1.50E+04 | |
| Lindane | | | | |
| Methanol | | | | 4.35E+05 |
| Methylene Chloride | | | | |
| Methylcyclohexane | | | | |
| Methyl Isobutyl Ketone | | | | 1.82E+04 |
| Methyl Methacrylate | | | | 3.49E+05 |

**Table H-11. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)**

| COPC | Carcinogenic (pCi/g - rads or mg/mg - haz) | | HI PreWAC (pCi/g - rads or mg/kg - haz) | |
|---|---|---|---|---|
| | EMWMF WAC | Proposed EMDF PreWAC | EMWMF WAC | Proposed EMDF PreWAC |
| 1-Methyl-4-(1-methylethyl)-benzene | | | | |
| 2-Methylnapthalene | | | | |
| **ORGANICS (continued), [mg/kg]** | | | | |
| (1-Methylpropyl)benzene | | | | |
| Naphthalene | | | | |
| 4-Nitrobenzenamine [4-Nitroaniline] | | | | |
| Nitrobenzene | | | | 3.46E+02 |
| 2-Nitrophenol | | | | |
| 4-Nitrophenol | | | | |
| N-nitroso-di-n-propylamine | | | | |
| N-Nitrosodiphenylamine | | | | |
| Phenol | | | | |
| Propylbenzene | | | | |
| Propylene glycol | | | | 4.12E+06 |
| Pyridine | | | | 2.40E+02 |
| Styrene | | | | |
| 1,1,1,2-Tetrachloroethane | | | | |
| 1,1,2,2-Tetrachloroethane | | | | |
| Tetrachloroethylene | 4.40E+02 | | 2.90E+03 | |
| 2,3,4,6-Tetrachlorophenol | | | | |
| Toluene | | | 4.90E+04 | |
| 1,2,4-Trichlorobenzene | | | | |
| Trichloroethylene | 7.80E+02 | | | |
| Trichlorofluoromethane | | | | |
| 2,4,6-Trichlorophenol | | | | |
| 1,2,3-Trichloropropane | | | | |
| Trimethylbenzene [mixture of isomers] | | | | |
| 1,2,4-Trimethylbenzene | | | | |
| 1,3,5-Trimethylbenzene | | | | |
| Vinyl Chloride | | | | |
| Total Xylenes [mixture of isomers] | | | | |

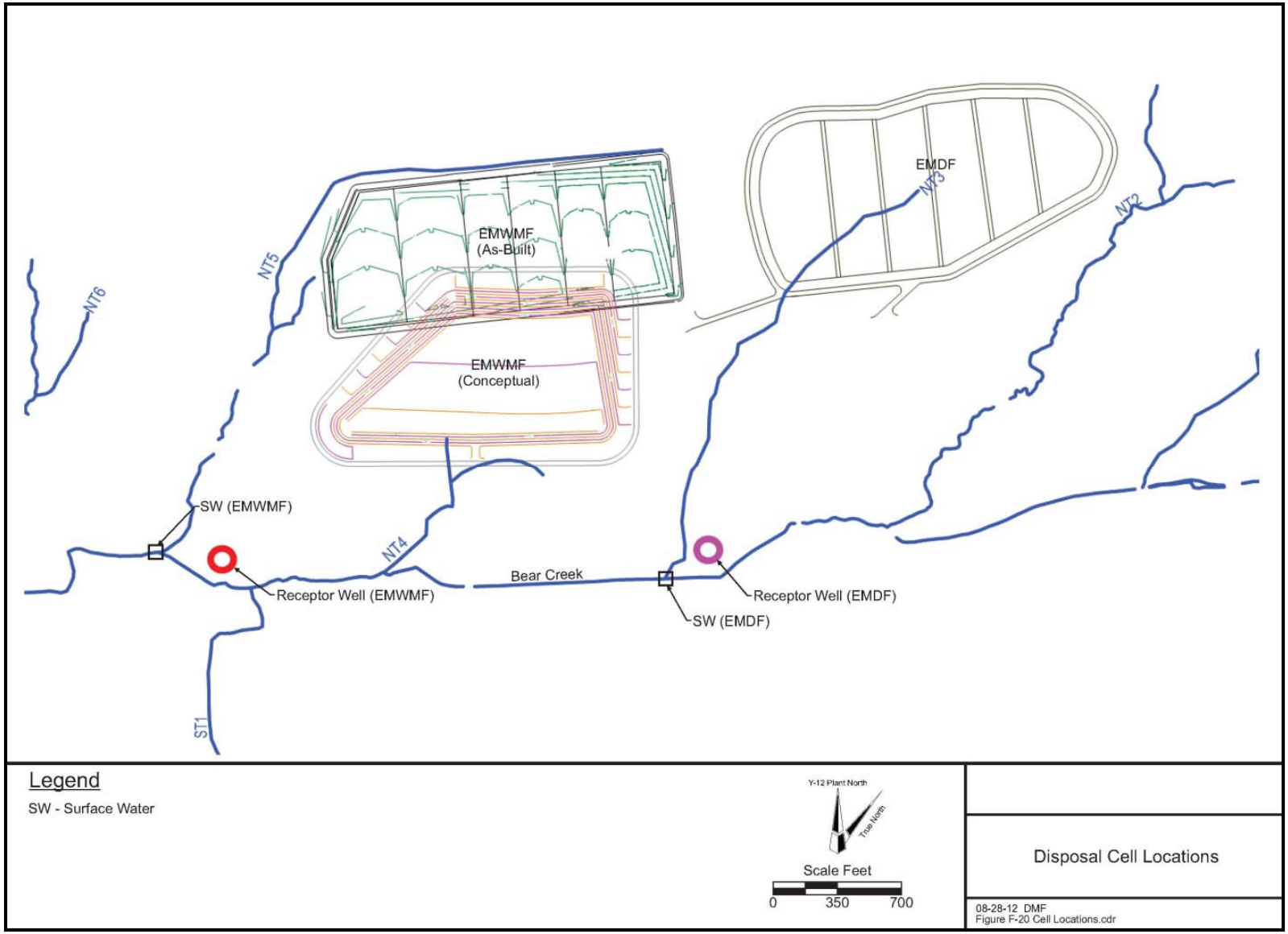



**Figure H-26. EMWMF Conceptual Design, EMWMF As-built, EMDF Conceptual Design, and Hypothetical Receptor Well Locations**

# 6. REFERENCES


Albrecht, B. and Benson, C. 2001. "Effect of desiccation on compacted natural clays", *J. Geotech. and Geoenvironmental Eng.*, 127(1), pp. 67-76.

Bailey, Z. C. 1988. *Preliminary Evaluation of Ground-Water Flow in Bear Creek Valley, Oak Ridge Reservation, Tennessee*. USGS Water-Resources Investigations Report: 88-4010.

BJC 2003. *Engineering Feasibility Plan for Groundwater Suppression at the Environmental Management Waste Facility, Oak Ride, Tennessee*. BJC/OR-1478/R1. Bechtel Jacobs Company LLC, Oak Ridge, TN.

BJC 2010a. *Summary Report on the Environmental Management Waste Management Facility Groundwater Model Flow/Fate-Transport Analyses*. BJC/OR-3434. Oak Ridge, TN.

BJC 2010b. *Calculation Package for the Analysis of Performance of Cells 1-6, with Underdrain, of the Environmental Management Waste Management Facility, Oak Ridge, Tennessee*.

Bonaparte, R., Koerner, R.M. and Daniel, D.E. 2002. "Assessment and recommendations for improving the performance of waste containment systems," research report published by the U.S. Environmental Protection Agency, National Risk Management Research Laboratory, EPA/600/R-02/099.

Boynton, S.S. and Daniel, D.E. 1985. "Hydraulic Conductivity Tests on Compacted Clay," *Journal of Geotechnical Engineering*, 111(4), pp. 465-478.

DOE 1993. *Final Report on the Background Soil Characterization Project at the Oak Ridge Reservation, Oak Ridge, Tennessee*. DOE/OR/01-1175/V1 – V3.

DOE 1996. *Guidance for a Composite Analysis of the Impact of Interacting Source Terms on the Radiological Protection of the Public from Department of Energy Low-Level Waste Disposal Facilities*. Washington, D.C.

DOE 1997. *Feasibility Study for Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1525/V2&D2, Volume II: Appendixes, Appendix F. Regional Groundwater Flow Model Construction and Calibration.

DOE 1998a. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637& D2, Oak Ridge, TN.

DOE 1998b. *Addendum to Remedial Investigation Feasibility Study for the Disposal of Oak Ridge Reservation, Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/ORl02-1637&D2/A1. Oak Ridge, TN.

DOE 1999a. *Record of Decision for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/01-1791&D3, Jacobs EM (Environmental Management) Team, Oak Ridge, TN.

DOE 1999b. *Radioactive Waste Management Manual*, DOE M 435.1-1 Chg.2, U.S. Department of Energy, June 8, 2011, Washington, D.C.

DOE 2000. *Record of Decision for the Phase I Activities in Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1750&D4, U.S. Department of Energy, Office of Environmental Management, May 2000, Oak Ridge, TN.

DOE 2001a. *Attainment Plan for Risk/Toxicity-Based Waste Acceptance Criteria at the Oak Ridge Reservation*, DOE/OR/01-1909&D3. Oak Ridge, TN.

DOE 2001b. *Remedial Design Report for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, Tennessee*. DOE/ORl01-1987&D2, Duratek Federal Services, Inc. Oak Ridge, TN.

DOE 2001c. *Radioactive Waste Management*, DOE O 435.1, Change Notice 1. U.S. Department of Energy, Washington, D.C., 2001.

DOE 2004. *Addendum to Remedial Design Report for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, Tennessee*. Volume 1. DOE/OR/01-1873&D2/A3/R1. Bechtel Jacobs Company LLC, Oak Ridge, TN.

DOE 2010. *Addendum to Remedial Design Report for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, TN*. DOE/OR/01-1873/V1-V3/A6/R1.

DOE 2011. *Derived Concentration Technical Standard*, DOE-STD-1196-2011, April 2011, Washington, D.C.

EPA 1987. Low-Level and NARM Radioactive Wastes. Model Documentation: PATHRAE-EPA. Methodology and Users Manual. EPA 520/1-87-028.

EPA 1989. *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A),* EPA/540/1-89/002, December 1989.

EPA 1996. *Documenting Ground Water Modeling at Sites Contaminated with Radioactive Substances*, EPA 540-R-96-003, January, 1996.

EPA 1997. *Mercury Study Report to Congress: Volume III: Fate and Transport of Mercury in the Environment,* U.S. Environmental Protection Agency, EPA-452/R-97-005, December 1997.

EPA 1999a. *Understanding Variation in Partition Coefficient, Kd, Values, Volume I: The Kd Model, Methods of Measurement and Application of Chemical Reaction Codes*, EPA 402-R-99-004A, U.S. Environmental Protection Agency, August.

EPA 1999b. *Understanding Variation in Partition Coefficient, Kd, Values, Volume II: Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (3H), and Uranium*, EPA 402-R-99-004B, U.S. Environmental Protection Agency, August.

EPA 2004. *Understanding Variation in Partition Coefficient, Kd, Values, Volume III: Review of Geochemistry and Available Kd Values for Americium, Arsenic, Curium, Iodine, Neptunium, Radium, and Technetium*, EPA 402-R-04-002C, U.S. Environmental Protection Agency, July.

EPA 2014. Preliminary Remediation Goals for Radionuclides (website) http://epa-prgs.ornl.gov/radionuclides/ November, 2014.

Evans E. K., Lu, C., Ahmed, S., and Archer, J., 1996. *Application of particle tracking and inverse modeling to reduce flow model calibration uncertainty in an anisotropic aquifer system: Proceedings of the ModelCARE 96 Conference*, IAHS Publ. no. 237, p. 61-70.

Faillace, E., Cheng, J., and Yu, C. 1994. *RESRAD Benchmarking Against Six Radiation Exposure Pathway Models*, ANL/EAD/TM-24.

Geraghty & Miller, Inc. 1987. *Hydrogeologic Investigation of the S-3 Ponds area at the Y-12 Plant*, Y/SUB/87-00206C/18.

Geraghty & Miller, Inc. 1989. *Tracer study of the hydrologic system of upper Bear Creek, Y-12 Plant*, Oak Ridge, Tennessee, Y/SUB/89-00206C/4.

Giroud, J.P. 1984. "Analysis of Stresses and Elongations in Geomembranes", *Proceedings of the International Conference on Geomembranes*, Vol. 2, Denver, CO, USA, pp. 481-486.

Golder Associates Inc.,1988. *Task 2, Well Logging and Geohydrologic Testing, Site Characterization and Groundwater Flow Computer Model Application*.

Hatcher, Jr., R. D., P. J. Lemiszki, R. B. Dreier, R. H. Ketelle, R. R. Lee, D. A. Leitzke,W. M. McMaster, J. L. Foreman, and S. Y. Lee. 1992. *Status Report on the Geology of the Oak Ridge Reservation*, ORNL TM-12074, Environmental Sciences Division Publication No. 3860. ORNL, Oak Ridge, TN.

Hsuan, Y.G. 2002. "Approach to the study of durability of reinforcement fibers and yarns in geosynthetic clay liners", *Geotextiles and Geomembranes,* Vol. 20, pp. 63-76.

Koerner, R.M., Te-Yang Soong, Koerner, G.R. and Gontar, A. 2001. "Creep testing and data extrapolation of reinforced GCL", *Geotextiles and Geomembranes,* Vol. 19. pp. 413–425.

Law Engineering,1983. *Results of Groundwater Monitoring Studies*, Y/SUB/83-47936/1

Lee, R.R., et al. 1992. *Aquifer Analysis and Modeling in a Fractured, Heterogeneous Medium,* Groundwater, V30, 589-597.

McDonald, M.G., and A.W. Harbaugh 1988. *A Modular Three-Dimensional Finite Difference Groundwater Flow Model*. Book 6, Modeling Techniques, Chapter A1, U.S. Geological Survey, Reston, VA.

NRCS (Natural Resource Conservation Service) 2013. *Custom Soil Resource Report for Anderson County, Tennessee: EMDF Soils Map and Data*. Accessed February 13, 2013 at www.websoilsurvey.sc.usda.gov/App/HomePage.htm.

Pollock, D.W. 1989. *Documentation of Computer Programs to Compute and Display Pathlines Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Groundwater Flow Model*, Open-file Report 89-381. U.S. Geological Survey, Reston, VA.

Robinson, J. and Johnson, G. C. 1995. *Results of a Seepage Investigation at Bear Creek Valley, Oak Ridge, Tennessee*, January–September 1994. U.S. Geological Survey Open-File Report 95-459.

Rogers and Associates Engineering 1995a. *The PATHRAE-HAZ/RAD-RAD Performance Assessment Code for the Land Disposal of Radioactive Wastes*, Rogers and Associates Engineering Corporation, RAE-9500/2-1, Salt Lake City, UT.

Rogers and Associates Engineering 1995b. *The PATHRAE-HAZ/RAD-HAZ Performance Assessment Code for the Land Disposal of Hazardous Chemical Wastes*, Rogers and Associates Engineering Corporation, RAE-9500/2-2, Salt Lake City, UT.

Rogers, V. and Hung, C. 1987. *PATHREA-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code - Methodology and Users Manual*, EPA 520/1-87-028 (RAE 8706/1-6), prepared by Rogers and Associates, Salt Lake City, Utah, for U.S. Environmental Protection Agency, Washington, D.C.

Rowe, R.K., Rimal, S., and H. Sangam 2009. *Ageing of HDPE Geomembrane Exposed to Air, Water, and Leachate at Different Temperatures*, Geotextiles and Geomembranes, Vol. 27, No. 2, pp. 137-151.

Rowe, R. K. 2005. "Long-term performance of contaminant barrier systems", in *Geotechnique*, v. 55, no. 9, pp. 631 – 678.

Rowe, R.K. 1998. "Geosynthetics and the minimization of contaminant migration through barrier systems beneath solid waste," *Keynote Lecture, Proceedings of the Sixth International Conference on Geosynthetics*, Atlanta, GA, Vol. 1, pp. 27-103.

Schroeder, P.R., T.S. Dozier, P.A. Zappi, B.M. McEnroe, J.W. Sjostrom, and R.L. Peyton 1994. *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3*, EPA/600/R-94/168b. U.S. Environmental Protection Agency Office of Research and Development, Washington, D.C.

Solomon, D.K., G.K. Moore, L.E. Toran, R.B. Dreier, and W.M. McMaster, 1992. *Status Report: A Hydrologic Framework for the Oak Ridge Reservation. ORNL/TM-12026, Environmental Sciences Division* Publication No. 3815. ORNL, Oak Ridge, TN.

TVA Maps and Surveys Division 1935 and 1941. Bethel Valley, TN Quadrangle 130-NE. From the USGS website: http://geonames.usgs.gov/pls/topomaps/.

UCOR 2012. *Treatment Study Report for Y-12 Site Mercury Contaminated Soil, Oak Ridge*, UCOR-4323, and *Treatment Study Report for Y-12 Site Mercury Contaminated Soil, Oak Ridge – BUSINESS SENSITIVE VERSION*, UCOR 4344, URS|CH2M Oak Ridge LLC, December 2012, Oak Ridge, TN.

UCOR 2015. *Focused Feasibility Study for Water Management from the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee*, DOE/OR/01-2664&D1, URS|CH2M Oak Ridge LLC, February 2015, Oak Ridge, TN.

USGS (U.S. Geological Survey) 2006. *Description, Properties, and Degradation of Selected Volatile Organic Compounds in Ground Water – A Review of Selected Literature*. USGS Open-File Report 2006-1338

Yu et al.1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD*, Version 5.0, ANL/EAD/LD-2, C. Yu, A.J. Zielen, J.J. Cheng, Y.C. Yuan, L.G. Jones, D.J. LePoire, Y.U. Wang, C.O. Loureiro, E. Gnanapragasam, E. Faillace, A.Wallo III, W.A. Williams, and H. Peterson, September.

Zheng, 1990. *A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems*, S.S. Papadopulos & Associates, Inc.

# APPENDIX H - ATTACHMENT A:
# CONTAMINANTS OF POTENTIAL CONCERN

# APPENDIX H - ATTACHMENT B:
# SUPPLEMENTAL MODELING INFORMATION

# APPENDIX H – ATTACHMENT A:
# CONTAMINANTS OF POTENTIAL CONCERN

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... ii
1. INTRODUCTION ..... 1
2. RADIONUCLIDES ..... 1
3. HAZARDOUS CONSTITUENTS ..... 14
4. REFERENCES ..... 23

# TABLES

Table 2-1. Summary of Radionuclides and Parameters Used in Modeling ..... 3
Table 2-2. Radionuclides Considered but not Modeled ..... 5
Table 2-3. Slope Factors for Radioactive Constituents used in Modeling ..... 12
Table 2-4. Ingestion Dose Conversion Factors for Radioactive Constituents used in Modeling ..... 13
Table 3-1. $K_d$ Values for Hazardous Constituents used in PATHRAE ..... 15
Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs ..... 19

# ACRONYMS

| | |
|---|---|
| BCV | Bear Creek Valley |
| COPC | contaminant of potential concern |
| DOE | U.S. Department of Energy |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| $K_d$ | solid-liquid partition coefficient or distribution coefficient |
| PreWAC | Preliminary Waste Acceptance Criteria |
| SF | Slope Factor |
| U.S. | United States |

# 1. INTRODUCTION

This attachment provides a listing of contaminants of potential concern (COPCs) and pertinent data for those contaminants to supplement Appendix H, *On-site Disposal Facility Preliminary Waste Acceptance Criteria*, which discusses development of the Preliminary Waste Acceptance Criteria (PreWAC) for the On-site Disposal Alternative.

PATHRAE-RAD and PATHRAE-HAZ (Rogers and Associates Engineering, 1995a, 1995b) fate and transport models are used to calculate the peak time of arrival and peak concentrations for the potential radioactive constituents and toxicological constituents at the hypothetical receptor surface water location. Various contaminant-specific parameters are required to run the models. Section 2 provides those parameters for radionuclides. Section 3 provides parameters for hazardous constituents. References for all data are given.

# 2. RADIONUCLIDES

Table 2-1 summarizes the radioisotopes used in the modeling along with associated parameters (e.g., specific activity and solid-liquid partition coefficients [$K_d$s]). Those COPCs that were determined not to require modeling to the receptor are summarized in Table 2-2, along with the logic for their removal from consideration.

Solid-liquid partition coefficients, also known as distribution coefficients, are one key variable in determining a contaminant's fate-transport in the PATHRAE model. They are used frequently in this type of modeling, because of their conceptual simplicity. $K_d$ is the ratio of the concentration of a nuclide present in the solid phase (sorbed or reacted on soil or sediment) divided by the equilibrium concentration in the contacting liquid phase (water). Use of a $K_d$ implies a linear equilibrium isotherm between sorbed and non-sorbed species of an element, which is a simplification that holds true at lower concentrations and at constant temperature (as is the situation for most species modeled). Because values of $K_d$ are very site-specific dependent (for example the presence of various competing contaminants, soil properties [e.g., sandy soil versus clay], and water properties [e.g., pH] all affect the $K_d$ value determined for a species), it is best to determine $K_d$s in the environment expected. In practice $K_d$ is measured and used for much more complex systems, and the lack of fit of the simple $K_d$ model to the real system becomes part of the overall uncertainty in the values of $K_d$.

In the risk evaluation and determination of PreWAC, $K_d$ is used as a quantitative indicator of the environmental mobility of the element. In general, all isotopes of an element are assumed to have the same $K_d$ value, because sorption is a chemical property and not dependent on the isotopic mass. Because $K_d$ is a simplification, the values are necessarily empirical and highly dependent on the system where they are measured.

The solid-liquid $K_d$ values used in the PATHRAE modeling were based on site-specific and generic $K_d$ factors for soils. Because the waste to be disposed in the landfill consists of debris surrounded by soil, as well as waste soil, soil $K_d$s were assumed to represent the advective movement of contaminants in the landfill/waste zone as well as the vadose zone. Where multiple $K_d$s were reported in the references, conservative values were selected for use in this modeling. Several references were consulted. Those references were given an order of preference (as noted in the Table 2-1 footnote):

1. ORNL 1990. *Laboratory Measurement of Radionuclide Sorption in Solid Waste Storage Area 6 Soil/Groundwater Systems*, ORNL-TM-10561, June 1990, Oak Ridge, TN.
2. ORNL 1984a. *Characterization of Soils at Proposed Solid Waste Storage Area (SWSA) 7,* ORNL/TM-9326, December 1984, Oak Ridge, TN.

3. ORNL 1997. *Performance Assessment for the Class L-II Disposal Facility*, ORNL/TM-13401, March 1997, Oak Ridge, TN.
4. ORNL 1984b. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL--5786, September 1984, Oak Ridge, TN.
5. DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste.* DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

The primary two references were those that gave site-specific $K_d$s. Both of these first two references gave site-specific $K_d$s that were determined experimentally for soils on the Oak Ridge Reservation in Melton Valley, similar to soils in Bear Creek Valley (BCV). The third reference consulted was the Performance Assessment for a proposed tumulus facility in Bear Creek. That reference reported $K_d$s for many isotopes obtained from various literature sources, and primarily drew data from the first two references given. Only a handful of element-specific $K_d$s were obtained from the fourth reference listed above. This document had an extensive list of $K_d$s, which compared closely with the values determined from the other previously consulted sources. The $K_d$ for only a single element, carbon, was taken directly from the Environmental Management Waste Management Facility (EMWMF) Remedial Investigation/Feasibility Study; however, many of the previously consulted references served as the basis for the $K_d$s used in the EMWMF document.

**Table 2-1. Summary of Radionuclides and Parameters Used in Modeling**

| Isotope | TRU Elements noted | Half-life (yr)[a] | Specific Activity (Ci/g)[b] | Previous Uses/Determination of Isotope | | | | Soil Partition Coefficient (mL/g) | Partition Coefficient Reference[c] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | Include in EMDF RI/FS Modeling | | |
| Ac-227 | | 21.773 | 7.20E+01 | | | | | 1.50E+03 | ORNL 1984b. |
| Ag-108m | | 127 | 2.60E+01 | | | | | 4.50E+01 | ORNL 1984b. |
| Al-26 | | 7.16E+05 | 1.90E-02 | | | | | 3.00E+03 | ORNL 1997. |
| Am-241 | TRU | 432.2 | 3.40E+00 | | | | | 4.00E+01 | ORNL 1997. |
| Am-243 | TRU | 7380 | 2.00E-01 | | | | | 4.00E+01 | ORNL 1997. |
| Ba-133 | | 10.74 | 2.60E+02 | | | | | 6.00E+01 | ORNL 1984b. |
| Bi-207 | | 38 | 5.20E+01 | | | | | 5.00E+02 | ORNL 1997. |
| C-14 | | 5730 | 4.50E+00 | | | | | 1.09E+00 | DOE 1998 (EMWMF RI/FS). |
| Cf-249 | TRU | 350.6 | 4.10E+00 | | | | | 4.00E+01 | ORNL 1997. |
| Cf-250 | | 13.08 | 1.10E+02 | | | | | 4.00E+01 | ORNL 1997. |
| Cf-251 | TRU | 898 | 1.60E+00 | | | | | 4.00E+01 | ORNL 1997. |
| Cl-36 | | 3.01E+05 | 3.30E-02 | | | | | 2.50E-01 | ORNL 1984b. |
| Cm-243 | TRU | 28.5 | 5.20E+01 | | | | | 4.00E+01 | ORNL 1997. |
| Cm-244 | | 18.11 | 8.10E+01 | | | | | 4.00E+01 | ORNL 1997. |
| Cm-245 | TRU | 8500 | 1.70E-01 | | | | | 4.00E+01 | ORNL 1997. |
| Cm-246 | TRU | 4730 | 3.10E-01 | | | | | 4.00E+01 | ORNL 1997. |
| Cm-247 | TRU | 1.56E+07 | 9.30E-05 | | | | | 4.00E+01 | ORNL 1997. |
| Cm-248 | TRU | 3.39E+05 | 4.20E-03 | | | | | 4.00E+01 | ORNL 1997. |
| Co-60 | | 5.271 | 1.10E+03 | | | | | 3.00E+03 | ORNL 1990. |
| Cs-135 | | 2.30E+06 | 1.20E-03 | | | | | 3.00E+03 | ORNL 1990. |
| Cs-137 | | 30 | 8.70E+01 | | | | | 3.00E+03 | ORNL 1990. |
| Eu-150 | | 34.2 | 1.60E+06 | | | | | 3.00E+03 | ORNL 1990. |
| Eu-152 | | 13.33 | 1.80E+02 | | | | | 3.00E+03 | ORNL 1990. |
| Eu-154 | | 8.8 | 2.60E+02 | | | | | 3.00E+03 | ORNL 1990. |
| H-3 | | 12.35 | 9.70E+03 | | | | | 1.99E-01 | ORNL 1997. |
| I-129 | | 1.57E+07 | 1.80E-04 | | | | | 4.00E+00 | ORNL 1984a. |
| K-40 | | 1.28E+09 | 6.40E-06 | | | | | 3.00E+01 | ORNL 1997. |
| Nb-93m | | 13.6 | 2.40E+02 | | | | | 1.00E+02 | ORNL 1997. |
| Nb-94 | | 2.03E+04 | 1.90E-01 | | | | | 1.00E+02 | ORNL 1997. |
| Ni-59 | | 7.50E+04 | 8.00E-02 | | | | | 2.00E+03 | ORNL 1997. |
| Ni-63 | | 96 | 5.70E+01 | | | | | 2.00E+03 | ORNL 1997. |
| Np-237 | TRU | 2.14E+06 | 7.10E-04 | | | | | 4.00E+01 | ORNL 1997. |
| Pa-231 | | 3.28E+04 | 4.70E-02 | | | | | 4.00E+02 | ORNL 1997. |
| Pb-210 | | 22.3 | 7.60E+01 | | | | | 1.00E+02 | ORNL 1997. |
| Pd-107 | | 6.50E+06 | 5.10E-04 | | | | | 2.00E+03 | ORNL 1997. |

**Table 2-1. Summary of Radionuclides and Parameters Used in Modeling (Continued)**

| Isotope | TRUElementas noted | Half-Life (yr)[a] | Specific Activity (Ci/g)[b] | Previous Uses/Determination of Isotope | | | | Soil Partition Coefficient (mL/g) | Partition Coefficient Reference[c] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | Include in EMDF RI/FS Modeling | | |
| Pu-238 | TRU | 87.74 | 1.70E+01 | | | | | 4.00E+01 | ORNL 1997. |
| Pu-239 | TRU | 24,065 | 6.20E-02 | | | | | 4.00E+01 | ORNL 1997. |
| Pu-240 | TRU | 6537 | 2.30E-01 | | | | | 4.00E+01 | ORNL 1997. |
| Pu-241 | | 14.4 | 1.00E+02 | | | | | 4.00E+01 | ORNL 1997. |
| Pu-242 | TRU | 3.76E+05 | 3.90E-03 | | | | | 4.00E+01 | ORNL 1997. |
| Pu-244 | TRU | 8.26E+07 | 1.80E-05 | | | | | 4.00E+01 | ORNL 1997. |
| Ra-226 | | 1600 | 1.00E+00 | | | | | 3.00E+03 | ORNL 1997. |
| Ra-228 | | 5.75 | 2.70E+02 | | | | | 3.00E+03 | ORNL 1997. |
| Se-79 | | 65,000 | 7.00E-02 | | | | | 3.00E+02 | ORNL 1984b. |
| Si-32 | | 450 | 1.10E+02 | | | | | 3.00E+01 | ORNL 1984b. |
| Sm-151 | | 90 | 2.60E+01 | | | | | 1.00E+03 | ORNL 1997. |
| Sn-121m | | 55 | 5.40E+01 | | | | | 1.00E+02 | ORNL 1997. |
| Sn-126 | | 1.00E+05 | 2.80E-02 | | | | | 1.00E+02 | ORNL 1997. |
| Sr-90 | | 29.12 | 1.40E+02 | | | | | 3.00E+01 | ORNL 1990. |
| Tc-99 | | 2.13E+05 | 1.70E-02 | | | | | 1.50E+00 | ORNL 1984b. |
| Th-229 | | 7340 | 2.10E-01 | | | | | 3.00E+03 | ORNL 1997. |
| Th-230 | | 7.70E+04 | 2.10E-02 | | | | | 3.00E+03 | ORNL 1997. |
| Th-232 | | 1.41E+10 | 1.10E-07 | | | | | 3.00E+03 | ORNL 1997. |
| U-232 | | 72 | 2.20E+01 | | | | | 5.00E+01 | ORNL 1990. Document recommends Kd 40 mL/g for U. States that at lower U concentrations, 50-60 mL/g is appropriate. The value of 40 was obtained at U concentrations of 235,000 ppm. EMWMF leachate average is 6 ppm uranium. Use the low end of the range for low U concentrations, 50 mL/g. |
| U-233 | | 1.59E+05 | 9.70E-03 | | | | | 5.00E+01 | |
| U-234 | | 2.45E+05 | 6.20E-03 | | | | | 5.00E+01 | |
| U-235 | | 7.04E+08 | 2.20E-06 | | | | | 5.00E+01 | |
| U-236 | | 2.34E+07 | 6.50E-05 | | | | | 5.00E+01 | |
| U-238 | | 4.47E+09 | 3.40E-07 | | | | | 5.00E+01 | |
| Zr-93 | | 1.53E+06 | 2.50E-03 | | | | | 5.00E+01 | ORNL 1997. |

PA = Performance Assessment; RI/FS = Remedial Investigation/Feasibility Study; TRU = transuranic

[a] The half-lives above are taken from the International Commission on Radiological Protection Publication 107 (ICRP 2008).
[b] Specific activities (Ci/g) taken from 10 CFR 71, Appendix A.
[c] Partition coefficient ($K_d$) taken from references used in the following heirarchical order:

1 ORNL 1990. *Laboratory Measurement of Radionuclide Sorption in Solid Waste Storage Area 6 Soil/Groundwater Systems*, ORNL-TM-10561, June 1990, Oak Ridge, TN.

2 ORNL 1984a. *Characterization of Soils at Proposed Solid Waste Storage Area (SWSA) 7*, ORNL/TM-9326, December 1984, Oak Ridge, TN.

3 ORNL 1997. *Performance Assessment for the Class L-II Disposal Facility*, ORNL/TM-13401, March 1997, Oak Ridge, TN.

4 ORNL 1984b. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL--5786, September 1984, Oak Ridge, TN.

5 DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

**Table 2-2. Radionuclides Considered but not Modeled**

| Isotope | TRU Element as noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Ac-228 | | 7.0E-04 | | | | Excluded, half-life < 5 years. |
| Ag-105 | | 1.1E-01 | | | | Excluded, half-life < 5 years. |
| Ag-110m | | 6.8E-01 | | | | Excluded, half-life < 5 years. |
| Ag-111 | | 2.0E-02 | | | | Excluded, half-life < 5 years. |
| Am-240 | | 5.8E-03 | | | | Excluded, half-life < 5 years. |
| Am-242m | TRU | 1.41E+02 | | | | Excluded, covered in modeling by Am-241, -243. |
| Am-242 | | 1.8E-03 | | | | Excluded, half-life < 5 years. |
| As-72 | | 3.0E-03 | | | | Excluded, half-life < 5 years. |
| As-73 | | 2.2E-01 | | | | Excluded, half-life < 5 years. |
| As-74 | | 4.9E-02 | | | | Excluded, half-life < 5 years. |
| Au-194 | | 4.3E-03 | | | | Excluded, half-life < 5 years. |
| Au-195 | | 5.1E-01 | | | | Excluded, half-life < 5 years. |
| Ba-137m | | 4.9E-06 | | | | Excluded, half-life < 5 years. |
| Ba-139 | | 1.6E-04 | | | | Excluded, half-life < 5 years. |
| Ba-140 | | 3.5E-02 | | | | Excluded, half-life < 5 years. |
| Be-10 | | 1.5E+06 | | | | Excluded, no source, low mobility. |
| Be-7 | | 1.5E-01 | | | | Excluded, half-life < 5 years. |
| Bi-210 | | 1.4E-02 | | | | Excluded, half-life < 5 years. |
| Bi-211 | | 4.1E-06 | | | | Excluded, half-life < 5 years. |
| Bi-212 | | 1.2E-04 | | | | Excluded, half-life < 5 years. |
| Bi-214 | | 3.8E-05 | | | | Excluded, half-life < 5 years. |
| Bk-247 | TRU | 1.4E+03 | | | | Exclude, low quantity, low mobility. |
| Bk-249 | | 9.0E-01 | | | | Excluded, half-life < 5 years. |
| Br-76 | | 1.8E-03 | | | | Excluded, half-life < 5 years. |
| Br-77 | | 6.5E-03 | | | | Excluded, half-life < 5 years. |
| Br-82 | | 4.0E-03 | | | | Excluded, half-life < 5 years. |
| Ca-41 | | 1.0E+05 | | | | Excluded, no source. |
| Ca-45 | | 4.5E-01 | | | | Excluded, half-life < 5 years. |
| Cd-109 | | 1.3E+00 | | | | Excluded, half-life < 5 years. |
| Cd-113m | | 1.4E+01 | | | | Excluded, short half-life, low quantity, low mobility. |

**Table 2-2. Radionuclides Considered but not Modeled (Continued)**

| Isotope | TRU Element as noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Cd-115 | | 6.1E-03 | | | | Excluded, half-life < 5 years. |
| Ce-137 | | 1.0E-03 | | | | Excluded, half-life < 5 years. |
| Ce-139 | | 3.8E-01 | | | | Excluded, half-life < 5 years. |
| Ce-141 | | 8.9E-02 | | | | Excluded, half-life < 5 years. |
| Ce-144 | | 7.8E-01 | | | | Excluded, half-life < 5 years. |
| Cf-252 | | 2.6E+00 | | | | Excluded, half-life < 5 years. |
| Cm-242 | | 4.5E-01 | | | | Excluded, half-life < 5 years. |
| Co-56 | | 2.1E-01 | | | | Excluded, half-life < 5 years. |
| Co-57 | | 7.4E-01 | | | | Excluded, half-life < 5 years. |
| Co-58 | | 1.9E-01 | | | | Excluded, half-life < 5 years. |
| Cr-51 | | 7.6E-02 | | | | Excluded, half-life < 5 years. |
| Cs-134 | | 2.1E+00 | | | | Excluded, half-life < 5 years. |
| Cs-136 | | 3.6E-02 | | | | Excluded, half-life < 5 years. |
| Cu-67 | | 7.1E-03 | | | | Excluded, half-life < 5 years. |
| Dy-154 | | 3.0E+06 | | | | Excluded, no source, low mobility. |
| Dy-159 | | 4.0E-01 | | | | Excluded, half-life < 5 years. |
| Eu-149 | | 2.6E-01 | | | | Excluded, half-life < 5 years. |
| Eu-155 | | 4.8E+00 | | | | Excluded, half-life < 5 years. |
| Eu-156 | | 4.2E-02 | | | | Excluded, half-life < 5 years. |
| Eu-158 | | 8.7E-05 | | | | Excluded, half-life < 5 years. |
| Fe-52 | | 9.5E-04 | | | | Excluded, half-life < 5 years. |
| Fe-55 | | 2.7E+00 | | | | Excluded, half-life < 5 years. |
| Fe-59 | | 1.2E-01 | | | | Excluded, half-life < 5 years. |
| Ga-68 | | 1.3E-04 | | | | Excluded, half-life < 5 years. |
| Gd-146 | | 1.3E-01 | | | | Excluded, half-life < 5 years. |
| Gd-148 | | 7.5E+01 | | | | Excluded, no source, low mobility. |
| Gd-150 | | 1.8E+06 | | | | Excluded, no source, low mobility. |
| Gd-151 | | 3.4E-01 | | | | Excluded, half-life < 5 years. |
| Gd-152 | | 1.1E+14 | | | | Excluded, no source, low mobility. |
| Gd-153 | | 6.6E-01 | | | | Excluded, half-life < 5 years. |
| Ge-68 | | 7.4E-01 | | | | Excluded, half-life < 5 years. |
| Hf-172 | | 1.9E+00 | | | | Excluded, half-life < 5 years. |
| Hf-175 | | 1.9E-01 | | | | Excluded, half-life < 5 years. |

**Table 2-2. Radionuclides Considered but not Modeled (Continued)**

| Isotope | TRU Element as noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Hf-178m | | 3.1E+01 | | | | Excluded, no source, low mobility. |
| Hf-181 | | 1.2E-01 | | | | Excluded, half-life < 5 years. |
| Hg-203 | | 1.3E-01 | | | | Excluded, half-life < 5 years. |
| Ho-163 | | 4.6E+03 | | | | Excluded, no source, low mobility. |
| Ho-166 | | 3.1E-03 | | | | Excluded, half-life < 5 years. |
| Ho-166m | | 1.2E+03 | | | | Excluded, no source, low mobility. |
| I-125 | | 1.6E-01 | | | | Excluded, half-life < 5 years. |
| I-131 | | 2.2E-02 | | | | Excluded, half-life < 5 years. |
| In-114m | | 1.4E-01 | | | | Excluded, half-life < 5 years. |
| In-115m | | 5.1E-04 | | | | Excluded, half-life < 5 years. |
| Ir-192 | | 2.0E-01 | | | | Excluded, half-life < 5 years. |
| Ir-194 | | 2.2E-03 | | | | Excluded, half-life < 5 years. |
| Kr-81 | | 2.3E+05 | | | | Excluded, gas. |
| Kr-85 | | 1.1E+01 | | | | Excluded, gas. |
| La-137 | | 6.0E+04 | | | | Excluded, low quantity, low mobility. |
| La-140 | | 1.7E+00 | | | | Excluded, half-life < 5 years. |
| Lu-172 | | 1.8E-02 | | | | Excluded, half-life < 5 years. |
| Lu-172m | | 7.0E-06 | | | | Excluded, half-life < 5 years. |
| Lu-173 | | 1.4E+00 | | | | Excluded, half-life < 5 years. |
| Lu-174 | | 3.3E+00 | | | | Excluded, half-life < 5 years. |
| Lu-176 | | 3.8E+10 | | | | Excluded, low quantity, low mobility. |
| Lu-177 | | 1.8E-02 | | | | Excluded, half-life < 5 years. |
| Mn-52 | | 1.5E-02 | | | | Excluded, half-life < 5 years. |
| Mn-52m | | 4.0E-05 | | | | Excluded, half-life < 5 years. |
| Mn-54 | | 8.6E-01 | | | | Excluded, half-life < 5 years. |
| Mn-56 | | 2.9E-04 | | | | Excluded, half-life < 5 years. |
| Mo-93 | | 3.5E+03 | | | | Excluded, low quantity, low mobility. |
| Mo-99 | | 7.5E-03 | | | | Excluded, half-life < 5 years. |
| Na-22 | | 2.6E+00 | | | | Excluded, half-life < 5 years. |
| Na-24 | | 1.7E-03 | | | | Excluded, half-life < 5 years. |
| Nb-91 | | 7.0E+02 | | | | Excluded, represented by Nb-93m, Nb-94 in modeling. |
| Nb-91m | | 1.7E-01 | | | | Excluded, half-life < 5 years. |
| Nb-92 | | 3.5E+07 | | | | Excluded, represented by Nb-93m, Nb-94 in modeling. |

**Table 2-2. Radionuclides Considered but not Modeled (Continued)**

| Isotope | TRU Element as noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Nb-92m | | 2.8E-02 | | | | Excluded, half-life < 5 years. |
| Nb-95 | | 9.6E-02 | | | | Excluded, half-life < 5 years. |
| Nd-144 | | 2.4E+15 | | | | Excluded, low quantity, low mobility. |
| Nd-147 | | 3.0E-02 | | | | Excluded, half-life < 5 years. |
| Ni-56 | | 1.6E-02 | | | | Excluded, half-life < 5 years. |
| Ni-57 | | 4.1E-03 | | | | Excluded, half-life < 5 years. |
| Ni-65 | | 2.9E-04 | | | | Excluded, half-life < 5 years. |
| Np-235 | | 1.1E+00 | | | | Excluded, half-life < 5 years. |
| Np-239 | | 6.5E-03 | | | | Excluded, half-life < 5 years. |
| Np-242 | | 1.0E-05 | | | | Excluded, half-life < 5 years. |
| Os-194 | | 6.0E+00 | | | | Excluded, short half-life and low quantity. |
| P-32 | | 3.9E-02 | | | | Excluded, half-life < 5 years. |
| P-33 | | 6.9E-02 | | | | Excluded, half-life < 5 years. |
| Pa-233 | | 7.4E-02 | | | | Excluded, half-life < 5 years. |
| Pa-234 | | 7.6E-04 | | | | Excluded, half-life < 5 years. |
| Pa-234m | | 2.2E-06 | | | | Excluded, half-life < 5 years. |
| Pb-203 | | 5.9E-03 | | | | Excluded, half-life < 5 years. |
| Pb-211 | | 6.9E-05 | | | | Excluded, half-life < 5 years. |
| Pb-212 | | 1.2E-03 | | | | Excluded, half-life < 5 years. |
| Pb-214 | | 5.1E-05 | | | | Excluded, half-life < 5 years. |
| Pm-143 | | 7.3E-01 | | | | Excluded, half-life < 5 years. |
| Pm-145 | | 1.8E+01 | | | | Excluded, short half-life and low quantity. |
| Pm-146 | | 5.5E+00 | | | | Excluded, short half-life and low quantity. |
| Pm-147 | | 2.6E+00 | | | | Excluded, half-life < 5 years. |
| Po-210 | | 3.8E-01 | | | | Excluded, half-life < 5 years. |
| Pu-233 | | 4.0E-05 | | | | Excluded, half-life < 5 years. |
| Pu-234 | | 1.0E-03 | | | | Excluded, half-life < 5 years. |
| Pu-236 | | 2.9E+00 | | | | Excluded, half-life < 5 years. |
| Ra-223 | | 3.1E-02 | | | | Excluded, half-life < 5 years. |
| Ra-224 | | 1.0E-02 | | | | Excluded, half-life < 5 years. |
| Rb-82 | | 2.4E-06 | | | | Excluded, half-life < 5 years. |
| Rb-83 | | 2.4E-01 | | | | Excluded, half-life < 5 years. |
| Rb-84 | | 9.0E-02 | | | | Excluded, half-life < 5 years. |

**Table 2-2. Radionuclides Considered but not Modeled (Continued)**

| Isotope | TRU Element as noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Rb-86 | | 5.1E-02 | | | | Excluded, half-life < 5 years. |
| Rb-87 | | 4.80E+10 | | | | Excluded, no source, low mobility. |
| Re-183 | | 1.9E-01 | | | | Excluded, half-life < 5 years. |
| Re-184 | | 1.0E-01 | | | | Excluded, half-life < 5 years. |
| Re-184m | | 1.8E-01 | | | | Excluded, half-life < 5 years. |
| Re-188 | | 1.9E-03 | | | | Excluded, half-life < 5 years. |
| Rh-101 | | 3.3E+00 | | | | Excluded, half-life < 5 years. |
| Rh-102 | | 5.7E-01 | | | | Excluded, half-life < 5 years. |
| Rh-102m | | 3.7E+00 | | | | Excluded, half-life < 5 years. |
| Rh-106 | | 9.5E-07 | | | | Excluded, half-life < 5 years. |
| Rh-97 | | 5.9E-05 | | | | Excluded, half-life < 5 years. |
| Rh-99 | | 4.4E-02 | | | | Excluded, half-life < 5 years. |
| Rn-219 | | 1.3E-07 | | | | Excluded, half-life < 5 years. |
| Ru-103 | | 1.1E-01 | | | | Excluded, half-life < 5 years. |
| Ru-106 | | 1.0E+00 | | | | Excluded, half-life < 5 years. |
| S-35 | | 2.4E-01 | | | | Excluded, half-life < 5 years. |
| Sb-124 | | 1.6E-01 | | | | Excluded, half-life < 5 years. |
| Sb-125 | | 2.8E+00 | | | | Excluded, half-life < 5 years. |
| Sb-126 | | 3.4E-02 | | | | Excluded, half-life < 5 years. |
| Sc-43 | | 4.5E-04 | | | | Excluded, half-life < 5 years. |
| Sc-44 | | 4.5E-04 | | | | Excluded, half-life < 5 years. |
| Sc-46 | | 2.3E-01 | | | | Excluded, half-life < 5 years. |
| Sc-48 | | 4.2E-04 | | | | Excluded, half-life < 5 years. |
| Se-73 | | 8.1E-04 | | | | Excluded, half-life < 5 years. |
| Se-75 | | 3.3E-01 | | | | Excluded, half-life < 5 years. |
| Sm-145 | | 9.3E-01 | | | | Excluded, half-life < 5 years. |
| Sn-113 | | 3.2E-01 | | | | Excluded, half-life < 5 years. |
| Sn-119m | | 8.0E-01 | | | | Excluded, half-life < 5 years. |
| Sn-121 | | 3.1E-03 | | | | Excluded, half-life < 5 years. |
| Sn-123 | | 3.5E-01 | | | | Excluded, half-life < 5 years. |
| Sr-82 | | 6.9E-02 | | | | Excluded, half-life < 5 years. |
| Sr-85 | | 1.8E-01 | | | | Excluded, half-life < 5 years. |
| Sr-89 | | 1.4E-01 | | | | Excluded, half-life < 5 years. |

**Table 2-2. Radionuclides Considered but not Modeled (Continued)**

| Isotope | TRU Element as noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Ta-179 | | 1.8E+00 | | | | Excluded, half-life < 5 years. |
| Ta-182 | | 3.1E-01 | | | | Excluded, half-life < 5 years. |
| Ta-183 | | 1.4E-02 | | | | Excluded, half-life < 5 years. |
| Tb-157 | | 7.0E+01 | | | | Excluded, low quantity, low mobility. |
| Tb-158 | | 1.8E+02 | | | | Excluded, low quantity, low mobility. |
| Tb-160 | | 2.0E-01 | | | | Excluded, half-life < 5 years. |
| Tc-95 | | 2.3E-03 | | | | Excluded, half-life < 5 years. |
| Tc-95m | | 1.7E-01 | | | | Excluded, half-life < 5 years. |
| Tc-97 | | 4.2E+06 | | | | Excluded, low quantity and covered by Tc-99 in modeling. |
| Tc-99m | | 6.9E-04 | | | | Excluded, half-life < 5 years. |
| Te-125m | | 1.6E-01 | | | | Excluded, half-life < 5 years. |
| Te-129m | | 9.2E-02 | | | | Excluded, half-life < 5 years. |
| Th-227 | | 5.1E-02 | | | | Excluded, half-life < 5 years. |
| Th-228 | | 1.9E+00 | | | | Excluded, half-life < 5 years. |
| Th-231 | | 2.9E-03 | | | | Excluded, half-life < 5 years. |
| Th-231 | | 2.9E-03 | | | | Excluded, half-life < 5 years. |
| Th-234 | | 6.6E-02 | | | | Excluded, half-life < 5 years. |
| Ti-44 | | 6.0E+01 | | | | Excluded, low quantity, low mobility. |
| Tl-204 | | 3.8E+00 | | | | Excluded, half-life < 5 years. |
| Tl-208 | | 5.8E-06 | | | | Excluded, half-life < 5 years. |
| Tm-170 | | 3.5E-01 | | | | Excluded, half-life < 5 years. |
| Tm-171 | | 1.9E+00 | | | | Excluded, half-life < 5 years. |
| U-237 | | 2.1E-03 | | | | Excluded, half-life < 5 years. |
| U-239 | | 4.5E-05 | | | | Excluded, half-life < 5 years. |
| V-48 | | 4.4E-02 | | | | Excluded, half-life < 5 years. |
| V-49 | | 9.1E-01 | | | | Excluded, half-life < 5 years. |
| V-52 | | 1.4E-06 | | | | Excluded, half-life < 5 years. |
| W-178 | | 5.9E-02 | | | | Excluded, half-life < 5 years. |
| W-181 | | 3.3E-01 | | | | Excluded, half-life < 5 years. |
| W-185 | | 2.0E-01 | | | | Excluded, half-life < 5 years. |
| Xe-133 | | 1.4E-02 | | | | Excluded, half-life < 5 years. |

**Table 2-2. Radionuclides Considered but not Modeled (Continued)**

| Isotope | TRU Elementas noted | Half-life (yr)[a] | Previous Uses/Determination of Isotope | | | Reason for Removal from COPC List |
|---|---|---|---|---|---|---|
| | | | In BCV Tumulus PA | In EMWMF RI/FS List | Characterized in EMWMF Waste Lot Analyses | |
| Y-88 | | 2.9E-01 | | | | Excluded, half-life < 5 years. |
| Y-90 | | 7.3E-03 | | | | Excluded, half-life < 5 years. |
| Y-91 | | 1.6E-01 | | | | Excluded, half-life < 5 years. |
| Yb-169 | | 8.8E-02 | | | | Excluded, half-life < 5 years. |
| Zn-65 | | 6.7E-01 | | | | Excluded, half-life < 5 years. |
| Zn-69m | | 1.6E-03 | | | | Excluded, half-life < 5 years. |
| Zn-72 | | 7.4E-04 | | | | Excluded, half-life < 5 years. |
| Zr-88 | | 2.3E-01 | | | | Excluded, half-life < 5 years. |
| Zr-95 | | 1.8E-01 | | | | Excluded, half-life < 5 years. |

PA Performance Assessment;
RI/FS Remedial Investigation/Feasibility Study
TRU transuranic
[a] The half-lifes above are taken from the International Commission on Radiological Protection Publication 107 (ICRP 2008).

Reference Doses for toxicological COPCs and Slope Factors (SFs) for carcinogenic COPCs, as given in recent U.S. Environmental Protection Agency (EPA) risk guidance (EPA 2014a), are used to calculate the EMDF PreWAC. Where no values are provided in the EPA risk guidance, values previously used to calculate the EMWMF PreWAC are used. This chapter, Chapter 2, provides parameters for radionuclides. Chapter 3 provides parameters for toxicological COPCs.

Table 2-3 lists SF values for radioactive constituents. Table 2-4 lists the dose conversion factors for ingestion of the listed radionuclides (ORNL 2015).

**Table 2-3. Slope Factors for Radioactive Constituents used in Modeling**

| Nuclide | Water Ingestion Slope Factor (1/pCi) | Nuclide | Water Ingestion Slope Factor (1/pCi) |
|---|---|---|---|
| Ac-227 | 2.01E-10 | Ni-63 | 6.81E-13 |
| Ag-108m | 8.10E-12 | Np-237 | 6.22E-11 |
| Al-26 | 1.73E-11 | Pa-231 | 1.72E-10 |
| Am-241 | 1.04E-10 | Pb-210 | 8.84e-10 |
| Am-243 | 1.04E-10 | Pd-107 | 2.59E-13 |
| Ba-133 | 6.88E-12 | Pu-238 | 1.31E-10 |
| Bi-207 | 5.74E-12 | Pu-239 | 1.35E-10 |
| C-14 | 1.55E-12 | Pu-240 | 1.35E-10 |
| Cf-249 | 1.27E-10 | Pu-241 | 1.76E-12 |
| Cf-250 | 8.92E-11 | Pu-242 | 1.28E-10 |
| Cf-251 | 1.31E-10 | Pu-244 | 1.44E-10 |
| Cl-36 | 3.30E-12 | Ra-226 | 3.85E-10 |
| Cm-243 | 9.51E-11 | Ra-228 | 1.04E-09 |
| Cm-244 | 8.36E-11 | Se-79 | 6.92E-12 |
| Cm-245 | 1.05E-10 | Si-32 | 3.56E-12 |
| Cm-246 | 1.03E-10 | Sm-151 | 5.59E-13 |
| Cm-247 | 9.95E-11 | Sn-121m | 2.36E-12 |
| Cm-248 | 4.55E-10 | Sn-126 | 2.58E-11 |
| Co-60 | 1.58E-11 | Sr-90 | 5.59E-11 |
| Cs-135 | 6.29E-12 | Tc-99 | 2.75E-12 |
| Cs-137 | 3.05E-11 | Th-229 | 2.23E-10 |
| Eu-150 | 4.03E-12 | Th-230 | 9.14E-11 |
| Eu-152 | 5.85E-12 | Th-232 | 1.01E-10 |
| Eu-154 | 9.84E-12 | U-232 | 2.90E-10 |
| H-3 | 5.07E-14 | U-233 | 7.18E-11 |
| I-129 | 1.51E-10 | U-234 | 7.07E-11 |
| K-40 | 2.47E-11 | U-235 | 6.96E-11 |
| Nb-93m | 8.33E-13 | U-236 | 6.66E-11 |
| Nb-94 | 7.77E-12 | U-238 | 6.40E-11 |
| Ni-59 | 2.72E-13 | Zr-93 | 1.08E-12 |

**Table 2-4. Ingestion Dose Conversion Factors for Radioactive Constituents used in Modeling**

| Nuclide | Ingestion Dose Conversion Factor (mrem/pCi) | Nuclide | Ingestion Dose Conversion Factor (mrem/pCi) |
|---|---|---|---|
| Ac-227 | 4.07E-03 | Ni-63 | 5.55E-07 |
| Ag-108m | 8.51E-06 | Np-237 | 4.07E-04 |
| Al-26 | 1.30E-05 | Pa-231 | 2.63E-03 |
| Am-241 | 7.40E-04 | Pb-210 | 2.55E-03 |
| Am-243 | 7.40E-04 | Pd-107 | 1.37E-07 |
| Ba-133 | 5.55E-06 | Pu-238 | 8.51E-04 |
| Bi-207 | 4.81E-06 | Pu-239 | 9.25E-04 |
| C-14 | 2.15E-06 | Pu-240 | 9.25E-04 |
| Cf-249 | 1.30E-03 | Pu-241 | 1.78E-05 |
| Cf-250 | 5.92E-04 | Pu-242 | 8.88E-04 |
| Cf-251 | 1.33E-03 | Pu-244 | 8.88E-04 |
| Cl-36 | 3.44E-06 | Ra-226 | 1.04E-03 |
| Cm-243 | 5.55E-04 | Ra-228 | 2.55E-03 |
| Cm-244 | 4.44E-04 | Se-79 | 1.07E-05 |
| Cm-245 | 7.77E-04 | Si-32 | 2.07E-06 |
| Cm-246 | 7.77E-04 | Sm-151 | 3.63E-07 |
| Cm-247 | 7.03E-04 | Sn-121m | 1.41E-06 |
| Cm-248 | 2.85E-03 | Sn-126 | 1.74E-05 |
| Co-60 | 1.26E-05 | Sr-90 | 1.04E-04 |
| Cs-135 | 7.40E-06 | Tc-99 | 2.37E-06 |
| Cs-137 | 4.81E-05 | Th-229 | 1.81E-03 |
| Eu-150 | 4.81E-06 | Th-230 | 7.77E-04 |
| Eu-152 | 5.18E-06 | Th-232 | 8.51E-04 |
| Eu-154 | 7.40E-06 | U-232 | 1.22E-03 |
| H-3 | 1.55E-07 | U-233 | 1.89E-04 |
| I-129 | 4.07E-04 | U-234 | 1.81E-04 |
| K-40 | 2.29E-05 | U-235 | 1.74E-04 |
| Nb-93m | 4.44E-07 | U-236 | 1.74E-04 |
| Nb-94 | 6.29E-06 | U-238 | 1.67E-04 |
| Ni-59 | 2.33E-07 | Zr-93 | 4.07E-06 |

# 3. HAZARDOUS CONSTITUENTS

This section lists partition coefficients, slope factors, and reference doses for hazardous COPCs. Table 3-1 contains solid-liquid soil partition coefficients for the hazardous COPCs, taken from DOE 1998. Table 3-2 contains SFs and references doses for hazardous COPCs. Those COPCs with SFs are considered carcinogenic. Data were taken from EPA screening level tables (EPA 2014b) and DOE 1998.

**Table 3-1. $K_d$ Values for Hazardous Constituents used in PATHRAE**

| COPC | CAS | Soil Partition Coefficient (mL/g) |
|---|---|---|
| Antimony | (7440-36-0) | 1.90E+01 |
| Arsenic | (7440-38-2) | 2.90E+01 |
| Barium | (7440-39-3) | 5.50E+01 |
| Beryllium | (7440-41-7) | 7.90E+02 |
| Boron | (7440-42-8) | 3.00E+00 |
| Cadmium | (7440-43-9) | 7.50E+01 |
| Chromium VI | (18540-29-9) | 1.00E+01 |
| Chromium III | (7440-47-3) | 1.00E+01 |
| Copper | (7440-50-8) | 3.50E+01 |
| Lead | (7439-92-1) | 1.00E+02 |
| Manganese | (7439-96-5) | 2.00E+02 |
| Mercury | (7439-97-6) | 5.80E+02 |
| Molybdenum | (7439-98-7) | 2.00E+01 |
| Nickel | (7440-02-0) | 6.50E+01 |
| Selenium | (7782-49-2) | 1.50E+01 |
| Silver | (7440-22-4) | 8.30E+00 |
| Strontium | (7440-24-6) | 1.35E+01 |
| Tin | (7440-31-5) | 2.50E+00 |
| U-233 | (1-1) | 5.00E+01 |
| U-234 | (1-2) | 5.00E+01 |
| U-235 | (1-3) | 5.00E+01 |
| U-236 | (1-4) | 5.00E+01 |
| U-238 | (1-5) | 5.00E+01 |
| Vanadium | (7440-62-2) | 1.00E+02 |
| Zinc | (7440-66-6) | 6.20E+01 |
| 2,4-D | (94-75-7) | 5.88E-02 |
| 2,4,5-T[Silvex] | (93-72-1) | 1.61E-01 |
| Acenaphthene | (83-32-9) | 9.20E+01 |
| Acenaphthylene | (208-96-8) | 1.22E+01 |
| Acetone | (67-64-1) | 4.40E-02 |
| Acetonitrile | (75-05-8) | 1.54E-03 |
| Acetophenone | (98-86-2) | 9.24E-02 |
| Acrolein | (107-02-8) | 2.78E-03 |
| Acrylonitrile | (107-13-1) | 4.44E-03 |

**Table 3-1. $K_d$ Values for Hazardous Constituents used in PATHRAE (Continued)**

| COPC | CAS | Soil Partition Coefficient (mL/g) |
|---|---|---|
| Aldrin | (309-00-2) | 9.74E+01 |
| Aroclor-1221 | (11104-28-2) | 1.20E+02 |
| Aroclor-1232 | (11141-16-5) | 1.50E+01 |
| Benzene | (71-43-2) | 1.70E+00 |
| Benzoic Acid | (65-85-0) | 1.20E-03 |
| Benzyl Alcohol | (100-51-6) | 3.13E-02 |
| Benzidine | (92-87-5) | 5.48E+00 |
| alpha-BHC | (319-84-6) | 3.52E+00 |
| beta-BHC | (319-85-7) | 4.28E+00 |
| delta-BHC | (319-86-8) | 4.28E+00 |
| Bromodichloromethane | (75-27-4) | 1.08E-02 |
| Bromoform | (75-25-2) | 2.52E-01 |
| Bromomethane | (74-83-9) | 2.83E-02 |
| Butylbenzene | (104-51-8) | 1.63E+00 |
| Carbazole | (86-74-8) | 6.78E+00 |
| Carbon Disulfide | (75-15-0) | 1.03E-01 |
| Carbon Tetrachloride | (56-23-5) | 2.20E+00 |
| Chlordane | (57-74-9) | 1.73E+02 |
| Chlorobenzene | (108-90-7) | 4.38E-01 |
| Chloroform | (67-66-3) | 6.20E-01 |
| Chloromethane [Methyl Chloride] | (74-87-3) | 2.86E-02 |
| o-Chlorotoluene | (95-49-8) | 8.86E-01 |
| m-Cresol | (108-39-4) | 9.56E-02 |
| o-Cresol | (95-48-7) | 1.82E-01 |
| p-Cresol | (106-44-5) | 9.22E-02 |
| Cumene [Isopropylbenzene] | (98-82-8) | 1.65E+00 |
| Cyanide | (57-12-5) | 9.90E+00 |
| DDD | (72-54-8) | 9.16E+01 |
| DDE | (72-55-9) | 1.73E+00 |
| Di-n-butylphthalate | (84-74-2) | 1.00E-06 |
| Dibenz(a,h)anthracene | (53-70-3) | 3.58E+03 |
| Dibenzofuran | (123-64-9) | 2.26E+02 |
| Dibromochloromethane | (124-48-1) | 1.41E-01 |
| 1,2-Dichlorobenzene | (95-50-1) | 7.58E-01 |
| 1,3-Dichlorobenzene | (541-73-1) | 1.61E+01 |
| 1,4-Dichlorobenzene | (106-46-7) | 1.23E+00 |
| 1,2,-cis-Dichloroethylene | (156-59-2) | 9.96E-01 |

**Table 3-1. $K_d$ Values for Hazardous Constituents used in PATHRAE (Continued)**

| COPC | CAS | Soil Partition Coefficient (mL/g) |
|---|---|---|
| 1,2-trans-Dichloroethylene | (156-60-5) | 7.60E-02 |
| Dichlorodifluoromethane | (75-71-8) | 1.37E-02 |
| 1,2-Dichloropropane | (78-87-5) | 9.40E-02 |
| Dieldrin | (60-57-1) | 3.40E+01 |
| Diethylphthalate | (84-66-2) | 2.52E-01 |
| 1,2-Dimethylbenzene | (95-47-6) | 4.80E-01 |
| 2,4-Dimethylphenol | (105-67-9) | 2.52E+00 |
| Dimethylphthalate | (131-11-3) | 7.42E-02 |
| 2,4 Dinitrotoluene | (121-14-2) | 1.02E-01 |
| 2,6 Dinitrotoluene | (606-20-2) | 8.39E-02 |
| Endosulfan plus metabolites**** | (959-98-8) | 4.08E-01 |
| Endrin | (72-20-8) | 2.16E+01 |
| Endrin Aldehyde | (7421-93-4) | 2.16E+00 |
| Endrin Ketone | (53494-70-5) | 2.16E+00 |
| Ethylbenzene | (100-41-4) | 4.08E-01 |
| Ethylchloride | (75-00-3) | 0.0E=00 |
| Heptachlor | (76-44-8) | 4.80E+01 |
| Heptachlor Epoxide | (1024-57-3) | 1.73E+01 |
| Hexachlorobenzene | (118-74-1) | 1.10E+02 |
| Hexachloroethane | (67-72-1) | 3.56E+00 |
| n-Hexane | (110-54-3) | 3.00E-01 |
| 1-Hexanol | (111-27-3) | 0.00E+00 |
| 2-Hexanone | (591-78-6) | 0.00E+00 |
| Isophorone | (78-59-1) | 1.70E+00 |
| Lindane | (58-89-9) | 6.80E+00 |
| Methanol | (67-56-1) | 0.00E+00 |
| Dichloromethane | (75-09-2) | 2.01E+03 |
| Methylcyclohexane | (108-87-2) | 0.00E+00 |
| Methyl Isobutyl Ketone | (108-10-1) | 4.70E-03 |
| Methyl Methacrylate | (80-62-6) | 2.00E-02 |
| 1-Methyl-4-(1-methylethyl)-benzene | (99-87-6) | 1.65E+00 |
| 2-Methylnapthalene | (91-57-6) | 5.94E+00 |
| (1-Methylpropyl)benzene | (135-98-8) | 1.65E+00 |
| Naphthalene | (91-20-3) | 1.90E+01 |
| 4-Nitrobenzenamine [4-Nitroaniline] | (100-01-6) | 3.44E-01 |
| Nitrobenzene | (98-95-3) | 1.29E-01 |
| 2-Nitrophenol | (88-75-5) | 7.10E-01 |

**Table 3-1. $K_d$ Values for Hazardous Constituents used in PATHRAE (Continued)**

| COPC | CAS | Soil Partition Coefficient (mL/g) |
|---|---|---|
| 4-Nitrophenol | (100-02-7) | 8.74E-01 |
| N-nitrosodipropylamine | (621-64-7) | 3.00E-01 |
| N-Nitrosodiphenylamine | (86-30-6) | 6.54E-01 |
| Phenol | (108-95-2) | 2.80E-01 |
| Propylbenzene | (103-65-1) | 1.65E+00 |
| Propylene glycol | (57-55-6) | 2.00E-03 |
| Pyridine | (110-86-1) | 1.38E-02 |
| Styrene | (100-42-5) | 1.82E+00 |
| 1,1,1,2-Tetrachloroethane | (630-20-6) | 3.18E-01 |
| 1,1,2,2-Tetrachloroethane | (79-34-5) | 1.56E-01 |
| Tetrachloroethylene | (127-18-4) | 7.20E+00 |
| 2,3,4,6-Tetrachlorophenol | (58-90-2) | 2.49E+02 |
| Toluene | (108-88-3) | 6.00E+00 |
| 1,2,4-Trichlorobenzene | (120-82-1) | 1.44E+00 |
| Trichloroethylene | (79-01-6) | 2.60E+00 |
| Trichlorofluoromethane | (75-69-4) | 2.68E-01 |
| 2,4,6-Trichlorophenol | (88-06-02) | 6.36E-01 |
| 1,2,3-Trichloropropane | (96-18-4) | 1.61E-01 |
| Trimethylbenzene [mixture of isomers] | (25551-13-7) | 1.44E+00 |
| 1,2,4-Trimethylbenzene | (95-63-6) | 1.44E+00 |
| 1,3,5-Trimethylbenzene | (108-67-8) | 3.34E+00 |
| Vinyl Chloride | (75-01-4) | 3.72E-01 |
| Xylene [mixture of isomers] | (1330-20-7) | 8.86E-01 |

**Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs**

| COPC | Slope Factor (1/(mg/kg-d)) | Reference Dose (mg/kg-day) |
|---|---|---|
| Antimony | | 4.00E-04 |
| Arsenic | 1.5 | 3.00E-04 |
| Barium | | 2.00E-01 |
| Beryllium | | 2.00E-03 |
| Boron | | 2.00E-01 |
| Cadmium | | 5.00E-04 |
| Chromium III | | 1.00E+00 |
| Chromium VI | 0.5 | 3.00E-03 |
| Copper | | 4.00E-02 |
| Lead | | 1.40E-03 |
| Manganese | | 1.40E-01 |
| Mercury | | 3.00E-04 |
| Molybdenum | | 5.00E-03 |
| Nickel | | 2.00E-02 |
| Selenium | | 5.00E-03 |
| Silver | | 5.00E-03 |
| Strontium | | 6.00E-01 |
| Tin | | 6.00E-01 |
| U-233 | | 3.00E-03 |
| U-234 | | 3.00E-03 |
| U-235 | | 3.00E-03 |
| U-236 | | 3.00E-03 |
| U-238 | | 3.00E-03 |
| Vanadium | | 5.00E-03 |
| Zinc | | 3.00E-01 |
| 2,4-D | | 1.00E-02 |
| 2,4,5-T[Silvex] | | 8.00E-03 |
| Acenaphthene | | 6.00E-02 |
| Acenaphthylene | | 6.00E-02 |
| Acetone | | 9.00E-01 |
| Acetonitrile | | 6.00E-03 |
| Acetophenone | | 1.00E-01 |
| Acrolein | | 5.00E-04 |
| Acrylonitrile | 5.40E-01 | 4.00E-02 |
| Aldrin | 1.70E+01 | 3.00E-05 |

**Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs (Continued)**

| COPC | Slope Factor (1/(mg/kg-d)) | Reference Dose (mg/kg-day) |
|---|---|---|
| Aroclor-1221 | 2.00E+00 | |
| Aroclor-1232 | 2.00E+00 | |
| Benzene | 5.50E-02 | 4.00E-03 |
| Benzoic Acid | | 4.00E+00 |
| Benzyl Alcohol | | 1.00E-01 |
| Benzidine | 2.30E+02 | 3.00E-03 |
| alpha-BHC | 6.30E+00 | 8.00E-03 |
| beta-BHC | 1.80E+00 | |
| delta-BHC | 1.80E+00 | |
| Bromodichloromethane | 6.20E-02 | 2.00E-02 |
| Bromoform | 7.90E-03 | 2.00E-02 |
| Bromomethane | | 1.40E-03 |
| Butylbenzene | | 5.00E-02 |
| Carbazole | 2.00E-02 | |
| Carbon Disulfide | | 1.00E-01 |
| Carbon tetrachloride | 7.00E-02 | 4.00E-03 |
| Chlordane | 3.50E-01 | 5.00E-04 |
| Chlorobenzene | | 2.00E-02 |
| Chloroform | 3.10E-02 | 1.00E-02 |
| | | |
| o-Chlorotoluene | | 2.00E-02 |
| m-Cresol | | 5.00E-02 |
| o-Cresol | | 5.00E-02 |
| p-Cresol | | 1.00E-01 |
| Cumene [Isopropylbenzene] | | 1.00E-01 |
| Cyanide | | 6.00E-04 |
| DDD | 2.40E-01 | |
| DDE | 3.40E-01 | |
| Di-n-butylphthalate | | 1.00E-01 |
| Dibenz(a,h)anthracene | 7.30E+00 | |
| Dibenzofuran | | 1.00E-03 |
| Dibromochloromethane | 8.40E-02 | 2.00E-02 |
| 1,2-Dichlorobenzene | | 9.00E-02 |
| 1,3-Dichlorobenzene | | 8.90E-02 |
| 1,4-Dichlorobenzene | 5.40E-03 | 7.00E-02 |
| 1,2,-cis-Dichloroethylene | | 2.00E-03 |
| 1,2-trans-Dichloroethylene | | 2.00E-02 |
| Dichlorodifluoromethane | | 2.00E-01 |

**Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs (Continued)**

| COPC | Slope Factor (1/(mg/kg-d)) | Reference Dose (mg/kg-day) |
|---|---|---|
| 1,2-Dichloropropane | 3.60E-02 | 9.00E-02 |
| Dieldrin | 1.60E+01 | 5.00E-05 |
| Diethylphthalate | | 8.00E-01 |
| 1,2-Dimethylbenzene | | 2.00E-01 |
| 2,4-Dimethylphenol | | 2.00E-02 |
| Dimethylphthalate | | 1.00E+01 |
| 2,4 Dinitrotoluene | 3.10E-01 | 2.00E-03 |
| 2,6 Dinitrotoluene | 1.50E+00 | 3.00E-04 |
| Endosulfan plus metabolites | | 6.00E-03 |
| Endrin | | 3.00E-04 |
| Endrin Aldehyde | | 3.00E-04 |
| Endrin Ketone | | 3.00E-04 |
| Ethylbenzene | 1.10E-02 | 1.00E-01 |
| Ehtylchloride | 0.00E+00 | 0.00E+00 |
| Heptachlor | 4.50E+00 | 5.00E-04 |
| Heptachlor Epoxide | 9.10E+00 | 1.30E-05 |
| Hexachlorobenzene | 1.60E+00 | 8.00E-04 |
| Hexachloroethane | 4.00E-02 | 7.00E-04 |
| n-Hexane | | 6.00E-02 |
| 1-Hexanol | | 4.00E-02 |
| 2-Hexanone | | 5.00E-03 |
| Isophorone | 9.50E-04 | 2.00E-01 |
| Lindane | 1.10E+00 | 3.00E-04 |
| Methanol | | 2.00E+00 |
| Dichloromethane | 2.00E-03 | 6.00E-03 |
| Methylcyclohexane | | 6.00E-02 |
| Methyl Isobutyl Ketone | | 8.00E-02 |
| Methyl Methacrylate | | 1.40E+00 |
| 1-Methyl-4-(1-methylethyl)-benzene | | 3.70E-02 |
| 2-Methylnapthalene | | 4.00E-03 |
| (1-Methylpropyl)benzene | | 3.70E-02 |
| Naphthalene | | 2.00E-02 |
| 4-Nitrobenzenamine [4-Nitroaniline] | 2.00E-02 | 4.00E-03 |
| Nitrobenzene | | 2.00E-03 |
| 2-Nitrophenol | | 6.20E-02 |
| 4-Nitrophenol | | 6.20E-02 |
| N-Nitrosodipropylamine | 7.00E+00 | |
| N-Nitrosodiphenylamine | 4.90E-03 | |

**Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs (Continued)**

| COPC | Slope Factor (1/(mg/kg-d)) | Reference Dose (mg/kg-day) |
|---|---|---|
| Phenol | | 3.00E-01 |
| Propylbenzene | | 1.00E-01 |
| Propylene glycol | | 2.00E+01 |
| Pyridine | | 1.00E-03 |
| Styrene | | 2.00E-01 |
| 1,1,1,2-Tetrachloroethane | 2.60E-02 | 3.00E-02 |
| 1,1,2,2-Tetrachloroethane | 2.00E-01 | 2.00E-02 |
| Tetrachloroethylene | 2.10E-03 | 6.00E-03 |
| 2,3,4,6-Tetrachlorophenol | | 3.00E-02 |
| Toluene | | 8.00E-02 |
| 1,2,4-Trichlorobenzene | 2.90E-02 | 1.00E-02 |
| Trichloroethylene | 4.60E-02 | 5.00E-04 |
| Trichlorofluoromethane | | 3.00E-01 |
| 2,4,6-Trichlorophenol | 1.10E-02 | 1.00E-03 |
| 1,2,3-Trichloropropane | 3.00E+01 | 4.00E-03 |
| Trimethylbenzene [mixture of isomers] | 0.00E+00 | 0.00E+00 |
| 1,2,4-Trimethylbenzene | 0.00E+00 | 0.00E+00 |
| 1,3,5-Trimethylbenzene | | 1.00E-02 |
| Vinyl Chloride | 7.20E-01 | 3.00E-03 |
| Xylene [mixture of isomers] | | 2.00E-01 |

# 4. REFERENCES


DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

EPA 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion:* Federal Guidance Report No. 11, EPA-520/1-88-020, September 1988.

EPA 2014a. *Preliminary Remediation Goals for Radionuclides (website)* http://epa-prgs.ornl.gov/radionuclides/ November, 2014.

EPA 2014b. *Generic chemical risk screening levels*. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_run_NOV2014.pdf

ORNL 1990. *Laboratory Measurement of Radionuclide Sorption in Solid Waste Storage Area 6 Soil/Groundwater Systems*, ORNL-TM-10561, June 1990, Oak Ridge, TN.

ORNL 1984a. *Characterization of Soils at Proposed Solid Waste Storage Area (SWSA) 7*, ORNL/TM-9326, December 1984, Oak Ridge, TN.

ORNL 1997. *Performance Assessment for the Class L-II Disposal Facility*, ORNL/TM-13401, March 1997, Oak Ridge, TN.

ORNL 1984b. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL-5786, September 1984, Oak Ridge, TN.

ORNL 2015. Risk Assessment Information System, Oak Ridge National Laboratory, 2015.

This page intentionally left blank.

# APPENDIX H – ATTACHMENT B:
# SUPPLEMENTAL MODELING INFORMATION

This page intentionally left blank.

# CONTENTS

ACRONYMS ..... ii
1. INTRODUCTION ..... 1
2. HELP MODEL ..... 1
2.1 HELP MODEL INPUT PARAMETER SUMMARY ..... 1
2.1.1 Evapotranspiration and Weather Data ..... 2
2.1.2 Design Failure Profile and Parameters ..... 3
2.1.3 Long-term (Worst-case) Profile and Parameters ..... 5
2.1.4 General Design and Evaporative Zone Data ..... 8
2.2 HELP MODEL OUTPUT SUMMARY ..... 8
2.2.1 Initial Long-term Scenario ..... 9
2.2.2 Long-term (Worst-case) Scenario ..... 10
3. PATHRAE MODEL ..... 10
3.1 PATHRAE MODEL INPUT AND OUTPUT FILES ..... 10
3.1.1 PATHRAE-HAZ ..... 32
3.1.1.1 First Contaminants of Concern (Inorganics) ..... 32
3.1.1.2 Remaining Contaminants of Concern (Organics) ..... 38

# ACRONYMS

| | |
|---|---|
| COC | contaminant of concern |
| EMDF | Environmental Management Disposal Facility |
| HELP | Hydrologic Evaluation of Landfill Performance |
| PreWAC | Preliminary Waste Acceptance Criteria |

# 1. INTRODUCTION

This attachment provides supplemental modeling information to Appendix H, *On-site Disposal Facility Preliminary Waste Acceptance Criteria* (PreWAC). Section 2 provides information about the Hydrologic Evaluation of Landfill Performance (HELP) model, including model input and output files. Section 3 provides information about the PATHRAE model and PreWAC calculations, including PATHRAE input and output files.

# 2. HELP MODEL

Detailed information about the HELP modeling analysis that was conducted to support PreWAC development is presented in this section. HELP model input parameters are summarized in Section 2.1, including the complete design and long-term (worst-case) scenarios. The long-term (worst-case) scenario was used for PreWAC development. HELP model output parameters are summarized in Section 2.2.

## 2.1 HELP MODEL INPUT PARAMETER SUMMARY

The HELP model requires general climatic data, design parameters, and soil characteristics to perform the analysis. These are as follows:

- **Climatic Data:** General climatic data input include the growing season, average quarterly relative humidity, normal mean monthly temperatures and precipitation, maximum leaf area index, evaporative zone depth, and latitude.
- **Design Parameters:** Disposal cell design parameters include the slope and maximum drainage distance for lateral drainage layers, layer thickness, layer description, area, leachate recirculation procedures, subsurface inflows, surface characteristics, and geomembrane characteristics.
- **Soil Characteristics:** Necessary soil data input include porosity, field capacity, wilting point, saturated hydraulic conductivity, initial moisture storage, and the United States Soil Conservation Service runoff curve number. The porosity, field capacity, wilting point, and saturated hydraulic conductivity are used to estimate the soil-water evaporation coefficient and Brooks-Corey soil moisture retention parameters. The HELP model contains default soil characteristics for 42 material types that are used when measurements or site-specific estimates are not available. Geotechnical parameters used in the model for each layer may be adjusted based on final design criteria as information becomes available.

### 2.1.1 Evapotranspiration and Weather Data

The same evapotranspiration and weather data were used for all profile runs.

```
    NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
             KNOXVILLE             TENNESSEE

        STATION LATITUDE                        =  35.49 DEGREES
        MAXIMUM LEAF AREA INDEX                 =   3.50
        START OF GROWING SEASON (JULIAN DATE)   =     85
        END OF GROWING SEASON (JULIAN DATE)     =    307
        EVAPORATIVE ZONE DEPTH                  =  21.0  INCHES
        AVERAGE ANNUAL WIND SPEED               =   7.10 MPH
        AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  68.00 %
        AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  69.00 %
        AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  76.00 %
        AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  72.00 %

    NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    KNOXVILLE           TENNESSEE

               NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
  4.65        4.18        5.49        3.87        3.71        3.95
  4.33        3.02        2.90        2.73        3.78        4.59

    NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    KNOXVILLE           TENNESSEE

          NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
 38.20       41.50       49.70       59.60       67.40       74.30
 77.60       77.00       71.50       59.50       48.80       41.10

    NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    KNOXVILLE           TENNESSEE
               AND STATION LATITUDE  =  35.49 DEGREES
```

### 2.1.2 Design Failure Profile and Parameters

These parameters were set to indicate failure of geosynthetics. Six layers were not included in run.

```
                          LAYER  1
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   4
  THICKNESS                   =     48.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.1050 VOL/VOL
  WILTING POINT               =      0.0470 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1771 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.170000002000E-02 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                          LAYER  2
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   3
  THICKNESS                   =     12.00   INCHES
  POROSITY                    =      0.4570 VOL/VOL
  FIELD CAPACITY              =      0.0830 VOL/VOL
  WILTING POINT               =      0.0330 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1916 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.310000009000E-02 CM/SEC


                          LAYER  3
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4170 VOL/VOL
  FIELD CAPACITY              =      0.0450 VOL/VOL
  WILTING POINT               =      0.0180 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1355 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC


                          LAYER  4
                          --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  21
  THICKNESS                   =     12.00   INCHES
  POROSITY                    =      0.3970 VOL/VOL
  FIELD CAPACITY              =      0.0320 VOL/VOL
  WILTING POINT               =      0.0130 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0360 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC
  SLOPE                       =      5.00   PERCENT
  DRAINAGE LENGTH             =    100.0    FEET


                          LAYER  5
                          --------
```

```
            TYPE 3 - BARRIER SOIL LINER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.349999993000E-07 CM/SEC


                       LAYER  6
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4195 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


                       LAYER  7
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3970 VOL/VOL
FIELD CAPACITY              =      0.0320 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0483 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC


                       LAYER  8
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  22
THICKNESS                   =    600.00   INCHES
POROSITY                    =      0.4190 VOL/VOL
FIELD CAPACITY              =      0.3070 VOL/VOL
WILTING POINT               =      0.1800 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3070 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.189999992000E-04 CM/SEC


                       LAYER  9
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  26
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4450 VOL/VOL
FIELD CAPACITY              =      0.3930 VOL/VOL
WILTING POINT               =      0.2770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3930 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
```

```
                          LAYER 10
                          --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
 THICKNESS                    =     36.00   INCHES
 POROSITY                     =      0.4270 VOL/VOL
 FIELD CAPACITY               =      0.4180 VOL/VOL
 WILTING POINT                =      0.3670 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                          LAYER 11
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  26
 THICKNESS                    =    120.00   INCHES
 POROSITY                     =      0.4450 VOL/VOL
 FIELD CAPACITY               =      0.3930 VOL/VOL
 WILTING POINT                =      0.2770 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.3930 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.190000003000E-05 CM/SEC
```

### 2.1.3 Long-term (Worst-case) Profile and Parameters

Assumes failure of geosynthetics (removal of six layers) and 20% erosion in Layer 1 (top layer of cap).

```
                          LAYER  1
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   4
 THICKNESS                    =     38.40   INCHES
 POROSITY                     =      0.4370 VOL/VOL
 FIELD CAPACITY               =      0.1050 VOL/VOL
 WILTING POINT                =      0.0470 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.1687 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   3
 THICKNESS                    =     12.00   INCHES
 POROSITY                     =      0.4570 VOL/VOL
 FIELD CAPACITY               =      0.0830 VOL/VOL
 WILTING POINT                =      0.0330 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.1870 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.310000009000E-02 CM/SEC


                          LAYER  3
                          --------
```

```
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1328 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC


                        LAYER  4
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0353 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
SLOPE                        =      5.00   PERCENT
DRAINAGE LENGTH              =    100.0    FEET


                        LAYER  5
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.349999993000E-07 CM/SEC


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4193 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                        LAYER  7
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0483 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
```

LAYER 8
---

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 22

| | | | |
|---|---|---|---|
| THICKNESS | = | 600.00 | INCHES |
| POROSITY | = | 0.4190 | VOL/VOL |
| FIELD CAPACITY | = | 0.3070 | VOL/VOL |
| WILTING POINT | = | 0.1800 | VOL/VOL |
| INITIAL SOIL WATER CONTENT | = | 0.3070 | VOL/VOL |
| EFFECTIVE SAT. HYD. COND. | = | 0.189999992000E-04 | CM/SEC |

LAYER 9
---

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

| | | | |
|---|---|---|---|
| THICKNESS | = | 12.00 | INCHES |
| POROSITY | = | 0.4450 | VOL/VOL |
| FIELD CAPACITY | = | 0.3930 | VOL/VOL |
| WILTING POINT | = | 0.2770 | VOL/VOL |
| INITIAL SOIL WATER CONTENT | = | 0.3930 | VOL/VOL |
| EFFECTIVE SAT. HYD. COND. | = | 0.190000003000E-05 | CM/SEC |

LAYER 10
---

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

| | | | |
|---|---|---|---|
| THICKNESS | = | 36.00 | INCHES |
| POROSITY | = | 0.4270 | VOL/VOL |
| FIELD CAPACITY | = | 0.4180 | VOL/VOL |
| WILTING POINT | = | 0.3670 | VOL/VOL |
| INITIAL SOIL WATER CONTENT | = | 0.4270 | VOL/VOL |
| EFFECTIVE SAT. HYD. COND. | = | 0.100000001000E-06 | CM/SEC |

LAYER 11
---

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

| | | | |
|---|---|---|---|
| THICKNESS | = | 120.00 | INCHES |
| POROSITY | = | 0.4450 | VOL/VOL |
| FIELD CAPACITY | = | 0.3930 | VOL/VOL |
| WILTING POINT | = | 0.2770 | VOL/VOL |
| INITIAL SOIL WATER CONTENT | = | 0.3930 | VOL/VOL |
| EFFECTIVE SAT. HYD. COND. | = | 0.190000003000E-05 | CM/SEC |

### 2.1.4 General Design and Evaporative Zone Data

```
 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF 5%
          AND A SLOPE LENGTH OF 450 FEET.

SCS RUNOFF CURVE NUMBER             =     49.30
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     35.000  ACRES
EVAPORATIVE ZONE DEPTH              =     21.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.971  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      9.177  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.987  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    276.668  INCHES
TOTAL INITIAL WATER                 =    276.668  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

## 2.2 HELP MODEL OUTPUT SUMMARY

HELP model simulations provide the water budget for the proposed waste Environmental Management Disposal Facility (EMDF) and estimate infiltration rates to groundwater. The modeling results for the complete design scenario and long-term (worst-case) scenario are presented in Section 2.2.1 and Section 2.2.2, respectively.

### 2.2.1 Initial Long-term Scenario

This scenario assumed failure of geosynthetics (see Appendix H).

```
*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
 ------------------------------------------------------------------------------
                                      INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
  PRECIPITATION                   47.55    (   6.811)    6041623.0     100.00

  RUNOFF                           0.061   (  0.2780)       7778.17      0.129

  EVAPOTRANSPIRATION              29.628   (  2.8561)    3764212.25     62.305

  LATERAL DRAINAGE COLLECTED      17.43797 (  5.02535)   2215494.500   36.67052
    FROM LAYER  4

  PERCOLATION/LEAKAGE THROUGH      0.42578 (  0.00527)     54094.914     0.89537
    LAYER  5

  AVERAGE HEAD ON TOP              0.057 (    0.016)
    OF LAYER  5

  PERCOLATION/LEAKAGE THROUGH      0.42581 (  0.00647)     54098.836     0.89544
    LAYER 10

  AVERAGE HEAD ON TOP              0.002 (    0.000)
    OF LAYER 10

  PERCOLATION/LEAKAGE THROUGH      0.42581 (  0.00640)     54099.172     0.89544
    LAYER 11

  CHANGE IN WATER STORAGE          0.000   (  2.2872)         37.65      0.001

 *******************************************************************************
```

### 2.2.2 Long-term (Worst-case) Scenario

This scenario was completed assuming 20% reduction in the top layer due to erosion.

```
********************************************************************************

      AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
 ------------------------------------------------------------------------------
                                        INCHES            CU. FEET       PERCENT
                                    ------------------   ------------   ---------
  PRECIPITATION                     47.55    (   6.811)    6041623.0     100.00

  RUNOFF                             0.061   (  0.2780)       7778.17      0.129

  EVAPOTRANSPIRATION                29.628   (  2.8561)    3764212.25     62.305

  LATERAL DRAINAGE COLLECTED        17.43734 (  5.08529)   2215413.500   36.66918
    FROM LAYER  4

  PERCOLATION/LEAKAGE THROUGH        0.42489 (  0.00496)     53982.109     0.89350
    LAYER  5

  AVERAGE HEAD ON TOP                0.057 (    0.016)
    OF LAYER  5

  PERCOLATION/LEAKAGE THROUGH        0.42487 (  0.00658)     53979.531     0.89346
    LAYER 10

  AVERAGE HEAD ON TOP                0.002 (    0.000)
    OF LAYER 10

  PERCOLATION/LEAKAGE THROUGH        0.42487 (  0.00667)     53980.160     0.89347
    LAYER 11

  CHANGE IN WATER STORAGE            0.002   (  2.0556)        237.60      0.004

 ********************************************************************************
```

# 3. PATHRAE MODEL

## 3.1 PATHRAE MODEL INPUT AND OUTPUT FILES

The PATHRAE-RAD model was used for radionuclides and the PATHRAE-HAZ model was used for hazardous constituents. The PATHRAE-RAD and PATHRAE-HAZ output (text) files are listed in Section 3.2.1 and Section 3.2.2 below, respectively. The output files contain a mirror image of the input files used to conduct PATHRAE model simulation. Note that two time scenarios are run for the radioactive contaminants: (1) up to 15,000 years, with one time step, and (2) up to 1,000,000 years with a much longer time step.

PATHRAE-RAD

```
PATHRAE-RAD(PC)  Version 2.2d  February 1995

 *****  Mirror Image of Input Files  *****

 -- Input File:  ABCDEF.DAT
PATHRAE-RAD(PC)  Version 2.2d  February 1995
   Date:  2- 4-2015
   Time: 21:47:56
```

```
pWAC RAD – January, 2015 EMDF in UBCV

*****  Mirror Image of Input Files  *****

-- Input File:  ABCDEF.DAT
pWAC RAD – January, 2015 EMDF in UBCV
10, 0., 100., 200., 300., 400.,500.,700.,1000.,1200.,1500.
60,0,2
1,2, 2,3,
0.0, 243.19, 486.37, 4.91E+05, 1., 476., 0.
1800., 6., 0., 0., 0., 0., 0.315, 0.
20, 2, 0, 1, 1, 0
3.35, 16.16, 1.91E+06, 1., 0., 1600., 0.40, 0.705, 0.90, 1.
1.0E-7, 8000., 0.705, 100., 1.0E+00, 0.01
240., 5.56E-04, 0.22, 0.02, 3.0E-4, 20., 0.01
4, 6.3, 0.23, 0., 1.1E-06, 0.01, 0., 0., 0., 0., 0.
0, 0, 0, 0, 0, 0, 0
1, 0, 0, 1
0.0109, 4.27, 0.25, 7.0, 0.025, 24., 0.00001, 1., 0., 0.25

-- Input File:  BRCDCF.DAT
101,Ac-227   4.07E-03,  8.14E-01,  1.65E-08,
102,Ag-108m  8.51E-06,  2.74E-05,  1.81E-04,
103,Al-26    1.30E-05,  7.40E-05,  2.88E-04,
104,Am-241   7.40E-04,  1.55E-01,  2.72E-06,
105,Am-243   7.40E-04,  1.52E-01,  5.59E-06,
106,Ba-133   5.55E-06,  1.15E-05,  4.35E-05,
107,Bi-207   4.81E-06,  2.07E-05,  1.69E-04,
108,C-14     2.15E-06,  2.29E-08,  1.48E-09,
109,Cf-249   1.30E-03,  2.59E-01,  3.68E-05,
110,Cf-250   5.92E-04,  1.26E-01,  6.21E-08,
111,Cf-251   1.33E-03,  2.63E-01,  1.32E-05,
112,Cl-36    3.44E-06,  2.70E-05,  1.31E-06,
113,Cm-243   5.55E-04,  1.15E-01,  1.38E-05,
114,Cm-244   4.44E-04,  9.99E-02,  7.52E-08,
115,Cm-245   7.77E-04,  1.55E-01,  9.39E-06,
116,Cm-246   7.77E-04,  1.55E-01,  6.72E-08,
117,Cm-247   7.03E-04,  1.44E-01,  3.49E-05,
118,Cm-248   2.85E-03,  5.55E-01,  1.42E-04,
119,Co-60    1.26E-05,  3.70E-05,  2.68E-04,
120,Cs-135   7.40E-06,  2.55E-06,  3.14E-09,
121,Cs-137   4.81E-05,  1.70E-05,  3.49E-07,
122,Eu-150   4.81E-06,  1.96E-04,  1.66E-04,
123,Eu-152   5.18E-06,  1.55E-04,  1.26E-04,
124,Eu-154   7.40E-06,  1.96E-04,  1.37E-04,
125,H-3      1.55E-07,  1.52E-07,  0.00E+00,
126,I-129    4.07E-04,  2.74E-04,  2.28E-06,
127,K-40     2.29E-05,  7.77E-06,  2.38E-05,
128,Nb-93m   4.44E-07,  1.89E-06,  7.96E-08,
129,Nb-94    6.29E-06,  4.07E-05,  1.74E-04,
130,Ni-59    2.33E-07,  4.81E-07,  0.00E+00,
131,Ni-63    5.55E-07,  1.78E-06,  0.00E+00,
132,Np-237   4.07E-04,  8.51E-02,  2.94E-06,
133,Pa-231   2.63E-03,  5.18E-01,  4.41E-06,
134,Pb-210   2.55E-03,  4.07E-03,  2.49E-07,
135,Pd-107   1.37E-07,  3.15E-07,  0.00E+00,
136,Pu-238   8.51E-04,  1.70E-01,  7.31E-08,
137,Pu-239   9.25E-04,  1.85E-01,  3.31E-08,
138,Pu-240   9.25E-04,  1.85E-01,  7.01E-08,
139,Pu-241   1.78E-05,  3.33E-03,  2.01E-10,
140,Pu-242   8.88E-04,  1.78E-01,  5.81E-08,
141,Pu-244   8.88E-04,  1.74E-01,  2.36E-06,
142,Ra-226   1.04E-03,  1.30E-02,  7.13E-07,
143,Ra-228   2.55E-03,  9.62E-03,  0.00E+00,
144,Se-79    1.07E-05,  4.07E-06,  1.91E-09,
145,Si-32    2.07E-06,  6.29E-05,  2.92E-09,
146,Sm-151   3.63E-07,  1.48E-05,  4.13E-10,
147,Sn-121m  1.41E-06,  1.67E-05,  4.20E-07,
148,Sn-126   1.74E-05,  1.04E-04,  5.62E-06,
149,Sr-90    1.04E-04,  1.33E-04,  1.91E-07,
150,Tc-99    2.37E-06,  1.48E-05,  7.55E-09,
151,Th-229   1.81E-03,  2.63E-01,  9.21E-06,
152,Th-230   7.77E-04,  5.18E-02,  7.43E-08,
153,Th-232   8.51E-04,  9.25E-02,  5.31E-08,
154,U-232    1.22E-03,  2.89E-02,  9.42E-08,
155,U-233    1.89E-04,  1.33E-02,  6.99E-08,
156,U-234    1.81E-04,  1.30E-02,  6.84E-08,
157,U-235    1.74E-04,  1.15E-02,  1.63E-05,
158,U-236    1.74E-04,  1.18E-02,  5.87E-08,
159,U-238    1.67E-04,  1.07E-02,  4.94E-08,
```

```
160,Zr-93    4.07E-06,  3.70E-05,  0.00E+00,

-- Input File:  INVNTRY.DAT
101,  2.18E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ac-227
102,  1.27E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ag-108m
103,  7.16E+05,  1.91E+06,      43.5,       0.1,       0.0,       0.0,       1.0,            Al-26
104,  4.32E+02,  1.91E+06,      22.2,       0.2,       0.0,       0.0,       1.0,            Am-241
105,  7.38E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Am-243
106,  1.07E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ba-133
107,  3.80E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Bi-207
108,  5.73E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            C-14
109,  3.51E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-249
110,  1.31E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-250
111,  8.98E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-251
112,  3.01E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cl-36
113,  2.85E+01,  1.91E+06,      22.0,       0.2,       0.0,       0.0,       1.0,            Cm-243
114,  1.81E+01,  1.91E+06,      43.5,       0.1,       0.0,       0.0,       1.0,            Cm-244
115,  8.50E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-245
116,  4.73E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-246
117,  1.56E+07,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-247
118,  3.39E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-248
119,  5.27E+00,  1.91E+06,       9.2,       1.3,       0.0,       0.0,       1.0,            Co-60
120,  2.30E+06,  1.91E+06,      12.1,       0.7,       0.0,       0.0,       1.0,            Cs-135
121,  3.00E+01,  1.91E+06,      12.8,       0.6,       0.0,       0.0,       1.0,            Cs-137
122,  3.42E+01,  1.91E+06,      14.0,       0.5,       0.0,       0.0,       1.0,            Eu-150
123,  1.33E+01,  1.91E+06,      12.5,       0.7,       0.0,       0.0,       1.0,            Eu-152
124,  8.80E+00,  1.91E+06,      32.1,       0.1,       0.0,       0.0,       1.0,            Eu-154
125,  1.24E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            H-3
126,  1.57E+07,  1.91E+06,      62.0,       0.0,       0.0,       0.0,       1.0,            I-129
127,  1.28E+09,  1.91E+06,      10.3,       1.0,       0.0,       0.0,       1.0,            K-40
128,  1.36E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Nb-93m
129,  2.03E+04,  1.91E+06,      11.6,       0.8,       0.0,       0.0,       1.0,            Nb-94
130,  7.50E+04,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ni-59
131,  9.60E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ni-63
132,  2.14E+06,  1.91E+06,      34.9,       0.1,       0.0,       0.0,       1.0,            Np-237
133,  3.28E+04,  1.91E+06,      22.8,       0.1,       0.0,       0.0,       1.0,            Pa-231
134,  2.23E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pb-210
135,  6.50E+06,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pd-107
136,  8.77E+01,  1.91E+06,      45.3,       0.1,       0.0,       0.0,       1.0,            Pu-238
137,  2.41E+04,  1.91E+06,      25.8,       0.1,       0.0,       0.0,       1.0,            Pu-239
138,  6.54E+03,  1.91E+06,      46.3,       0.1,       0.0,       0.0,       1.0,            Pu-240
139,  1.44E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-241
140,  3.76E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-242
141,  8.26E+07,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-244
142,  1.60E+03,  1.91E+06,      21.5,       0.2,       0.0,       0.0,       1.0,            Ra-226
143,  5.75E+00,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ra-228
144,  6.50E+04,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Se-79
145,  4.50E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Si-32
146,  9.00E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sm-151
147,  5.50E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sn-121m
148,  1.00E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sn-126
149,  2.91E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sr-90
150,  2.13E+05,  1.91E+06,      29.2,       0.1,       0.0,       0.0,       1.0,            Tc-99
151,  7.34E+03,  1.91E+06,      28.8,       0.1,       0.0,       0.0,       1.0,            Th-229
152,  7.70E+04,  1.91E+06,      30.3,       0.1,       0.0,       0.0,       1.0,            Th-230
153,  1.41E+10,  1.91E+06,      35.5,       0.1,       0.0,       0.0,       1.0,            Th-232
154,  7.20E+01,  1.91E+06,      25.7,       0.0,       0.0,       0.0,       1.0,            U-232
155,  1.59E+05,  1.91E+06,      25.7,       0.1,       0.0,       0.0,       1.0,            U-233
156,  2.45E+05,  1.91E+06,      35.5,       0.1,       0.0,       0.0,       1.0,            U-234
157,  7.04E+08,  1.91E+06,      21.6,       0.2,       0.0,       0.0,       1.0,            U-235
158,  2.34E+07,  1.91E+06,      36.6,       0.1,       0.0,       0.0,       1.0,            U-236
159,  4.47E+09,  1.91E+06,      12.0,       0.7,       0.0,       0.0,       1.0,            U-238
160,  1.53E+06,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Zr-93

-- Input File:  RQSITE.DAT
101, -1.50E+03,  1.50E+02,  1.50E+03,       Ac-227
102, -4.50E+01,  4.50E+00,  4.50E+01,       Ag-108m
103, -3.00E+03,  3.00E+02,  3.00E+03,       Al-26
104, -4.00E+01,  4.00E+00,  4.00E+01,       Am-241
105, -4.00E+01,  4.00E+00,  4.00E+01,       Am-243
106, -6.00E+01,  6.00E+00,  6.00E+01,       Ba-133
107, -5.00E+02,  5.00E+01,  5.00E+02,       Bi-207
108, -1.09E+00,  1.09E-01,  1.09E+00,       C-14
109, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-249
110, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-250
111, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-251
112, -2.50E-01,  2.50E-02,  2.50E-01,       Cl-36
113, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-243
114, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-244
115, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-245
116, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-246
```

```
117, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-247
118, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-248
119, -3.00E+03,  3.00E+02,  3.00E+03,       Co-60
120, -3.00E+03,  3.00E+02,  3.00E+03,       Cs-135
121, -3.00E+03,  3.00E+02,  3.00E+03,       Cs-137
122, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-150
123, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-152
124, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-154
125, -1.99E-01,  1.99E-02,  1.99E-01,       H-3
126, -4.00E+00,  4.00E-01,  4.00E+00,       I-129
127, -3.00E+01,  3.00E+00,  3.00E+01,       K-40
128, -1.00E+02,  1.00E+01,  1.00E+02,       Nb-93m
129, -1.00E+02,  1.00E+01,  1.00E+02,       Nb-94
130, -2.00E+03,  2.00E+02,  2.00E+03,       Ni-59
131, -2.00E+03,  2.00E+02,  2.00E+03,       Ni-63
132, -4.00E+01,  4.00E+00,  4.00E+01,       Np-237
133, -4.00E+02,  4.00E+01,  4.00E+02,       Pa-231
134, -1.00E+02,  1.00E+01,  1.00E+02,       Pb-210
135, -2.00E+03,  2.00E+02,  2.00E+03,       Pd-107
136, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-238
137, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-239
138, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-240
139, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-241
140, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-242
141, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-244
142, -3.00E+03,  3.00E+02,  3.00E+03,       Ra-226
143, -3.00E+03,  3.00E+02,  3.00E+03,       Ra-228
144, -3.00E+02,  3.00E+01,  3.00E+02,       Se-79
145, -3.00E+01,  3.00E+00,  3.00E+01,       Si-32
146, -1.00E+03,  1.00E+02,  1.00E+03,       Sm-151
147, -1.00E+02,  1.00E+01,  1.00E+02,       Sn-121m
148, -1.00E+02,  1.00E+01,  1.00E+02,       Sn-126
149, -3.00E+01,  3.00E+00,  3.00E+01,       Sr-90
150, -1.50E+00,  1.50E-01,  1.50E+00,       Tc-99
151, -3.00E+03,  3.00E+02,  3.00E+03,       Th-229
152, -3.00E+03,  3.00E+02,  3.00E+03,       Th-230
153, -3.00E+03,  3.00E+02,  3.00E+03,       Th-232
154, -5.00E+01,  5.00E+00,  5.00E+01,       U-232
155, -5.00E+01,  5.00E+00,  5.00E+01,       U-233
156, -5.00E+01,  5.00E+00,  5.00E+01,       U-234
157, -5.00E+01,  5.00E+00,  5.00E+01,       U-235
158, -5.00E+01,  5.00E+00,  5.00E+01,       U-236
159, -5.00E+01,  5.00E+00,  5.00E+01,       U-238
160, -5.00E+01,  5.00E+00,  5.00E+01,       Zr-93

-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
0.0,   2160.,  24.,     1440.,     1.,  0.83
50.,   6.,     48.,      480.,    48.
.05,  0.0008,  60.,        8.,    50.
14.,    176., 110.,        0.,    95.,   730., 0.0
Ac-227      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-05,  0.00E+00
Ag-108m     0.25,1.50E-01,  1.50E-02,  2.50E-02,       0.0,  3.00E-03,  0.00E+00
Al-26       0.25,4.00E-03,  4.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Am-241      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  5.00E-05,  0.00E+00
Am-243      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  5.00E-05,  0.00E+00
Ba-133      0.25,5.00E-03,  5.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Bi-207      0.25,1.00E-01,  1.00E-02,  5.00E-04,       0.0,  2.00E-03,  0.00E+00
C-14        0.25,5.50E+00,  5.50E-01,  1.20E-02,       0.0,  3.10E-02,  0.00E+00
Cf-249      0.25,1.00E-03,  1.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Cf-250      0.25,1.00E-03,  1.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Cf-251      0.25,1.00E-03,  1.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Cl-36       0.25,2.00E+01,  2.00E+00,  2.00E-02,       0.0,  6.00E-02,  0.00E+00
Cm-243      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-244      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-245      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-246      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-247      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-248      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Co-60       0.25,8.00E-02,  8.00E-03,  2.00E-03,       0.0,  2.00E-02,  0.00E+00
Cs-135      0.25,4.00E-02,  4.00E-03,  8.00E-03,       0.0,  3.00E-02,  0.00E+00
Cs-137      0.25,4.00E-02,  4.00E-03,  8.00E-03,       0.0,  3.00E-02,  0.00E+00
Eu-150      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-03,  0.00E+00
Eu-152      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-03,  0.00E+00
Eu-154      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-03,  0.00E+00
H-3         0.25,4.80E+00,  4.80E-01,  1.00E-02,       0.0,  1.20E-02,  0.00E+00
I-129       0.25,2.00E-02,  2.00E-03,  1.00E-02,       0.0,  7.00E-03,  0.00E+00
K-40        0.25,3.00E-01,  3.00E-02,  7.00E-03,       0.0,  2.00E-02,  0.00E+00
Nb-93m      0.25,1.00E-02,  1.00E-03,  2.00E-06,       0.0,  3.00E-07,  0.00E+00
Nb-94       0.25,1.00E-02,  1.00E-03,  2.00E-06,       0.0,  3.00E-07,  0.00E+00
```

| | | | | | | |
|---|---|---|---|---|---|---|
| Ni-59 | 0.25,5.00E-02, | 5.00E-03, | 2.00E-02, | 0.0, | 5.00E-03, | 0.00E+00 |
| Ni-63 | 0.25,5.00E-02, | 5.00E-03, | 2.00E-02, | 0.0, | 5.00E-03, | 0.00E+00 |
| Np-237 | 0.25,2.00E-02, | 2.00E-03, | 5.00E-06, | 0.0, | 1.00E-03, | 0.00E+00 |
| Pa-231 | 0.25,1.00E-02, | 1.00E-03, | 5.00E-06, | 0.0, | 5.00E-03, | 0.00E+00 |
| Pb-210 | 0.25,1.00E-02, | 1.00E-03, | 3.00E-04, | 0.0, | 8.00E-04, | 0.00E+00 |
| Pd-107 | 0.25,1.00E-01, | 1.00E-02, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Pu-238 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-239 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-240 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-241 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-242 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-244 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Ra-226 | 0.25,4.00E-02, | 4.00E-03, | 1.00E-03, | 0.0, | 1.00E-03, | 0.00E+00 |
| Ra-228 | 0.25,4.00E-02, | 4.00E-03, | 1.00E-03, | 0.0, | 1.00E-03, | 0.00E+00 |
| Se-79 | 0.25,1.00E-01, | 1.00E-02, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Si-32 | 0.25,0.00E+00, | 0.00E+00, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Sm-151 | 0.25,2.50E-03, | 2.50E-04, | 2.00E-05, | 0.0, | 2.00E-03, | 0.00E+00 |
| Sn-121m | 0.25,2.50E-03, | 2.50E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Sn-126 | 0.25,2.50E-03, | 2.50E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Sr-90 | 0.25,3.00E-01, | 3.00E-02, | 2.00E-03, | 0.0, | 8.00E-03, | 0.00E+00 |
| Tc-99 | 0.25,5.00E+00, | 5.00E-01, | 1.00E-03, | 0.0, | 1.00E-04, | 0.00E+00 |
| Th-229 | 0.25,1.00E-03, | 1.00E-04, | 5.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Th-230 | 0.25,1.00E-03, | 1.00E-04, | 5.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Th-232 | 0.25,1.00E-03, | 1.00E-04, | 5.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| U-232 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-233 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-234 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-235 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-236 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-238 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| Zr-93 | 0.25,1.00E-03, | 1.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |

1

TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

| NUCLIDE | UT(J,1) RIVER L/YR | UT(J,2) WELL L/YR | UT(J,3) EROSION L/YR | UT(J,4) BATHTUB L/YR | UT(J,5) SPILLAGE L/YR | UT(J,6) FOOD KG/YR |
|---|---|---|---|---|---|---|
| Ac-227 | 7.302E+02 | 7.300E+02 | 7.302E+02 | 7.302E+02 | 7.302E+02 | 1.064E-02 |
| Ag-108m | 9.092E+02 | 7.300E+02 | 9.092E+02 | 9.094E+02 | 9.092E+02 | 6.956E+00 |
| Al-26 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.301E+02 | 1.686E-02 |
| Am-241 | 7.303E+02 | 7.300E+02 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 4.283E-03 |
| Am-243 | 7.303E+02 | 7.300E+02 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 4.284E-03 |
| Ba-133 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 2.090E-02 |
| Bi-207 | 7.428E+02 | 7.300E+02 | 7.428E+02 | 7.428E+02 | 7.428E+02 | 7.603E-01 |
| C-14 | 9.564E+02 | 7.300E+02 | 9.564E+02 | 9.564E+02 | 9.564E+02 | 0.000E+00 |
| Cf-249 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.214E-03 |
| Cf-250 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.187E-03 |
| Cf-251 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.215E-03 |
| Cl-36 | 1.148E+03 | 7.300E+02 | 1.148E+03 | 1.150E+03 | 1.150E+03 | 2.280E+03 |
| Cm-243 | 7.301E+02 | 7.300E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.231E-03 |
| Cm-244 | 7.301E+02 | 7.300E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.224E-03 |
| Cm-245 | 7.301E+02 | 7.300E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.245E-03 |
| Cm-246 | 7.301E+02 | 7.300E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.245E-03 |
| Cm-247 | 7.301E+02 | 7.300E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.245E-03 |
| Cm-248 | 7.301E+02 | 7.300E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.245E-03 |
| Co-60 | 8.375E+02 | 7.300E+02 | 8.375E+02 | 8.375E+02 | 8.375E+02 | 2.653E+00 |
| Cs-135 | 9.253E+02 | 7.300E+02 | 9.253E+02 | 9.267E+02 | 9.378E+02 | 2.242E+00 |
| Cs-137 | 9.251E+02 | 7.300E+02 | 9.251E+02 | 9.251E+02 | 9.251E+02 | 2.236E+00 |
| Eu-150 | 7.396E+02 | 7.300E+02 | 7.396E+02 | 7.396E+02 | 7.396E+02 | 1.717E-02 |
| Eu-152 | 7.396E+02 | 7.300E+02 | 7.396E+02 | 7.396E+02 | 7.396E+02 | 1.710E-02 |
| Eu-154 | 7.396E+02 | 7.300E+02 | 7.396E+02 | 7.396E+02 | 7.396E+02 | 1.705E-02 |
| H-3 | 1.166E+03 | 7.300E+02 | 1.166E+03 | 1.166E+03 | 1.166E+03 | 0.000E+00 |
| I-129 | 8.293E+02 | 7.300E+02 | 8.293E+02 | 8.293E+02 | 8.293E+02 | 5.749E-01 |
| K-40 | 8.712E+02 | 7.300E+02 | 8.712E+02 | 8.724E+02 | 8.725E+02 | 1.240E+01 |
| Nb-93m | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.191E-02 |
| Nb-94 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.219E-02 |
| Ni-59 | 8.858E+02 | 7.300E+02 | 8.858E+02 | 8.870E+02 | 8.944E+02 | 2.070E+00 |
| Ni-63 | 8.857E+02 | 7.300E+02 | 8.857E+02 | 8.858E+02 | 8.857E+02 | 2.068E+00 |
| Np-237 | 7.348E+02 | 7.300E+02 | 7.348E+02 | 7.348E+02 | 7.348E+02 | 1.109E-01 |
| Pa-231 | 7.538E+02 | 7.300E+02 | 7.538E+02 | 7.538E+02 | 7.539E+02 | 1.082E-01 |
| Pb-210 | 7.358E+02 | 7.300E+02 | 7.358E+02 | 7.358E+02 | 7.358E+02 | 5.708E-02 |
| Pd-107 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.303E+02 | 7.319E+02 | 4.215E-01 |
| Pu-238 | 7.305E+02 | 7.300E+02 | 7.305E+02 | 7.305E+02 | 7.305E+02 | 4.344E-03 |
| Pu-239 | 7.305E+02 | 7.300E+02 | 7.305E+02 | 7.305E+02 | 7.305E+02 | 4.349E-03 |
| Pu-240 | 7.305E+02 | 7.300E+02 | 7.305E+02 | 7.305E+02 | 7.305E+02 | 4.349E-03 |
| Pu-241 | 7.305E+02 | 7.300E+02 | 7.305E+02 | 7.305E+02 | 7.305E+02 | 4.322E-03 |
| Pu-242 | 7.305E+02 | 7.300E+02 | 7.305E+02 | 7.305E+02 | 7.305E+02 | 4.349E-03 |

```
  Pu-244      7.305E+02 7.300E+02 7.305E+02 7.305E+02 7.305E+02 4.349E-03
  Ra-226      7.414E+02 7.300E+02 7.414E+02 7.415E+02 7.414E+02 2.826E-01
  Ra-228      7.413E+02 7.300E+02 7.413E+02 7.413E+02 7.413E+02 2.787E-01
  Se-79       7.300E+02 7.300E+02 7.300E+02 7.302E+02 7.304E+02 4.215E-01
  Si-32       7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 0.000E+00
  Sm-151      7.396E+02 7.300E+02 7.396E+02 7.396E+02 7.396E+02 1.720E-02
  Sn-121m     7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 1.052E-02
  Sn-126      7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 1.054E-02
  Sr-90       7.812E+02 7.300E+02 7.812E+02 7.812E+02 7.811E+02 5.336E+00
  Tc-99       7.371E+02 7.300E+02 7.371E+02 7.372E+02 7.372E+02 2.938E+01
  Th-229      7.305E+02 7.300E+02 7.305E+02 7.305E+02 7.305E+02 4.355E-03
  Th-230      7.305E+02 7.300E+02 7.305E+02 7.305E+02 7.305E+02 4.355E-03
  Th-232      7.305E+02 7.300E+02 7.305E+02 7.305E+02 7.305E+02 4.355E-03
  U-232       7.356E+02 7.300E+02 7.356E+02 7.356E+02 7.356E+02 1.394E-02
  U-233       7.356E+02 7.300E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-234       7.356E+02 7.300E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-235       7.356E+02 7.300E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-236       7.356E+02 7.300E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-238       7.356E+02 7.300E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  Zr-93       7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 4.215E-03


**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 80 ISOTOPES IN THE DOSE FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS 10
YEARS TO BE CALCULATED ARE ...

      .00   100.00   200.00   300.00   400.00
   500.00   700.00  1000.00  1200.00  1500.00

THERE ARE  60 ISOTOPES IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  2

           PATHWAY           TYPE OF USAGE
                            FOR UPTAKE FACTORS
   1  GROUNDWATER TO RIVER         2
   2  GROUNDWATER TO WELL          3

TIME OF OPERATION OF WASTE FACILITY IN YEARS                    0.
LENGTH OF REPOSITORY (M)                                      243.
WIDTH OF REPOSITORY (M)                                       486.
RIVER FLOW RATE (M**3/YR)                                       4.91E+05
STREAM FLOW RATE (M**3/YR)                                      1.00E+00
DISTANCE TO RIVER (M)                                         476.

OPERATIONAL SPILLAGE FRACTION                                   0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                 1800.
LONGITUDINAL DISPERSIVITY (M)                                   6.00E+00
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)              0.00E+00
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION               20
FLAG FOR GAMMA PATHWAY OPTIONS                                  2
FLAG FOR GAMMA BUILDUP CALCULATION                              0
FLAG FOR ATMOSPHERIC PATHWAY                                    0

COVER THICKNESS OVER WASTE (M)                                  3.35
THICKNESS OF WASTE IN PITS (M)                                 16.16
TOTAL WASTE VOLUME (M**3)                                       1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)                            1.
DISTANCE TO WELL -- Y COORDINATE (M)                            0.
DENSITY OF WASTE (KG/M**3)                                   1600.

FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE                  .400
FRACTION OF YEAR SPENT IN DIRECT RADIATION FIELD                 .705
DEPTH OF PLANT ROOT ZONE (M)                                     .900
AREAL DENSITY OF PLANTS (KG/M**2)                               1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)                           1.00E-07
ANNUAL ADULT BREATHING RATE (M**3/YR)                        8000.

FRACTION OF YEAR EXPOSED TO DUST                                 .705
CANISTER LIFETIME (YEARS)                                     100.
INVENTORY SCALING FACTOR                                        1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)                       240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)                5.56E-04
RADON EMANATING POWER OF THE WASTE                              2.20E-01

DIFFUSION COEFF. OF RADON IN WASTE (CM**2/SEC)                  2.00E-02
DIFFUSION COEFF. OF RN IN CONCRETE (CM**2/SEC)                  3.00E-04
THICKNESS OF CONCRETE SLAB FLOOR (CM)                          20.0
```

| | |
|---|---|
| DIFFUSION COEFF. OF RADON IN COVER (CM**2/SEC) | 1.00E-02 |
| ATMOSPHERIC STABILITY CLASS | 4 |
| AVERAGE WIND SPEED (M/S) | 6.30 |
| FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR | .2300 |
| RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M) | .0 |
| DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S) | 1.10E-06 |
| DEPOSITION VELOCITY (M/S) | .0100 |
| STACK HEIGHT (M) | .0 |
| STACK INSIDE DIAMETER (M) | .00 |
| STACK GAS VELOCITY (M/S) | .0 |
| HEAT EMISSION RATE FROM BURNING (CAL/S) | 0.00E+00 |
| DECAY CHAIN FLAGS 0 0 0 0 0 0 | 0 |
| FLAG FOR INPUT SUMMARY PRINTOUT | 1 |
| FLAG FOR DIRECTION OF TRENCH FILLING | 0 |
| FLAG FOR GROUNDWATER PATHWAY OPTIONS | 1 |
| AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M) | 1.09E-02 |
| DEGREE OF SOIL SATURATION | 1.000 |
| RESIDUAL SOIL SATURATION | .000 |
| PERMEABILITY OF VERTICAL ZONE (M/YR) | .32 |
| SOIL NUMBER | .000 |
| POROSITY OF AQUIFER | .25 |
| POROSITY OF UNSATURATED ZONE | .25 |
| DISTANCE FROM AQUIFER TO WASTE (M) | 7.0 |
| AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR) | 2.50E-02 |
| HORIZONTAL VELOCITY OF AQUIFER (M/YR) | 4.3 |
| LENGTH OF PERFORATED WELL CASING (M) | 24.000 |
| SURFACE EROSION RATE (M/YR) | 1.000E-05 |
| LEACH RATE SCALING FACTOR | 1.000E+00 |
| ANNUAL RUNOFF OF PRECIPITATION (M) | 0.00E+00 |

| NUCLIDE | INGESTION DOSE FACTORS (MREM/PCI) | INHALATION DOSE FACTORS (MREM/PCI) | DIRECT GAMMA DOSE FACTORS (MREM-M2/PCI-YR) | HALF LIFE (YR) |
|---|---|---|---|---|
| Ac-227 | 4.070E-03 | 8.140E-01 | 1.650E-08 | 2.180E+01 |
| Ag-108m | 8.510E-06 | 2.740E-05 | 1.810E-04 | 1.270E+02 |
| Al-26 | 1.300E-05 | 7.400E-05 | 2.880E-04 | 7.160E+05 |
| Am-241 | 7.400E-04 | 1.550E-01 | 2.720E-06 | 4.320E+02 |
| Am-243 | 7.400E-04 | 1.520E-01 | 5.590E-06 | 7.380E+03 |
| Ba-133 | 5.550E-06 | 1.150E-05 | 4.350E-05 | 1.070E+01 |
| Bi-207 | 4.810E-06 | 2.070E-05 | 1.690E-04 | 3.800E+01 |
| C-14 | 2.150E-06 | 2.290E-08 | 1.480E-09 | 5.730E+03 |
| Cf-249 | 1.300E-03 | 2.590E-01 | 3.680E-05 | 3.510E+02 |
| Cf-250 | 5.920E-04 | 1.260E-01 | 6.210E-08 | 1.310E+01 |
| Cf-251 | 1.330E-03 | 2.630E-01 | 1.320E-05 | 8.980E+02 |
| Cl-36 | 3.440E-06 | 2.700E-05 | 1.310E-06 | 3.010E+05 |
| Cm-243 | 5.550E-04 | 1.150E-01 | 1.380E-05 | 2.850E+01 |
| Cm-244 | 4.440E-04 | 9.990E-02 | 7.520E-08 | 1.810E+01 |
| Cm-245 | 7.770E-04 | 1.550E-01 | 9.390E-06 | 8.500E+03 |
| Cm-246 | 7.770E-04 | 1.550E-01 | 6.720E-08 | 4.730E+03 |
| Cm-247 | 7.030E-04 | 1.440E-01 | 3.490E-05 | 1.560E+07 |
| Cm-248 | 2.850E-03 | 5.550E-01 | 1.420E-04 | 3.390E+05 |
| Co-60 | 1.260E-05 | 3.700E-05 | 2.680E-04 | 5.270E+00 |
| Cs-135 | 7.400E-06 | 2.550E-06 | 3.140E-09 | 2.300E+06 |
| Cs-137 | 4.810E-05 | 1.700E-05 | 3.490E-07 | 3.000E+01 |
| Eu-150 | 4.810E-06 | 1.960E-04 | 1.660E-04 | 3.420E+01 |
| Eu-152 | 5.180E-06 | 1.550E-04 | 1.260E-04 | 1.330E+01 |
| Eu-154 | 7.400E-06 | 1.960E-04 | 1.370E-04 | 8.800E+00 |
| H-3 | 1.550E-07 | 1.520E-07 | 0.000E+00 | 1.240E+01 |
| I-129 | 4.070E-04 | 2.740E-04 | 2.280E-06 | 1.570E+07 |
| K-40 | 2.290E-05 | 7.770E-06 | 2.380E-05 | 1.280E+09 |
| Nb-93m | 4.440E-07 | 1.890E-06 | 7.960E-08 | 1.360E+01 |
| Nb-94 | 6.290E-06 | 4.070E-05 | 1.740E-04 | 2.030E+04 |
| Ni-59 | 2.330E-07 | 4.810E-07 | 0.000E+00 | 7.500E+04 |
| Ni-63 | 5.550E-07 | 1.780E-06 | 0.000E+00 | 9.600E+01 |
| Np-237 | 4.070E-04 | 8.510E-02 | 2.940E-06 | 2.140E+06 |
| Pa-231 | 2.630E-03 | 5.180E-01 | 4.410E-06 | 3.280E+04 |
| Pb-210 | 2.550E-03 | 4.070E-03 | 2.490E-07 | 2.230E+01 |
| Pd-107 | 1.370E-07 | 3.150E-07 | 0.000E+00 | 6.500E+06 |
| Pu-238 | 8.510E-04 | 1.700E-01 | 7.310E-08 | 8.770E+01 |
| Pu-239 | 9.250E-04 | 1.850E-01 | 3.310E-08 | 2.410E+04 |
| Pu-240 | 9.250E-04 | 1.850E-01 | 7.010E-08 | 6.540E+03 |
| Pu-241 | 1.780E-05 | 3.330E-03 | 2.010E-10 | 1.440E+01 |
| Pu-242 | 8.880E-04 | 1.780E-01 | 5.810E-08 | 3.760E+05 |
| Pu-244 | 8.880E-04 | 1.740E-01 | 2.360E-06 | 8.260E+07 |

| | | | | |
|---|---|---|---|---|
| Ra-226 | 1.040E-03 | 1.300E-02 | 7.130E-07 | 1.600E+03 |
| Ra-228 | 2.550E-03 | 9.620E-03 | 0.000E+00 | 5.750E+00 |
| Se-79 | 1.070E-05 | 4.070E-06 | 1.910E-09 | 6.500E+04 |
| Si-32 | 2.070E-06 | 6.290E-05 | 2.920E-09 | 4.500E+02 |
| Sm-151 | 3.630E-07 | 1.480E-05 | 4.130E-10 | 9.000E+01 |
| Sn-121m | 1.410E-06 | 1.670E-05 | 4.200E-07 | 5.500E+01 |
| Sn-126 | 1.740E-05 | 1.040E-04 | 5.620E-06 | 1.000E+05 |
| Sr-90 | 1.040E-04 | 1.330E-04 | 1.910E-07 | 2.910E+01 |
| Tc-99 | 2.370E-06 | 1.480E-05 | 7.550E-09 | 2.130E+05 |
| Th-229 | 1.810E-03 | 2.630E-01 | 9.210E-06 | 7.340E+03 |
| Th-230 | 7.770E-04 | 5.180E-02 | 7.430E-08 | 7.700E+04 |
| Th-232 | 8.510E-04 | 9.250E-02 | 5.310E-08 | 1.410E+10 |
| U-232 | 1.220E-03 | 2.890E-02 | 9.420E-08 | 7.200E+01 |
| U-233 | 1.890E-04 | 1.330E-02 | 6.990E-08 | 1.590E+05 |
| U-234 | 1.810E-04 | 1.300E-02 | 6.840E-08 | 2.450E+05 |
| U-235 | 1.740E-04 | 1.150E-02 | 1.630E-05 | 7.040E+08 |
| U-236 | 1.740E-04 | 1.180E-02 | 5.870E-08 | 2.340E+07 |
| U-238 | 1.670E-04 | 1.070E-02 | 4.940E-08 | 4.470E+09 |
| Zr-93 | 4.070E-06 | 3.700E-05 | 0.000E+00 | 1.530E+06 |

| NUCLIDE | VOLATILITY FRACTION | GAMMA ENERGY (MEV) | GAMMA ATTENUATION (1/M) |
|---|---|---|---|
| Ac-227 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ag-108m | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Al-26 | 0.000E+00 | 1.000E-01 | 4.350E+01 |
| Am-241 | 0.000E+00 | 2.000E-01 | 2.220E+01 |
| Am-243 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ba-133 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Bi-207 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| C-14 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cf-249 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cf-250 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cf-251 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cl-36 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-243 | 0.000E+00 | 2.000E-01 | 2.200E+01 |
| Cm-244 | 0.000E+00 | 1.000E-01 | 4.350E+01 |
| Cm-245 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-246 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-247 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-248 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Co-60 | 0.000E+00 | 1.300E+00 | 9.200E+00 |
| Cs-135 | 0.000E+00 | 7.000E-01 | 1.210E+01 |
| Cs-137 | 0.000E+00 | 6.000E-01 | 1.280E+01 |
| Eu-150 | 0.000E+00 | 5.000E-01 | 1.400E+01 |
| Eu-152 | 0.000E+00 | 7.000E-01 | 1.250E+01 |
| Eu-154 | 0.000E+00 | 1.000E-01 | 3.210E+01 |
| H-3 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| I-129 | 0.000E+00 | 0.000E+00 | 6.200E+01 |
| K-40 | 0.000E+00 | 1.000E+00 | 1.030E+01 |
| Nb-93m | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Nb-94 | 0.000E+00 | 8.000E-01 | 1.160E+01 |
| Ni-59 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ni-63 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Np-237 | 0.000E+00 | 1.000E-01 | 3.490E+01 |
| Pa-231 | 0.000E+00 | 1.000E-01 | 2.280E+01 |
| Pb-210 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pd-107 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pu-238 | 0.000E+00 | 1.000E-01 | 4.530E+01 |
| Pu-239 | 0.000E+00 | 1.000E-01 | 2.580E+01 |
| Pu-240 | 0.000E+00 | 1.000E-01 | 4.630E+01 |
| Pu-241 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pu-242 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pu-244 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ra-226 | 0.000E+00 | 2.000E-01 | 2.150E+01 |
| Ra-228 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Se-79 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Si-32 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sm-151 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sn-121m | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sn-126 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sr-90 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Tc-99 | 0.000E+00 | 1.000E-01 | 2.920E+01 |
| Th-229 | 0.000E+00 | 1.000E-01 | 2.880E+01 |
| Th-230 | 0.000E+00 | 1.000E-01 | 3.030E+01 |
| Th-232 | 0.000E+00 | 1.000E-01 | 3.550E+01 |
| U-232 | 0.000E+00 | 0.000E+00 | 2.570E+01 |
| U-233 | 0.000E+00 | 1.000E-01 | 2.570E+01 |
| U-234 | 0.000E+00 | 1.000E-01 | 3.550E+01 |

| | | | |
|---|---|---|---|
| U-235 | 0.000E+00 | 2.000E-01 | 2.160E+01 |
| U-236 | 0.000E+00 | 1.000E-01 | 3.660E+01 |
| U-238 | 0.000E+00 | 7.000E-01 | 1.200E+01 |
| Zr-93 | 0.000E+00 | 0.000E+00 | 0.000E+00 |

| NUCLIDE | INPUT LEACH RATE (1/YR) | FINAL LEACH RATE (1/YR) | SOLUBILITY (MOLE/L) | INPUT INVENTORY (CI) |
|---|---|---|---|---|
| Ac-227 | -1.500E+03 | 2.810E-07 | 0.000E+00 | 1.910E+06 |
| Ag-108m | -4.500E+01 | 9.336E-06 | 0.000E+00 | 1.910E+06 |
| Al-26 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Am-241 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Am-243 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Ba-133 | -6.000E+01 | 7.008E-06 | 0.000E+00 | 1.910E+06 |
| Bi-207 | -5.000E+02 | 8.429E-07 | 0.000E+00 | 1.910E+06 |
| C-14 | -1.090E+00 | 3.383E-04 | 0.000E+00 | 1.910E+06 |
| Cf-249 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cf-250 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cf-251 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cl-36 | -2.500E-01 | 1.038E-03 | 0.000E+00 | 1.910E+06 |
| Cm-243 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-244 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-245 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-246 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-247 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-248 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Co-60 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Cs-135 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Cs-137 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Eu-150 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Eu-152 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Eu-154 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| H-3 | -1.990E-01 | 1.187E-03 | 0.000E+00 | 1.910E+06 |
| I-129 | -4.000E+00 | 1.014E-04 | 0.000E+00 | 1.910E+06 |
| K-40 | -3.000E+01 | 1.398E-05 | 0.000E+00 | 1.910E+06 |
| Nb-93m | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Nb-94 | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Ni-59 | -2.000E+03 | 2.108E-07 | 0.000E+00 | 1.910E+06 |
| Ni-63 | -2.000E+03 | 2.108E-07 | 0.000E+00 | 1.910E+06 |
| Np-237 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pa-231 | -4.000E+02 | 1.054E-06 | 0.000E+00 | 1.910E+06 |
| Pb-210 | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Pd-107 | -2.000E+03 | 2.108E-07 | 0.000E+00 | 1.910E+06 |
| Pu-238 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-239 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-240 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-241 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-242 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-244 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Ra-226 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Ra-228 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Se-79 | -3.000E+02 | 1.404E-06 | 0.000E+00 | 1.910E+06 |
| Si-32 | -3.000E+01 | 1.398E-05 | 0.000E+00 | 1.910E+06 |
| Sm-151 | -1.000E+03 | 4.215E-07 | 0.000E+00 | 1.910E+06 |
| Sn-121m | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Sn-126 | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Sr-90 | -3.000E+01 | 1.398E-05 | 0.000E+00 | 1.910E+06 |
| Tc-99 | -1.500E+00 | 2.545E-04 | 0.000E+00 | 1.910E+06 |
| Th-229 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Th-230 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Th-232 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| U-232 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-233 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-234 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-235 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-236 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-238 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| Zr-93 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |

| NUCLIDE | AQUIFER SORPTION | AQUIFER RETARDATION | VERTICAL SORPTION | VERTICAL RETARDATION |
|---|---|---|---|---|
| Ac-227 | 1.500E+02 | 1.081E+03 | 1.500E+03 | 1.080E+04 |
| Ag-108m | 4.500E+00 | 3.340E+01 | 4.500E+01 | 3.250E+02 |
| Al-26 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Am-241 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Am-243 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Ba-133 | 6.000E+00 | 4.420E+01 | 6.000E+01 | 4.330E+02 |
| Bi-207 | 5.000E+01 | 3.610E+02 | 5.000E+02 | 3.601E+03 |

| | | | | |
|---|---|---|---|---|
| C-14 | 1.090E-01 | 1.785E+00 | 1.090E+00 | 8.848E+00 |
| Cf-249 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cf-250 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cf-251 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cl-36 | 2.500E-02 | 1.180E+00 | 2.500E-01 | 2.800E+00 |
| Cm-243 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-244 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-245 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-246 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-247 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-248 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Co-60 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Cs-135 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Cs-137 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Eu-150 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Eu-152 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Eu-154 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| H-3 | 1.990E-02 | 1.143E+00 | 1.990E-01 | 2.433E+00 |
| I-129 | 4.000E-01 | 3.880E+00 | 4.000E+00 | 2.980E+01 |
| K-40 | 3.000E+00 | 2.260E+01 | 3.000E+01 | 2.170E+02 |
| Nb-93m | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Nb-94 | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Ni-59 | 2.000E+02 | 1.441E+03 | 2.000E+03 | 1.440E+04 |
| Ni-63 | 2.000E+02 | 1.441E+03 | 2.000E+03 | 1.440E+04 |
| Np-237 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pa-231 | 4.000E+01 | 2.890E+02 | 4.000E+02 | 2.881E+03 |
| Pb-210 | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Pd-107 | 2.000E+02 | 1.441E+03 | 2.000E+03 | 1.440E+04 |
| Pu-238 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-239 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-240 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-241 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-242 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-244 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Ra-226 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Ra-228 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Se-79 | 3.000E+01 | 2.170E+02 | 3.000E+02 | 2.161E+03 |
| Si-32 | 3.000E+00 | 2.260E+01 | 3.000E+01 | 2.170E+02 |
| Sm-151 | 1.000E+02 | 7.210E+02 | 1.000E+03 | 7.201E+03 |
| Sn-121m | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Sn-126 | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Sr-90 | 3.000E+00 | 2.260E+01 | 3.000E+01 | 2.170E+02 |
| Tc-99 | 1.500E-01 | 2.080E+00 | 1.500E+00 | 1.180E+01 |
| Th-229 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Th-230 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Th-232 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| U-232 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-233 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-234 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-235 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-236 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-238 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| Zr-93 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |

| | BIOACCUMULATION FACTORS | | | |
|---|---|---|---|---|
| NUCLIDE | SOIL-PLANT Bv | SOIL-PLANT Br | FORAGE-MILK Fm (D/L) | FORAGE-MEAT Ff (D/KG) |
| Ac-227 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-05 |
| Ag-108m | 1.500E-01 | 1.500E-02 | 2.500E-02 | 3.000E-03 |
| Al-26 | 4.000E-03 | 4.000E-04 | 0.000E+00 | 0.000E+00 |
| Am-241 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 5.000E-05 |
| Am-243 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 5.000E-05 |
| Ba-133 | 5.000E-03 | 5.000E-04 | 0.000E+00 | 0.000E+00 |
| Bi-207 | 1.000E-01 | 1.000E-02 | 5.000E-04 | 2.000E-03 |
| C-14 | 5.500E+00 | 5.500E-01 | 1.200E-02 | 3.100E-02 |
| Cf-249 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |
| Cf-250 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |
| Cf-251 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |
| Cl-36 | 2.000E+01 | 2.000E+00 | 2.000E-02 | 6.000E-02 |
| Cm-243 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-244 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-245 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-246 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-247 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-248 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Co-60 | 8.000E-02 | 8.000E-03 | 2.000E-03 | 2.000E-02 |
| Cs-135 | 4.000E-02 | 4.000E-03 | 8.000E-03 | 3.000E-02 |
| Cs-137 | 4.000E-02 | 4.000E-03 | 8.000E-03 | 3.000E-02 |
| Eu-150 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |

| | | | | |
|---|---|---|---|---|
| Eu-152 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| Eu-154 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| H-3 | 4.800E+00 | 4.800E-01 | 1.000E-02 | 1.200E-02 |
| I-129 | 2.000E-02 | 2.000E-03 | 1.000E-02 | 7.000E-03 |
| K-40 | 3.000E-01 | 3.000E-02 | 7.000E-03 | 2.000E-02 |
| Nb-93m | 1.000E-02 | 1.000E-03 | 2.000E-06 | 3.000E-07 |
| Nb-94 | 1.000E-02 | 1.000E-03 | 2.000E-06 | 3.000E-07 |
| Ni-59 | 5.000E-02 | 5.000E-03 | 2.000E-02 | 5.000E-03 |
| Ni-63 | 5.000E-02 | 5.000E-03 | 2.000E-02 | 5.000E-03 |
| Np-237 | 2.000E-02 | 2.000E-03 | 5.000E-06 | 1.000E-03 |
| Pa-231 | 1.000E-02 | 1.000E-03 | 5.000E-06 | 5.000E-03 |
| Pb-210 | 1.000E-02 | 1.000E-03 | 3.000E-04 | 8.000E-04 |
| Pd-107 | 1.000E-01 | 1.000E-02 | 0.000E+00 | 0.000E+00 |
| Pu-238 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-239 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-240 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-241 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-242 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-244 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Ra-226 | 4.000E-02 | 4.000E-03 | 1.000E-03 | 1.000E-03 |
| Ra-228 | 4.000E-02 | 4.000E-03 | 1.000E-03 | 1.000E-03 |
| Se-79 | 1.000E-01 | 1.000E-02 | 0.000E+00 | 0.000E+00 |
| Si-32 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sm-151 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| Sn-121m | 2.500E-03 | 2.500E-04 | 0.000E+00 | 0.000E+00 |
| Sn-126 | 2.500E-03 | 2.500E-04 | 0.000E+00 | 0.000E+00 |
| Sr-90 | 3.000E-01 | 3.000E-02 | 2.000E-03 | 8.000E-03 |
| Tc-99 | 5.000E+00 | 5.000E-01 | 1.000E-03 | 1.000E-04 |
| Th-229 | 1.000E-03 | 1.000E-04 | 5.000E-06 | 1.000E-04 |
| Th-230 | 1.000E-03 | 1.000E-04 | 5.000E-06 | 1.000E-04 |
| Th-232 | 1.000E-03 | 1.000E-04 | 5.000E-06 | 1.000E-04 |
| U-232 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-233 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-234 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-235 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-236 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-238 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| Zr-93 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

| NUCLIDE | PEAK CONCENTRATION (CI/M**3) | PEAK TIME (YR) | AVERAGE DOSE AT PEAK TIME (MREM/YR) | AVERAGE RISK AT PEAK TIME (HE/YR) |
|---|---|---|---|---|
| Ac-227 | | > 15000.0 | | |
| Ag-108m | | > 15000.0 | | |
| Al-26 | | > 15000.0 | | |
| Am-241 | | > 15000.0 | | |
| Am-243 | | > 15000.0 | | |
| Ba-133 | | > 15000.0 | | |
| Bi-207 | | > 15000.0 | | |
| C-14 | 9.16E-04 | 2971.6 | 1.88E+03 | 5.28E-04 |
| Cf-249 | | > 15000.0 | | |
| Cf-250 | | > 15000.0 | | |
| Cf-251 | | > 15000.0 | | |
| Cl-36 | 4.03E-03 | 1208.0 | 1.59E+04 | 4.45E-03 |
| Cm-243 | | > 15000.0 | | |
| Cm-244 | | > 15000.0 | | |
| Cm-245 | | > 15000.0 | | |
| Cm-246 | | > 15000.0 | | |
| Cm-247 | | > 15000.0 | | |
| Cm-248 | | > 15000.0 | | |
| Co-60 | | > 15000.0 | | |
| Cs-135 | | > 15000.0 | | |
| Cs-137 | | > 15000.0 | | |
| Eu-150 | | > 15000.0 | | |
| Eu-152 | | > 15000.0 | | |
| Eu-154 | | > 15000.0 | | |
| H-3 | 5.56E-26 | 913.2 | 1.00E-20 | 2.81E-27 |
| I-129 | 3.94E-04 | 9992.3 | 1.33E+05 | 3.73E-02 |
| K-40 | | > 15000.0 | | |
| Nb-93m | | > 15000.0 | | |
| Nb-94 | | > 15000.0 | | |
| Ni-59 | | > 15000.0 | | |
| Ni-63 | | > 15000.0 | | |

| | | | | |
|---|---|---|---|---|
| Np-237 | | > 15000.0 | | |
| Pa-231 | | > 15000.0 | | |
| Pb-210 | | > 15000.0 | | |
| Pd-107 | | > 15000.0 | | |
| Pu-238 | | > 15000.0 | | |
| Pu-239 | | > 15000.0 | | |
| Pu-240 | | > 15000.0 | | |
| Pu-241 | | > 15000.0 | | |
| Pu-242 | | > 15000.0 | | |
| Pu-244 | | > 15000.0 | | |
| Ra-226 | | > 15000.0 | | |
| Ra-228 | | > 15000.0 | | |
| Se-79 | | > 15000.0 | | |
| Si-32 | | > 15000.0 | | |
| Sm-151 | | > 15000.0 | | |
| Sn-121m | | > 15000.0 | | |
| Sn-126 | | > 15000.0 | | |
| Sr-90 | | > 15000.0 | | |
| Tc-99 | 9.77E-04 | 3937.3 | 1.71E+03 | 4.78E-04 |
| Th-229 | | > 15000.0 | | |
| Th-230 | | > 15000.0 | | |
| Th-232 | | > 15000.0 | | |
| U-232 | | > 15000.0 | | |
| U-233 | | > 15000.0 | | |
| U-234 | | > 15000.0 | | |
| U-235 | | > 15000.0 | | |
| U-236 | | > 15000.0 | | |
| U-238 | | > 15000.0 | | |
| Zr-93 | | > 15000.0 | | |

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 2 *****
***** WELL AT 1.0 M *****

| NUCLIDE | PEAK CONCENTRATION (CI/M**3) | PEAK TIME (YR) | AVERAGE DOSE AT PEAK TIME (MREM/YR) | AVERAGE RISK AT PEAK TIME (HE/YR) |
|---|---|---|---|---|
| Ac-227 | | > 15000.0 | | |
| Ag-108m | | > 15000.0 | | |
| Al-26 | | > 15000.0 | | |
| Am-241 | | > 15000.0 | | |
| Am-243 | | > 15000.0 | | |
| Ba-133 | | > 15000.0 | | |
| Bi-207 | | > 15000.0 | | |
| C-14 | 3.72E-02 | 2736.6 | 5.84E+04 | 1.63E-02 |
| Cf-249 | | > 15000.0 | | |
| Cf-250 | | > 15000.0 | | |
| Cf-251 | | > 15000.0 | | |
| Cl-36 | 1.59E-01 | 1024.4 | 3.98E+05 | 1.12E-01 |
| Cm-243 | | > 15000.0 | | |
| Cm-244 | | > 15000.0 | | |
| Cm-245 | | > 15000.0 | | |
| Cm-246 | | > 15000.0 | | |
| Cm-247 | | > 15000.0 | | |
| Cm-248 | | > 15000.0 | | |
| Co-60 | | > 15000.0 | | |
| Cs-135 | | > 15000.0 | | |
| Cs-137 | | > 15000.0 | | |
| Eu-150 | | > 15000.0 | | |
| Eu-152 | | > 15000.0 | | |
| Eu-154 | | > 15000.0 | | |
| H-3 | 2.15E-21 | 797.8 | 2.43E-16 | 6.81E-23 |
| I-129 | 1.55E-02 | 9506.7 | 4.62E+06 | 1.29E+00 |
| K-40 | | > 15000.0 | | |
| Nb-93m | | > 15000.0 | | |
| Nb-94 | | > 15000.0 | | |
| Ni-59 | | > 15000.0 | | |
| Ni-63 | | > 15000.0 | | |
| Np-237 | | > 15000.0 | | |
| Pa-231 | | > 15000.0 | | |
| Pb-210 | | > 15000.0 | | |
| Pd-107 | | > 15000.0 | | |
| Pu-238 | | > 15000.0 | | |
| Pu-239 | | > 15000.0 | | |
| Pu-240 | | > 15000.0 | | |
| Pu-241 | | > 15000.0 | | |
| Pu-242 | | > 15000.0 | | |

| | | | | |
|---|---|---|---|---|
| Pu-244 | | > 15000.0 | | |
| Ra-226 | | > 15000.0 | | |
| Ra-228 | | > 15000.0 | | |
| Se-79 | | > 15000.0 | | |
| Si-32 | | > 15000.0 | | |
| Sm-151 | | > 15000.0 | | |
| Sn-121m | | > 15000.0 | | |
| Sn-126 | | > 15000.0 | | |
| Sr-90 | | > 15000.0 | | |
| Tc-99 | 3.86E-02 | 3633.7 | 6.67E+04 | 1.87E-02 |
| Th-229 | | > 15000.0 | | |
| Th-230 | | > 15000.0 | | |
| Th-232 | | > 15000.0 | | |
| U-232 | | > 15000.0 | | |
| U-233 | | > 15000.0 | | |
| U-234 | | > 15000.0 | | |
| U-235 | | > 15000.0 | | |
| U-236 | | > 15000.0 | | |
| U-238 | | > 15000.0 | | |
| Zr-93 | | > 15000.0 | | |

---

# LONGER TIME RUN OUTPUT:

```
PATHRAE-RAD(PC)  Version 2.2d  February 1995
  Date:  2- 5-2015
  Time:  9:52:57

pWAC RAD – January, 2015 EMDF in UBCV

*****  Mirror Image of Input Files  *****

-- Input File:  ABCDEF.DAT
pWAC RAD – January, 2015 EMDF in UBCV
2, 1000., 100000.
60,0,5
1,2,
0.0, 243.19, 486.37, 4.91E+05, 1., 476., 0.
1800., 6., 0., 0., 0., 0., 0.315, 0.
20, 2, 0, 1, 1
3.35, 16.16, 1.91E+06, 476., 0., 1600., 0.40, 0.705, 0.90, 1.
1.0E-7, 8000., 0.705, 100., 1.0E+00, 0.01
240., 5.56E-04, 0.22, 0.02, 3.0E-4, 20., 0.01
4, 6.3, 0.23, 0., 1.1E-06, 0.01, 0., 0., 0., 0., 0.
0, 0, 0, 0, 0, 0, 0
1, 0, 0, 1
0.0109, 4.27, 0.25, 7.0, 0.025, 24., 0.00001, 1., 0., 0.25

-- Input File:  BRCDCF.DAT
101,Ac-227   4.07E-03,  8.14E-01,  1.65E-08,
102,Ag-108m  8.51E-06,  2.74E-05,  1.81E-04,
103,Al-26    1.30E-05,  7.40E-05,  2.88E-04,
104,Am-241   7.40E-04,  1.55E-01,  2.72E-06,
105,Am-243   7.40E-04,  1.52E-01,  5.59E-06,
106,Ba-133   5.55E-06,  1.15E-05,  4.35E-05,
107,Bi-207   4.81E-06,  2.07E-05,  1.69E-04,
108,C-14     2.15E-06,  2.29E-08,  1.48E-09,
109,Cf-249   1.30E-03,  2.59E-01,  3.68E-05,
110,Cf-250   5.92E-04,  1.26E-01,  6.21E-08,
111,Cf-251   1.33E-03,  2.63E-01,  1.32E-05,
112,Cl-36    3.44E-06,  2.70E-05,  1.31E-06,
113,Cm-243   5.55E-04,  1.15E-01,  1.38E-05,
114,Cm-244   4.44E-04,  9.99E-02,  7.52E-08,
115,Cm-245   7.77E-04,  1.55E-01,  9.39E-06,
116,Cm-246   7.77E-04,  1.55E-01,  6.72E-08,
117,Cm-247   7.03E-04,  1.44E-01,  3.49E-05,
118,Cm-248   2.85E-03,  5.55E-01,  1.42E-04,
119,Co-60    1.26E-05,  3.70E-05,  2.68E-04,
120,Cs-135   7.40E-06,  2.55E-06,  3.14E-09,
121,Cs-137   4.81E-05,  1.70E-05,  3.49E-07,
122,Eu-150   4.81E-06,  1.96E-04,  1.66E-04,
123,Eu-152   5.18E-06,  1.55E-04,  1.26E-04,
124,Eu-154   7.40E-06,  1.96E-04,  1.37E-04,
125,H-3      1.55E-07,  1.52E-07,  0.00E+00,
126,I-129    4.07E-04,  2.74E-04,  2.28E-06,
127,K-40     2.29E-05,  7.77E-06,  2.38E-05,
128,Nb-93m   4.44E-07,  1.89E-06,  7.96E-08,
129,Nb-94    6.29E-06,  4.07E-05,  1.74E-04,
130,Ni-59    2.33E-07,  4.81E-07,  0.00E+00,
131,Ni-63    5.55E-07,  1.78E-06,  0.00E+00,
132,Np-237   4.07E-04,  8.51E-02,  2.94E-06,
```

```
133,Pa-231   2.63E-03,  5.18E-01,  4.41E-06,
134,Pb-210   2.55E-03,  4.07E-03,  2.49E-07,
135,Pd-107   1.37E-07,  3.15E-07,  0.00E+00,
136,Pu-238   8.51E-04,  1.70E-01,  7.31E-08,
137,Pu-239   9.25E-04,  1.85E-01,  3.31E-08,
138,Pu-240   9.25E-04,  1.85E-01,  7.01E-08,
139,Pu-241   1.78E-05,  3.33E-03,  2.01E-10,
140,Pu-242   8.88E-04,  1.78E-01,  5.81E-08,
141,Pu-244   8.88E-04,  1.74E-01,  2.36E-06,
142,Ra-226   1.04E-03,  1.30E-02,  7.13E-07,
143,Ra-228   2.55E-03,  9.62E-03,  0.00E+00,
144,Se-79    1.07E-05,  4.07E-06,  1.91E-09,
145,Si-32    2.07E-06,  6.29E-05,  2.92E-09,
146,Sm-151   3.63E-07,  1.48E-05,  4.13E-10,
147,Sn-121m  1.41E-06,  1.67E-05,  4.20E-07,
148,Sn-126   1.74E-05,  1.04E-04,  5.62E-06,
149,Sr-90    1.04E-04,  1.33E-04,  1.91E-07,
150,Tc-99    2.37E-06,  1.48E-05,  7.55E-09,
151,Th-229   1.81E-03,  2.63E-01,  9.21E-06,
152,Th-230   7.77E-04,  5.18E-02,  7.43E-08,
153,Th-232   8.51E-04,  9.25E-02,  5.31E-08,
154,U-232    1.22E-03,  2.89E-02,  9.42E-08,
155,U-233    1.89E-04,  1.33E-02,  6.99E-08,
156,U-234    1.81E-04,  1.30E-02,  6.84E-08,
157,U-235    1.74E-04,  1.15E-02,  1.63E-05,
158,U-236    1.74E-04,  1.18E-02,  5.87E-08,
159,U-238    1.67E-04,  1.07E-02,  4.94E-08,
160,Zr-93    4.07E-06,  3.70E-05,  0.00E+00,

-- Input File:  INVNTRY.DAT
101,  2.18E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ac-227
102,  1.27E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ag-108m
103,  7.16E+05,  1.91E+06,      43.5,       0.1,       0.0,       0.0,       1.0,            Al-26
104,  4.32E+02,  1.91E+06,      22.2,       0.2,       0.0,       0.0,       1.0,            Am-241
105,  7.38E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Am-243
106,  1.07E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ba-133
107,  3.80E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Bi-207
108,  5.73E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            C-14
109,  3.51E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-249
110,  1.31E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-250
111,  8.98E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-251
112,  3.01E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cl-36
113,  2.85E+01,  1.91E+06,      22.0,       0.2,       0.0,       0.0,       1.0,            Cm-243
114,  1.81E+01,  1.91E+06,      43.5,       0.1,       0.0,       0.0,       1.0,            Cm-244
115,  8.50E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-245
116,  4.73E+03,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-246
117,  1.56E+07,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-247
118,  3.39E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-248
119,  5.27E+00,  1.91E+06,       9.2,       1.3,       0.0,       0.0,       1.0,            Co-60
120,  2.30E+06,  1.91E+06,      12.1,       0.7,       0.0,       0.0,       1.0,            Cs-135
121,  3.00E+01,  1.91E+06,      12.8,       0.6,       0.0,       0.0,       1.0,            Cs-137
122,  3.42E+01,  1.91E+06,      14.0,       0.5,       0.0,       0.0,       1.0,            Eu-150
123,  1.33E+01,  1.91E+06,      12.5,       0.7,       0.0,       0.0,       1.0,            Eu-152
124,  8.80E+00,  1.91E+06,      32.1,       0.1,       0.0,       0.0,       1.0,            Eu-154
125,  1.24E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            H-3
126,  1.57E+07,  1.91E+06,      62.0,       0.0,       0.0,       0.0,       1.0,            I-129
127,  1.28E+09,  1.91E+06,      10.3,       1.0,       0.0,       0.0,       1.0,            K-40
128,  1.36E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Nb-93m
129,  2.03E+04,  1.91E+06,      11.6,       0.8,       0.0,       0.0,       1.0,            Nb-94
130,  7.50E+04,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ni-59
131,  9.60E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ni-63
132,  2.14E+06,  1.91E+06,      34.9,       0.1,       0.0,       0.0,       1.0,            Np-237
133,  3.28E+04,  1.91E+06,      22.8,       0.1,       0.0,       0.0,       1.0,            Pa-231
134,  2.23E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pb-210
135,  6.50E+06,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pd-107
136,  8.77E+01,  1.91E+06,      45.3,       0.1,       0.0,       0.0,       1.0,            Pu-238
137,  2.41E+04,  1.91E+06,      25.8,       0.1,       0.0,       0.0,       1.0,            Pu-239
138,  6.54E+03,  1.91E+06,      46.3,       0.1,       0.0,       0.0,       1.0,            Pu-240
139,  1.44E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-241
140,  3.76E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-242
141,  8.26E+07,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-244
142,  1.60E+03,  1.91E+06,      21.5,       0.2,       0.0,       0.0,       1.0,            Ra-226
143,  5.75E+00,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ra-228
144,  6.50E+04,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Se-79
145,  4.50E+02,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Si-32
146,  9.00E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sm-151
147,  5.50E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sn-121m
148,  1.00E+05,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sn-126
149,  2.91E+01,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sr-90
150,  2.13E+05,  1.91E+06,      29.2,       0.1,       0.0,       0.0,       1.0,            Tc-99
151,  7.34E+03,  1.91E+06,      28.8,       0.1,       0.0,       0.0,       1.0,            Th-229
```

```
152,  7.70E+04,  1.91E+06,      30.3,       0.1,       0.0,       0.0,       1.0,            Th-230
153,  1.41E+10,  1.91E+06,      35.5,       0.1,       0.0,       0.0,       1.0,            Th-232
154,  7.20E+01,  1.91E+06,      25.7,       0.0,       0.0,       0.0,       1.0,            U-232
155,  1.59E+05,  1.91E+06,      25.7,       0.1,       0.0,       0.0,       1.0,            U-233
156,  2.45E+05,  1.91E+06,      35.5,       0.1,       0.0,       0.0,       1.0,            U-234
157,  7.04E+08,  1.91E+06,      21.6,       0.2,       0.0,       0.0,       1.0,            U-235
158,  2.34E+07,  1.91E+06,      36.6,       0.1,       0.0,       0.0,       1.0,            U-236
159,  4.47E+09,  1.91E+06,      12.0,       0.7,       0.0,       0.0,       1.0,            U-238
160,  1.53E+06,  1.91E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Zr-93

-- Input File:  RQSITE.DAT
101, -1.50E+03,  1.50E+02,  1.50E+03,       Ac-227
102, -4.50E+01,  4.50E+00,  4.50E+01,       Ag-108m
103, -3.00E+03,  3.00E+02,  3.00E+03,       Al-26
104, -4.00E+01,  4.00E+00,  4.00E+01,       Am-241
105, -4.00E+01,  4.00E+00,  4.00E+01,       Am-243
106, -6.00E+01,  6.00E+00,  6.00E+01,       Ba-133
107, -5.00E+02,  5.00E+01,  5.00E+02,       Bi-207
108, -1.09E+00,  1.09E-01,  1.09E+00,       C-14
109, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-249
110, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-250
111, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-251
112, -2.50E-01,  2.50E-02,  2.50E-01,       Cl-36
113, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-243
114, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-244
115, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-245
116, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-246
117, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-247
118, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-248
119, -3.00E+03,  3.00E+02,  3.00E+03,       Co-60
120, -3.00E+03,  3.00E+02,  3.00E+03,       Cs-135
121, -3.00E+03,  3.00E+02,  3.00E+03,       Cs-137
122, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-150
123, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-152
124, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-154
125, -1.99E-01,  1.99E-02,  1.99E-01,       H-3
126, -4.00E+00,  4.00E-01,  4.00E+00,       I-129
127, -3.00E+01,  3.00E+00,  3.00E+01,       K-40
128, -1.00E+02,  1.00E+01,  1.00E+02,       Nb-93m
129, -1.00E+02,  1.00E+01,  1.00E+02,       Nb-94
130, -2.00E+03,  2.00E+02,  2.00E+03,       Ni-59
131, -2.00E+03,  2.00E+02,  2.00E+03,       Ni-63
132, -4.00E+01,  4.00E+00,  4.00E+01,       Np-237
133, -4.00E+02,  4.00E+01,  4.00E+02,       Pa-231
134, -1.00E+02,  1.00E+01,  1.00E+02,       Pb-210
135, -2.00E+03,  2.00E+02,  2.00E+03,       Pd-107
136, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-238
137, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-239
138, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-240
139, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-241
140, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-242
141, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-244
142, -3.00E+03,  3.00E+02,  3.00E+03,       Ra-226
143, -3.00E+03,  3.00E+02,  3.00E+03,       Ra-228
144, -3.00E+02,  3.00E+01,  3.00E+02,       Se-79
145, -3.00E+01,  3.00E+00,  3.00E+01,       Si-32
146, -1.00E+03,  1.00E+02,  1.00E+03,       Sm-151
147, -1.00E+02,  1.00E+01,  1.00E+02,       Sn-121m
148, -1.00E+02,  1.00E+01,  1.00E+02,       Sn-126
149, -3.00E+01,  3.00E+00,  3.00E+01,       Sr-90
150, -1.50E+00,  1.50E-01,  1.50E+00,       Tc-99
151, -3.00E+03,  3.00E+02,  3.00E+03,       Th-229
152, -3.00E+03,  3.00E+02,  3.00E+03,       Th-230
153, -3.00E+03,  3.00E+02,  3.00E+03,       Th-232
154, -5.00E+01,  5.00E+00,  5.00E+01,       U-232
155, -5.00E+01,  5.00E+00,  5.00E+01,       U-233
156, -5.00E+01,  5.00E+00,  5.00E+01,       U-234
157, -5.00E+01,  5.00E+00,  5.00E+01,       U-235
158, -5.00E+01,  5.00E+00,  5.00E+01,       U-236
159, -5.00E+01,  5.00E+00,  5.00E+01,       U-238
160, -5.00E+01,  5.00E+00,  5.00E+01,       Zr-93

-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
0.0,   2160.,  24.,     1440.,     1.,  0.83
50.,   6.,     48.,      480.,    48.
.05,  0.0008,  60.,        8.,    50.
14.,    176., 110.,        0.,    95.,   730., 0.0
Ac-227      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-05,  0.00E+00
Ag-108m     0.25,1.50E-01,  1.50E-02,  2.50E-02,       0.0,  3.00E-03,  0.00E+00
```

| | | | | | | |
|---|---|---|---|---|---|---|
| Al-26 | 0.25,4.00E-03, | 4.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Am-241 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 5.00E-05, | 0.00E+00 |
| Am-243 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 5.00E-05, | 0.00E+00 |
| Ba-133 | 0.25,5.00E-03, | 5.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Bi-207 | 0.25,1.00E-01, | 1.00E-02, | 5.00E-04, | 0.0, | 2.00E-03, | 0.00E+00 |
| C-14 | 0.25,5.50E+00, | 5.50E-01, | 1.20E-02, | 0.0, | 3.10E-02, | 0.00E+00 |
| Cf-249 | 0.25,1.00E-03, | 1.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Cf-250 | 0.25,1.00E-03, | 1.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Cf-251 | 0.25,1.00E-03, | 1.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Cl-36 | 0.25,2.00E+01, | 2.00E+00, | 2.00E-02, | 0.0, | 6.00E-02, | 0.00E+00 |
| Cm-243 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 2.00E-05, | 0.00E+00 |
| Cm-244 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 2.00E-05, | 0.00E+00 |
| Cm-245 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 2.00E-05, | 0.00E+00 |
| Cm-246 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 2.00E-05, | 0.00E+00 |
| Cm-247 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 2.00E-05, | 0.00E+00 |
| Cm-248 | 0.25,1.00E-03, | 1.00E-04, | 2.00E-06, | 0.0, | 2.00E-05, | 0.00E+00 |
| Co-60 | 0.25,8.00E-02, | 8.00E-03, | 2.00E-03, | 0.0, | 2.00E-02, | 0.00E+00 |
| Cs-135 | 0.25,4.00E-02, | 4.00E-03, | 8.00E-03, | 0.0, | 3.00E-02, | 0.00E+00 |
| Cs-137 | 0.25,4.00E-02, | 4.00E-03, | 8.00E-03, | 0.0, | 3.00E-02, | 0.00E+00 |
| Eu-150 | 0.25,2.50E-03, | 2.50E-04, | 2.00E-05, | 0.0, | 2.00E-03, | 0.00E+00 |
| Eu-152 | 0.25,2.50E-03, | 2.50E-04, | 2.00E-05, | 0.0, | 2.00E-03, | 0.00E+00 |
| Eu-154 | 0.25,2.50E-03, | 2.50E-04, | 2.00E-05, | 0.0, | 2.00E-03, | 0.00E+00 |
| H-3 | 0.25,4.80E+00, | 4.80E-01, | 1.00E-02, | 0.0, | 1.20E-02, | 0.00E+00 |
| I-129 | 0.25,2.00E-02, | 2.00E-03, | 1.00E-02, | 0.0, | 7.00E-03, | 0.00E+00 |
| K-40 | 0.25,3.00E-01, | 3.00E-02, | 7.00E-03, | 0.0, | 2.00E-02, | 0.00E+00 |
| Nb-93m | 0.25,1.00E-02, | 1.00E-03, | 2.00E-06, | 0.0, | 3.00E-07, | 0.00E+00 |
| Nb-94 | 0.25,1.00E-02, | 1.00E-03, | 2.00E-06, | 0.0, | 3.00E-07, | 0.00E+00 |
| Ni-59 | 0.25,5.00E-02, | 5.00E-03, | 2.00E-02, | 0.0, | 5.00E-03, | 0.00E+00 |
| Ni-63 | 0.25,5.00E-02, | 5.00E-03, | 2.00E-02, | 0.0, | 5.00E-03, | 0.00E+00 |
| Np-237 | 0.25,2.00E-02, | 2.00E-03, | 5.00E-06, | 0.0, | 1.00E-03, | 0.00E+00 |
| Pa-231 | 0.25,1.00E-02, | 1.00E-03, | 5.00E-06, | 0.0, | 5.00E-03, | 0.00E+00 |
| Pb-210 | 0.25,1.00E-02, | 1.00E-03, | 3.00E-04, | 0.0, | 8.00E-04, | 0.00E+00 |
| Pd-107 | 0.25,1.00E-01, | 1.00E-02, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Pu-238 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-239 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-240 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-241 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-242 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Pu-244 | 0.25,1.00E-03, | 1.00E-04, | 1.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Ra-226 | 0.25,4.00E-02, | 4.00E-03, | 1.00E-03, | 0.0, | 1.00E-03, | 0.00E+00 |
| Ra-228 | 0.25,4.00E-02, | 4.00E-03, | 1.00E-03, | 0.0, | 1.00E-03, | 0.00E+00 |
| Se-79 | 0.25,1.00E-01, | 1.00E-02, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Si-32 | 0.25,0.00E+00, | 0.00E+00, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Sm-151 | 0.25,2.50E-03, | 2.50E-04, | 2.00E-05, | 0.0, | 2.00E-03, | 0.00E+00 |
| Sn-121m | 0.25,2.50E-03, | 2.50E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Sn-126 | 0.25,2.50E-03, | 2.50E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |
| Sr-90 | 0.25,3.00E-01, | 3.00E-02, | 2.00E-03, | 0.0, | 8.00E-03, | 0.00E+00 |
| Tc-99 | 0.25,5.00E+00, | 5.00E-01, | 1.00E-03, | 0.0, | 1.00E-04, | 0.00E+00 |
| Th-229 | 0.25,1.00E-03, | 1.00E-04, | 5.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Th-230 | 0.25,1.00E-03, | 1.00E-04, | 5.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| Th-232 | 0.25,1.00E-03, | 1.00E-04, | 5.00E-06, | 0.0, | 1.00E-04, | 0.00E+00 |
| U-232 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-233 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-234 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-235 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-236 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| U-238 | 0.25,2.50E-03, | 2.50E-04, | 6.00E-04, | 0.0, | 3.40E-04, | 0.00E+00 |
| Zr-93 | 0.25,1.00E-03, | 1.00E-04, | 0.00E+00, | 0.0, | 0.00E+00, | 0.00E+00 |

1

TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

| NUCLIDE | UT(J,1) RIVER L/YR | UT(J,2) WELL L/YR | UT(J,3) EROSION L/YR | UT(J,4) BATHTUB L/YR | UT(J,5) SPILLAGE L/YR | UT(J,6) FOOD KG/YR |
|---|---|---|---|---|---|---|
| Ac-227 | 7.302E+02 | 7.302E+02 | 7.302E+02 | 7.302E+02 | 7.302E+02 | 1.064E-02 |
| Ag-108m | 9.092E+02 | 9.092E+02 | 9.092E+02 | 9.092E+02 | 9.092E+02 | 6.956E+00 |
| Al-26 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.302E+02 | 7.301E+02 | 1.686E-02 |
| Am-241 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 4.283E-03 |
| Am-243 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 7.303E+02 | 4.284E-03 |
| Ba-133 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 2.090E-02 |
| Bi-207 | 7.428E+02 | 7.428E+02 | 7.428E+02 | 7.428E+02 | 7.428E+02 | 7.603E-01 |
| C-14 | 9.564E+02 | 9.564E+02 | 9.564E+02 | 9.564E+02 | 9.564E+02 | 0.000E+00 |
| Cf-249 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.214E-03 |
| Cf-250 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.187E-03 |
| Cf-251 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 7.300E+02 | 4.215E-03 |
| Cl-36 | 1.150E+03 | 1.150E+03 | 1.148E+03 | 1.150E+03 | 1.150E+03 | 2.280E+03 |
| Cm-243 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 7.301E+02 | 4.231E-03 |

```
  Cm-244      7.301E+02 7.301E+02 7.301E+02 7.301E+02 7.301E+02 4.224E-03
  Cm-245      7.301E+02 7.301E+02 7.301E+02 7.301E+02 7.301E+02 4.245E-03
  Cm-246      7.301E+02 7.301E+02 7.301E+02 7.301E+02 7.301E+02 4.245E-03
  Cm-247      7.301E+02 7.301E+02 7.301E+02 7.301E+02 7.301E+02 4.245E-03
  Cm-248      7.301E+02 7.301E+02 7.301E+02 7.301E+02 7.301E+02 4.245E-03
  Co-60       8.375E+02 8.375E+02 8.375E+02 8.375E+02 8.375E+02 2.653E+00
  Cs-135      9.253E+02 9.253E+02 9.253E+02 9.465E+02 9.378E+02 2.242E+00
  Cs-137      9.251E+02 9.251E+02 9.251E+02 9.251E+02 9.251E+02 2.236E+00
  Eu-150      7.396E+02 7.396E+02 7.396E+02 7.396E+02 7.396E+02 1.717E-02
  Eu-152      7.396E+02 7.396E+02 7.396E+02 7.396E+02 7.396E+02 1.710E-02
  Eu-154      7.396E+02 7.396E+02 7.396E+02 7.396E+02 7.396E+02 1.705E-02
  H-3         1.166E+03 1.166E+03 1.166E+03 1.166E+03 1.166E+03 0.000E+00
  I-129       8.293E+02 8.293E+02 8.293E+02 8.293E+02 8.293E+02 5.749E-01
  K-40        8.712E+02 8.712E+02 8.712E+02 8.725E+02 8.725E+02 1.240E+01
  Nb-93m      7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 4.191E-02
  Nb-94       7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 4.219E-02
  Ni-59       8.858E+02 8.858E+02 8.858E+02 8.944E+02 8.944E+02 2.070E+00
  Ni-63       8.857E+02 8.857E+02 8.857E+02 8.857E+02 8.857E+02 2.068E+00
  Np-237      7.348E+02 7.348E+02 7.348E+02 7.348E+02 7.348E+02 1.109E-01
  Pa-231      7.538E+02 7.538E+02 7.538E+02 7.538E+02 7.539E+02 1.082E-01
  Pb-210      7.358E+02 7.358E+02 7.358E+02 7.358E+02 7.358E+02 5.708E-02
  Pd-107      7.300E+02 7.300E+02 7.300E+02 7.328E+02 7.319E+02 4.215E-01
  Pu-238      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.344E-03
  Pu-239      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.349E-03
  Pu-240      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.349E-03
  Pu-241      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.322E-03
  Pu-242      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.349E-03
  Pu-244      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.349E-03
  Ra-226      7.414E+02 7.414E+02 7.414E+02 7.414E+02 7.414E+02 2.826E-01
  Ra-228      7.413E+02 7.413E+02 7.413E+02 7.413E+02 7.413E+02 2.787E-01
  Se-79       7.300E+02 7.300E+02 7.300E+02 7.303E+02 7.304E+02 4.215E-01
  Si-32       7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 0.000E+00
  Sm-151      7.396E+02 7.396E+02 7.396E+02 7.396E+02 7.396E+02 1.720E-02
  Sn-121m     7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 1.052E-02
  Sn-126      7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 1.054E-02
  Sr-90       7.812E+02 7.812E+02 7.812E+02 7.811E+02 7.811E+02 5.336E+00
  Tc-99       7.371E+02 7.371E+02 7.371E+02 7.372E+02 7.372E+02 2.938E+01
  Th-229      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.355E-03
  Th-230      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.355E-03
  Th-232      7.305E+02 7.305E+02 7.305E+02 7.305E+02 7.305E+02 4.355E-03
  U-232       7.356E+02 7.356E+02 7.356E+02 7.356E+02 7.356E+02 1.394E-02
  U-233       7.356E+02 7.356E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-234       7.356E+02 7.356E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-235       7.356E+02 7.356E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-236       7.356E+02 7.356E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  U-238       7.356E+02 7.356E+02 7.356E+02 7.356E+02 7.356E+02 1.395E-02
  Zr-93       7.300E+02 7.300E+02 7.300E+02 7.300E+02 7.300E+02 4.215E-03


**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 80 ISOTOPES IN THE DOSE FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  2
YEARS TO BE CALCULATED ARE ...

  1000.00100000.00

THERE ARE  60 ISOTOPES IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  5

           PATHWAY           TYPE OF USAGE
                            FOR UPTAKE FACTORS
   1  GROUNDWATER TO RIVER         2
   0  3X,I2,2X,A22,6X,I2))2626       0
   0  3X,I2,2X,A22,6X,I2))2626       0
   0  3X,I2,2X,A22,6X,I2))2626       0
   0  3X,I2,2X,A22,6X,I2))2626       0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                      0.
LENGTH OF REPOSITORY (M)                                        243.
WIDTH OF REPOSITORY (M)                                         486.
RIVER FLOW RATE (M**3/YR)                                        4.91E+05
STREAM FLOW RATE (M**3/YR)                                       1.00E+00
DISTANCE TO RIVER (M)                                           476.

OPERATIONAL SPILLAGE FRACTION                                    0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                    1800.
LONGITUDINAL DISPERSIVITY (M)                                    6.00E+00
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)               0.00E+00
```

| | |
|---|---|
| NUMBER OF MESH POINTS FOR DISPERSION CALCULATION | 20 |
| FLAG FOR GAMMA PATHWAY OPTIONS | 2 |
| FLAG FOR GAMMA BUILDUP CALCULATION | 0 |
| FLAG FOR ATMOSPHERIC PATHWAY | 0 |
| COVER THICKNESS OVER WASTE (M) | 3.35 |
| THICKNESS OF WASTE IN PITS (M) | 16.16 |
| TOTAL WASTE VOLUME (M**3) | 1.910E+06 |
| DISTANCE TO WELL -- X COORDINATE (M) | 476. |
| DISTANCE TO WELL -- Y COORDINATE (M) | 0. |
| DENSITY OF WASTE (KG/M**3) | 1600. |
| FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE | .400 |
| FRACTION OF YEAR SPENT IN DIRECT RADIATION FIELD | .705 |
| DEPTH OF PLANT ROOT ZONE (M) | .900 |
| AREAL DENSITY OF PLANTS (KG/M**2) | 1.000 |
| AVERAGE DUST LOADING IN AIR (KG/M**3) | 1.00E-07 |
| ANNUAL ADULT BREATHING RATE (M**3/YR) | 8000. |
| FRACTION OF YEAR EXPOSED TO DUST | .705 |
| CANISTER LIFETIME (YEARS) | 100. |
| INVENTORY SCALING FACTOR | 1.00E+00 |
| HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM) | 240. |
| AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC) | 5.56E-04 |
| RADON EMANATING POWER OF THE WASTE | 2.20E-01 |
| DIFFUSION COEFF. OF RADON IN WASTE (CM**2/SEC) | 2.00E-02 |
| DIFFUSION COEFF. OF RN IN CONCRETE (CM**2/SEC) | 3.00E-04 |
| THICKNESS OF CONCRETE SLAB FLOOR (CM) | 20.0 |
| DIFFUSION COEFF. OF RADON IN COVER (CM**2/SEC) | 1.00E-02 |
| ATMOSPHERIC STABILITY CLASS | 4 |
| AVERAGE WIND SPEED (M/S) | 6.30 |
| FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR | .2300 |
| RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M) | .0 |
| DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S) | 1.10E-06 |
| DEPOSITION VELOCITY (M/S) | .0100 |
| STACK HEIGHT (M) | .0 |
| STACK INSIDE DIAMETER (M) | .00 |
| STACK GAS VELOCITY (M/S) | .0 |
| HEAT EMISSION RATE FROM BURNING (CAL/S) | 0.00E+00 |
| DECAY CHAIN FLAGS 0 0 0 0 0 0 | 0 |
| FLAG FOR INPUT SUMMARY PRINTOUT | 1 |
| FLAG FOR DIRECTION OF TRENCH FILLING | 0 |
| FLAG FOR GROUNDWATER PATHWAY OPTIONS | 1 |
| AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M) | 1.09E-02 |
| DEGREE OF SOIL SATURATION | 1.000 |
| RESIDUAL SOIL SATURATION | .000 |
| PERMEABILITY OF VERTICAL ZONE (M/YR) | .32 |
| SOIL NUMBER | .000 |
| POROSITY OF AQUIFER | .25 |
| POROSITY OF UNSATURATED ZONE | .25 |
| DISTANCE FROM AQUIFER TO WASTE (M) | 7.0 |
| AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR) | 2.50E-02 |
| HORIZONTAL VELOCITY OF AQUIFER (M/YR) | 4.3 |
| LENGTH OF PERFORATED WELL CASING (M) | 24.000 |
| SURFACE EROSION RATE (M/YR) | 1.000E-05 |
| LEACH RATE SCALING FACTOR | 1.000E+00 |
| ANNUAL RUNOFF OF PRECIPITATION (M) | 0.00E+00 |

| NUCLIDE | INGESTION DOSE FACTORS (MREM/PCI) | INHALATION DOSE FACTORS (MREM/PCI) | DIRECT GAMMA DOSE FACTORS (MREM-M2/PCI-YR) | HALF LIFE (YR) |
|---|---|---|---|---|
| Ac-227 | 4.070E-03 | 8.140E-01 | 1.650E-08 | 2.180E+01 |
| Ag-108m | 8.510E-06 | 2.740E-05 | 1.810E-04 | 1.270E+02 |
| Al-26 | 1.300E-05 | 7.400E-05 | 2.880E-04 | 7.160E+05 |
| Am-241 | 7.400E-04 | 1.550E-01 | 2.720E-06 | 4.320E+02 |
| Am-243 | 7.400E-04 | 1.520E-01 | 5.590E-06 | 7.380E+03 |
| Ba-133 | 5.550E-06 | 1.150E-05 | 4.350E-05 | 1.070E+01 |
| Bi-207 | 4.810E-06 | 2.070E-05 | 1.690E-04 | 3.800E+01 |
| C-14 | 2.150E-06 | 2.290E-08 | 1.480E-09 | 5.730E+03 |
| Cf-249 | 1.300E-03 | 2.590E-01 | 3.680E-05 | 3.510E+02 |
| Cf-250 | 5.920E-04 | 1.260E-01 | 6.210E-08 | 1.310E+01 |
| Cf-251 | 1.330E-03 | 2.630E-01 | 1.320E-05 | 8.980E+02 |
| Cl-36 | 3.440E-06 | 2.700E-05 | 1.310E-06 | 3.010E+05 |

| | | | | |
|---|---|---|---|---|
| Cm-243 | 5.550E-04 | 1.150E-01 | 1.380E-05 | 2.850E+01 |
| Cm-244 | 4.440E-04 | 9.990E-02 | 7.520E-08 | 1.810E+01 |
| Cm-245 | 7.770E-04 | 1.550E-01 | 9.390E-06 | 8.500E+03 |
| Cm-246 | 7.770E-04 | 1.550E-01 | 6.720E-08 | 4.730E+03 |
| Cm-247 | 7.030E-04 | 1.440E-01 | 3.490E-05 | 1.560E+07 |
| Cm-248 | 2.850E-03 | 5.550E-01 | 1.420E-04 | 3.390E+05 |
| Co-60 | 1.260E-05 | 3.700E-05 | 2.680E-04 | 5.270E+00 |
| Cs-135 | 7.400E-06 | 2.550E-06 | 3.140E-09 | 2.300E+06 |
| Cs-137 | 4.810E-05 | 1.700E-05 | 3.490E-07 | 3.000E+01 |
| Eu-150 | 4.810E-06 | 1.960E-04 | 1.660E-04 | 3.420E+01 |
| Eu-152 | 5.180E-06 | 1.550E-04 | 1.260E-04 | 1.330E+01 |
| Eu-154 | 7.400E-06 | 1.960E-04 | 1.370E-04 | 8.800E+00 |
| H-3 | 1.550E-07 | 1.520E-07 | 0.000E+00 | 1.240E+01 |
| I-129 | 4.070E-04 | 2.740E-04 | 2.280E-06 | 1.570E+07 |
| K-40 | 2.290E-05 | 7.770E-06 | 2.380E-05 | 1.280E+09 |
| Nb-93m | 4.440E-07 | 1.890E-06 | 7.960E-08 | 1.360E+01 |
| Nb-94 | 6.290E-06 | 4.070E-05 | 1.740E-04 | 2.030E+04 |
| Ni-59 | 2.330E-07 | 4.810E-07 | 0.000E+00 | 7.500E+04 |
| Ni-63 | 5.550E-07 | 1.780E-06 | 0.000E+00 | 9.600E+01 |
| Np-237 | 4.070E-04 | 8.510E-02 | 2.940E-06 | 2.140E+06 |
| Pa-231 | 2.630E-03 | 5.180E-01 | 4.410E-06 | 3.280E+04 |
| Pb-210 | 2.550E-03 | 4.070E-03 | 2.490E-07 | 2.230E+01 |
| Pd-107 | 1.370E-07 | 3.150E-07 | 0.000E+00 | 6.500E+06 |
| Pu-238 | 8.510E-04 | 1.700E-01 | 7.310E-08 | 8.770E+01 |
| Pu-239 | 9.250E-04 | 1.850E-01 | 3.310E-08 | 2.410E+04 |
| Pu-240 | 9.250E-04 | 1.850E-01 | 7.010E-08 | 6.540E+03 |
| Pu-241 | 1.780E-05 | 3.330E-03 | 2.010E-10 | 1.440E+01 |
| Pu-242 | 8.880E-04 | 1.780E-01 | 5.810E-08 | 3.760E+05 |
| Pu-244 | 8.880E-04 | 1.740E-01 | 2.360E-06 | 8.260E+07 |
| Ra-226 | 1.040E-03 | 1.300E-02 | 7.130E-07 | 1.600E+03 |
| Ra-228 | 2.550E-03 | 9.620E-03 | 0.000E+00 | 5.750E+00 |
| Se-79 | 1.070E-05 | 4.070E-06 | 1.910E-09 | 6.500E+04 |
| Si-32 | 2.070E-06 | 6.290E-05 | 2.920E-09 | 4.500E+02 |
| Sm-151 | 3.630E-07 | 1.480E-05 | 4.130E-10 | 9.000E+01 |
| Sn-121m | 1.410E-06 | 1.670E-05 | 4.200E-07 | 5.500E+01 |
| Sn-126 | 1.740E-05 | 1.040E-04 | 5.620E-06 | 1.000E+05 |
| Sr-90 | 1.040E-04 | 1.330E-04 | 1.910E-07 | 2.910E+01 |
| Tc-99 | 2.370E-06 | 1.480E-05 | 7.550E-09 | 2.130E+05 |
| Th-229 | 1.810E-03 | 2.630E-01 | 9.210E-06 | 7.340E+03 |
| Th-230 | 7.770E-04 | 5.180E-02 | 7.430E-08 | 7.700E+04 |
| Th-232 | 8.510E-04 | 9.250E-02 | 5.310E-08 | 1.410E+10 |
| U-232 | 1.220E-03 | 2.890E-02 | 9.420E-08 | 7.200E+01 |
| U-233 | 1.890E-04 | 1.330E-02 | 6.990E-08 | 1.590E+05 |
| U-234 | 1.810E-04 | 1.300E-02 | 6.840E-08 | 2.450E+05 |
| U-235 | 1.740E-04 | 1.150E-02 | 1.630E-05 | 7.040E+08 |
| U-236 | 1.740E-04 | 1.180E-02 | 5.870E-08 | 2.340E+07 |
| U-238 | 1.670E-04 | 1.070E-02 | 4.940E-08 | 4.470E+09 |
| Zr-93 | 4.070E-06 | 3.700E-05 | 0.000E+00 | 1.530E+06 |

| NUCLIDE | VOLATILITY FRACTION | GAMMA ENERGY (MEV) | GAMMA ATTENUATION (1/M) |
|---|---|---|---|
| Ac-227 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ag-108m | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Al-26 | 0.000E+00 | 1.000E-01 | 4.350E+01 |
| Am-241 | 0.000E+00 | 2.000E-01 | 2.220E+01 |
| Am-243 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ba-133 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Bi-207 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| C-14 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cf-249 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cf-250 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cf-251 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cl-36 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-243 | 0.000E+00 | 2.000E-01 | 2.200E+01 |
| Cm-244 | 0.000E+00 | 1.000E-01 | 4.350E+01 |
| Cm-245 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-246 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-247 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cm-248 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Co-60 | 0.000E+00 | 1.300E+00 | 9.200E+00 |
| Cs-135 | 0.000E+00 | 7.000E-01 | 1.210E+01 |
| Cs-137 | 0.000E+00 | 6.000E-01 | 1.280E+01 |
| Eu-150 | 0.000E+00 | 5.000E-01 | 1.400E+01 |
| Eu-152 | 0.000E+00 | 7.000E-01 | 1.250E+01 |
| Eu-154 | 0.000E+00 | 1.000E-01 | 3.210E+01 |
| H-3 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| I-129 | 0.000E+00 | 0.000E+00 | 6.200E+01 |
| K-40 | 0.000E+00 | 1.000E+00 | 1.030E+01 |

| | | | |
|---|---|---|---|
| Nb-93m | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Nb-94 | 0.000E+00 | 8.000E-01 | 1.160E+01 |
| Ni-59 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ni-63 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Np-237 | 0.000E+00 | 1.000E-01 | 3.490E+01 |
| Pa-231 | 0.000E+00 | 1.000E-01 | 2.280E+01 |
| Pb-210 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pd-107 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pu-238 | 0.000E+00 | 1.000E-01 | 4.530E+01 |
| Pu-239 | 0.000E+00 | 1.000E-01 | 2.580E+01 |
| Pu-240 | 0.000E+00 | 1.000E-01 | 4.630E+01 |
| Pu-241 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pu-242 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pu-244 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ra-226 | 0.000E+00 | 2.000E-01 | 2.150E+01 |
| Ra-228 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Se-79 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Si-32 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sm-151 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sn-121m | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sn-126 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sr-90 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Tc-99 | 0.000E+00 | 1.000E-01 | 2.920E+01 |
| Th-229 | 0.000E+00 | 1.000E-01 | 2.880E+01 |
| Th-230 | 0.000E+00 | 1.000E-01 | 3.030E+01 |
| Th-232 | 0.000E+00 | 1.000E-01 | 3.550E+01 |
| U-232 | 0.000E+00 | 0.000E+00 | 2.570E+01 |
| U-233 | 0.000E+00 | 1.000E-01 | 2.570E+01 |
| U-234 | 0.000E+00 | 1.000E-01 | 3.550E+01 |
| U-235 | 0.000E+00 | 2.000E-01 | 2.160E+01 |
| U-236 | 0.000E+00 | 1.000E-01 | 3.660E+01 |
| U-238 | 0.000E+00 | 7.000E-01 | 1.200E+01 |
| Zr-93 | 0.000E+00 | 0.000E+00 | 0.000E+00 |

| NUCLIDE | INPUT LEACH RATE (1/YR) | FINAL LEACH RATE (1/YR) | SOLUBILITY (MOLE/L) | INPUT INVENTORY (CI) |
|---|---|---|---|---|
| Ac-227 | -1.500E+03 | 2.810E-07 | 0.000E+00 | 1.910E+06 |
| Ag-108m | -4.500E+01 | 9.336E-06 | 0.000E+00 | 1.910E+06 |
| Al-26 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Am-241 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Am-243 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Ba-133 | -6.000E+01 | 7.008E-06 | 0.000E+00 | 1.910E+06 |
| Bi-207 | -5.000E+02 | 8.429E-07 | 0.000E+00 | 1.910E+06 |
| C-14 | -1.090E+00 | 3.383E-04 | 0.000E+00 | 1.910E+06 |
| Cf-249 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cf-250 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cf-251 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cl-36 | -2.500E-01 | 1.038E-03 | 0.000E+00 | 1.910E+06 |
| Cm-243 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-244 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-245 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-246 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-247 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Cm-248 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Co-60 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Cs-135 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Cs-137 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Eu-150 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Eu-152 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Eu-154 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| H-3 | -1.990E-01 | 1.187E-03 | 0.000E+00 | 1.910E+06 |
| I-129 | -4.000E+00 | 1.014E-04 | 0.000E+00 | 1.910E+06 |
| K-40 | -3.000E+01 | 1.398E-05 | 0.000E+00 | 1.910E+06 |
| Nb-93m | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Nb-94 | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Ni-59 | -2.000E+03 | 2.108E-07 | 0.000E+00 | 1.910E+06 |
| Ni-63 | -2.000E+03 | 2.108E-07 | 0.000E+00 | 1.910E+06 |
| Np-237 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pa-231 | -4.000E+02 | 1.054E-06 | 0.000E+00 | 1.910E+06 |
| Pb-210 | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Pd-107 | -2.000E+03 | 2.108E-07 | 0.000E+00 | 1.910E+06 |
| Pu-238 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-239 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-240 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-241 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-242 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Pu-244 | -4.000E+01 | 1.050E-05 | 0.000E+00 | 1.910E+06 |
| Ra-226 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Ra-228 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |

| | | | | |
|---|---|---|---|---|
| Se-79 | -3.000E+02 | 1.404E-06 | 0.000E+00 | 1.910E+06 |
| Si-32 | -3.000E+01 | 1.398E-05 | 0.000E+00 | 1.910E+06 |
| Sm-151 | -1.000E+03 | 4.215E-07 | 0.000E+00 | 1.910E+06 |
| Sn-121m | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Sn-126 | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Sr-90 | -3.000E+01 | 1.398E-05 | 0.000E+00 | 1.910E+06 |
| Tc-99 | -1.500E+00 | 2.545E-04 | 0.000E+00 | 1.910E+06 |
| Th-229 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Th-230 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| Th-232 | -3.000E+03 | 1.405E-07 | 0.000E+00 | 1.910E+06 |
| U-232 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-233 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-234 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-235 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-236 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-238 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| Zr-93 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |

| NUCLIDE | AQUIFER SORPTION | AQUIFER RETARDATION | VERTICAL SORPTION | VERTICAL RETARDATION |
|---|---|---|---|---|
| Ac-227 | 1.500E+02 | 1.081E+03 | 1.500E+03 | 1.080E+04 |
| Ag-108m | 4.500E+00 | 3.340E+01 | 4.500E+01 | 3.250E+02 |
| Al-26 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Am-241 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Am-243 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Ba-133 | 6.000E+00 | 4.420E+01 | 6.000E+01 | 4.330E+02 |
| Bi-207 | 5.000E+01 | 3.610E+02 | 5.000E+02 | 3.601E+03 |
| C-14 | 1.090E-01 | 1.785E+00 | 1.090E+00 | 8.848E+00 |
| Cf-249 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cf-250 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cf-251 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cl-36 | 2.500E-02 | 1.180E+00 | 2.500E-01 | 2.800E+00 |
| Cm-243 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-244 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-245 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-246 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-247 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Cm-248 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Co-60 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Cs-135 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Cs-137 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Eu-150 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Eu-152 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Eu-154 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| H-3 | 1.990E-02 | 1.143E+00 | 1.990E-01 | 2.433E+00 |
| I-129 | 4.000E-01 | 3.880E+00 | 4.000E+00 | 2.980E+01 |
| K-40 | 3.000E+00 | 2.260E+01 | 3.000E+01 | 2.170E+02 |
| Nb-93m | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Nb-94 | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Ni-59 | 2.000E+02 | 1.441E+03 | 2.000E+03 | 1.440E+04 |
| Ni-63 | 2.000E+02 | 1.441E+03 | 2.000E+03 | 1.440E+04 |
| Np-237 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pa-231 | 4.000E+01 | 2.890E+02 | 4.000E+02 | 2.881E+03 |
| Pb-210 | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Pd-107 | 2.000E+02 | 1.441E+03 | 2.000E+03 | 1.440E+04 |
| Pu-238 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-239 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-240 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-241 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-242 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Pu-244 | 4.000E+00 | 2.980E+01 | 4.000E+01 | 2.890E+02 |
| Ra-226 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Ra-228 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Se-79 | 3.000E+01 | 2.170E+02 | 3.000E+02 | 2.161E+03 |
| Si-32 | 3.000E+00 | 2.260E+01 | 3.000E+01 | 2.170E+02 |
| Sm-151 | 1.000E+02 | 7.210E+02 | 1.000E+03 | 7.201E+03 |
| Sn-121m | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Sn-126 | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Sr-90 | 3.000E+00 | 2.260E+01 | 3.000E+01 | 2.170E+02 |
| Tc-99 | 1.500E-01 | 2.080E+00 | 1.500E+00 | 1.180E+01 |
| Th-229 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Th-230 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| Th-232 | 3.000E+02 | 2.161E+03 | 3.000E+03 | 2.160E+04 |
| U-232 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-233 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-234 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-235 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-236 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-238 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |

| | | | | |
|---|---|---|---|---|
| Zr-93 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |

BIOACCUMULATION FACTORS

| NUCLIDE | SOIL-PLANT Bv | SOIL-PLANT Br | FORAGE-MILK Fm (D/L) | FORAGE-MEAT Ff (D/KG) |
|---|---|---|---|---|
| Ac-227 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-05 |
| Ag-108m | 1.500E-01 | 1.500E-02 | 2.500E-02 | 3.000E-03 |
| Al-26 | 4.000E-03 | 4.000E-04 | 0.000E+00 | 0.000E+00 |
| Am-241 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 5.000E-05 |
| Am-243 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 5.000E-05 |
| Ba-133 | 5.000E-03 | 5.000E-04 | 0.000E+00 | 0.000E+00 |
| Bi-207 | 1.000E-01 | 1.000E-02 | 5.000E-04 | 2.000E-03 |
| C-14 | 5.500E+00 | 5.500E-01 | 1.200E-02 | 3.100E-02 |
| Cf-249 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |
| Cf-250 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |
| Cf-251 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |
| Cl-36 | 2.000E+01 | 2.000E+00 | 2.000E-02 | 6.000E-02 |
| Cm-243 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-244 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-245 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-246 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-247 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Cm-248 | 1.000E-03 | 1.000E-04 | 2.000E-06 | 2.000E-05 |
| Co-60 | 8.000E-02 | 8.000E-03 | 2.000E-03 | 2.000E-02 |
| Cs-135 | 4.000E-02 | 4.000E-03 | 8.000E-03 | 3.000E-02 |
| Cs-137 | 4.000E-02 | 4.000E-03 | 8.000E-03 | 3.000E-02 |
| Eu-150 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| Eu-152 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| Eu-154 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| H-3 | 4.800E+00 | 4.800E-01 | 1.000E-02 | 1.200E-02 |
| I-129 | 2.000E-02 | 2.000E-03 | 1.000E-02 | 7.000E-03 |
| K-40 | 3.000E-01 | 3.000E-02 | 7.000E-03 | 2.000E-02 |
| Nb-93m | 1.000E-02 | 1.000E-03 | 2.000E-06 | 3.000E-07 |
| Nb-94 | 1.000E-02 | 1.000E-03 | 2.000E-06 | 3.000E-07 |
| Ni-59 | 5.000E-02 | 5.000E-03 | 2.000E-02 | 5.000E-03 |
| Ni-63 | 5.000E-02 | 5.000E-03 | 2.000E-02 | 5.000E-03 |
| Np-237 | 2.000E-02 | 2.000E-03 | 5.000E-06 | 1.000E-03 |
| Pa-231 | 1.000E-02 | 1.000E-03 | 5.000E-06 | 5.000E-03 |
| Pb-210 | 1.000E-02 | 1.000E-03 | 3.000E-04 | 8.000E-04 |
| Pd-107 | 1.000E-01 | 1.000E-02 | 0.000E+00 | 0.000E+00 |
| Pu-238 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-239 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-240 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-241 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-242 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Pu-244 | 1.000E-03 | 1.000E-04 | 1.000E-06 | 1.000E-04 |
| Ra-226 | 4.000E-02 | 4.000E-03 | 1.000E-03 | 1.000E-03 |
| Ra-228 | 4.000E-02 | 4.000E-03 | 1.000E-03 | 1.000E-03 |
| Se-79 | 1.000E-01 | 1.000E-02 | 0.000E+00 | 0.000E+00 |
| Si-32 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Sm-151 | 2.500E-03 | 2.500E-04 | 2.000E-05 | 2.000E-03 |
| Sn-121m | 2.500E-03 | 2.500E-04 | 0.000E+00 | 0.000E+00 |
| Sn-126 | 2.500E-03 | 2.500E-04 | 0.000E+00 | 0.000E+00 |
| Sr-90 | 3.000E-01 | 3.000E-02 | 2.000E-03 | 8.000E-03 |
| Tc-99 | 5.000E+00 | 5.000E-01 | 1.000E-03 | 1.000E-04 |
| Th-229 | 1.000E-03 | 1.000E-04 | 5.000E-06 | 1.000E-04 |
| Th-230 | 1.000E-03 | 1.000E-04 | 5.000E-06 | 1.000E-04 |
| Th-232 | 1.000E-03 | 1.000E-04 | 5.000E-06 | 1.000E-04 |
| U-232 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-233 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-234 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-235 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-236 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| U-238 | 2.500E-03 | 2.500E-04 | 6.000E-04 | 3.400E-04 |
| Zr-93 | 1.000E-03 | 1.000E-04 | 0.000E+00 | 0.000E+00 |

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

| NUCLIDE | PEAK CONCENTRATION (CI/M**3) | PEAK TIME (YR) | AVERAGE DOSE AT PEAK TIME (MREM/YR) | AVERAGE RISK AT PEAK TIME (HE/YR) |
|---|---|---|---|---|
| Ac-227 | | > 1000000.0 | | |
| Al-26 | | > 1000000.0 | | |

| | | | | |
|---|---|---|---|---|
| Am-243 | 1.15E-08 | 86647.4 | 6.21E+00 | 1.74E-06 |
| Bi-207 | | > 1000000.0 | | |
| C-14 | 9.16E-04 | 2971.6 | 1.88E+03 | 5.28E-04 |
| Cf-251 | 5.99E-34 | 85380.6 | 5.82E-25 | 1.63E-31 |
| Cl-36 | 4.03E-03 | 1208.0 | 1.59E+04 | 4.46E-03 |
| Cm-245 | 3.36E-08 | 86708.6 | 1.91E+01 | 5.34E-06 |
| Cm-246 | 1.21E-10 | 86435.3 | 6.87E-02 | 1.92E-08 |
| Cm-247 | 4.07E-05 | 88999.2 | 2.09E+04 | 5.85E-03 |
| Cm-248 | 3.41E-05 | 88010.3 | 7.09E+04 | 1.99E-02 |
| Co-60 | | > 1000000.0 | | |
| Cs-135 | | > 1000000.0 | | |
| Cs-137 | | > 1000000.0 | | |
| Eu-150 | | > 1000000.0 | | |
| Eu-152 | | > 1000000.0 | | |
| Eu-154 | | > 1000000.0 | | |
| H-3 | 5.56E-26 | 913.2 | 1.00E-20 | 2.81E-27 |
| I-129 | 3.94E-04 | 9992.3 | 1.33E+05 | 3.73E-02 |
| K-40 | 5.44E-05 | 79264.4 | 1.08E+03 | 3.04E-04 |
| Nb-94 | 9.97E-09 | 215891.4 | 4.58E-02 | 1.28E-08 |
| Ni-59 | | > 1000000.0 | | |
| Ni-63 | | > 1000000.0 | | |
| Np-237 | 3.97E-05 | 88504.7 | 1.19E+04 | 3.32E-03 |
| Pa-231 | 5.03E-14 | 857601.7 | 9.96E-05 | 2.79E-11 |
| Pd-107 | | > 1000000.0 | | |
| Pu-239 | 3.30E-06 | 87138.0 | 2.23E+03 | 6.24E-04 |
| Pu-240 | 4.04E-09 | 86594.2 | 2.73E+00 | 7.65E-07 |
| Pu-242 | 3.47E-05 | 88010.3 | 2.25E+04 | 6.30E-03 |
| Pu-244 | 4.08E-05 | 89658.4 | 2.65E+04 | 7.41E-03 |
| Ra-226 | | > 1000000.0 | | |
| Ra-228 | | > 1000000.0 | | |
| Se-79 | 5.36E-09 | 646817.8 | 4.19E-02 | 1.17E-08 |
| Sm-151 | | > 1000000.0 | | |
| Sn-126 | 3.61E-06 | 217448.2 | 4.58E+01 | 1.28E-05 |
| Tc-99 | 9.77E-04 | 3937.3 | 1.71E+03 | 4.78E-04 |
| Th-229 | | > 1000000.0 | | |
| Th-230 | | > 1000000.0 | | |
| Th-232 | | > 1000000.0 | | |
| U-233 | 2.03E-05 | 109472.8 | 2.82E+03 | 7.88E-04 |
| U-234 | 2.40E-05 | 109678.6 | 3.19E+03 | 8.93E-04 |
| U-235 | 3.27E-05 | 131696.6 | 4.18E+03 | 1.17E-03 |
| U-236 | 3.26E-05 | 111119.0 | 4.17E+03 | 1.17E-03 |
| U-238 | 3.27E-05 | 131696.6 | 4.02E+03 | 1.12E-03 |
| Zr-93 | 3.11E-05 | 110295.9 | 9.24E+01 | 2.59E-05 |

### 3.1.1 PATHRAE-HAZ

The PATHRAE-HAZ model is limited to 99 contaminants of concern (COCs) per run. Two runs were conducted to address all the COCs. The input and output files for the run for the first group of COCs (inorganics) and the remaining COCs (organics) are provided in Section 3.2.2.1 and Section 3.2.2.2, respectively.

#### 3.1.1.1 First Contaminants of Concern (Inorganics)

```
PATHRAE-HAZ(PC)  Version 2.3d  January 1997
   Date:  3-23-2015
   Time: 14:26:42

 pWAC HAZ- Inorganic – 2015 EMDF in UBCV
```

TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

| CONTAMINANT | UT(J,1) RIVER L/YR | UT(J,2) WELL L/YR | UT(J,3) EROSION L/YR | UT(J,4) BATHTUB L/YR | UT(J,5) SPILLAGE L/YR | UT(J,6) FOOD KG/YR |
|---|---|---|---|---|---|---|
| Antimony | 7.332E+02 | 7.332E+02 | 7.332E+02 | 7.332E+02 | 7.332E+02 | 2.153E-01 |
| Barium | 7.372E+02 | 7.372E+02 | 7.372E+02 | 7.373E+02 | 7.373E+02 | 5.213E-01 |
| Boron | 7.474E+02 | 7.474E+02 | 7.474E+02 | 7.477E+02 | 7.477E+02 | 3.026E+01 |
| Chromium-III | 7.787E+02 | 7.787E+02 | 7.787E+02 | 7.787E+02 | 7.787E+02 | 6.445E-01 |
| Lead | 7.369E+02 | 7.369E+02 | 7.369E+02 | 7.371E+02 | 7.371E+02 | 4.682E-01 |
| Manganese | 7.355E+02 | 7.355E+02 | 7.355E+02 | 7.379E+02 | 7.378E+02 | 3.346E+00 |
| Molybdenum | 7.498E+02 | 7.498E+02 | 7.498E+02 | 7.500E+02 | 7.500E+02 | 3.254E+00 |
| Selenium | 1.312E+03 | 1.312E+03 | 1.312E+03 | 1.316E+03 | 1.316E+03 | 7.577E+01 |

```
  Strontium           7.941E+02 7.941E+02 7.931E+02 7.941E+02 7.941E+02 2.096E+01
  Tin                 7.907E+02 7.907E+02 7.907E+02 7.909E+02 7.909E+02 1.895E+01
  Vanadium            7.457E+02 7.457E+02 7.457E+02 7.457E+02 7.457E+02 4.151E-02
  U-233               7.371E+02 7.371E+02 7.371E+02 7.371E+02 7.371E+02 1.201E-01
  U-234               7.371E+02 7.371E+02 7.371E+02 7.371E+02 7.371E+02 1.201E-01
  U-235               7.371E+02 7.371E+02 7.371E+02 7.371E+02 7.371E+02 1.201E-01
  U-236               7.371E+02 7.371E+02 7.371E+02 7.371E+02 7.371E+02 1.201E-01
  U-238               7.371E+02 7.371E+02 7.371E+02 7.371E+02 7.371E+02 1.201E-01
  Mercury             7.870E+02 7.870E+02 7.870E+02 8.233E+02 8.198E+02 1.814E+01
  Arsenic             7.434E+02 7.434E+02 7.434E+02 7.434E+02 7.434E+02 2.779E-01
  Beryllium           7.379E+02 7.379E+02 7.379E+02 7.380E+02 7.380E+02 5.537E-02
  Cadmium             7.426E+02 7.426E+02 7.426E+02 7.435E+02 7.435E+02 3.559E+00
  Chromium-VI         7.713E+02 7.713E+02 7.713E+02 7.713E+02 7.713E+02 1.033E-01
  Copper              7.942E+02 7.942E+02 7.942E+02 7.952E+02 7.952E+02 7.885E+00
  Nickel              7.703E+02 7.703E+02 7.703E+02 7.705E+02 7.705E+02 8.200E-01
  Silver              8.880E+02 8.880E+02 8.880E+02 8.885E+02 8.885E+02 1.550E+01
  Zinc                1.242E+03 1.242E+03 1.242E+03 1.271E+03 1.271E+03 1.349E+02

**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC HAZ- Inorganic – 2015 EMDF in UBCV
3, 0., 1000., 100000.,
25,0,1
1,2
0.0, 243.19, 486.37, 4.91E+05, 1., 476., 0.
1800.,6.,0.,0.,0.,0.,0.315,0.
20,2,0,1,1
3.35, 16.16, 1.91E+06,476.,0.,1600.,.40,.705,0.90,1.
1.0E-7,8000.,.705,0.,1.0E+00,0.01
240.,5.56E-04,.22,.02,3.0E-4,20.,0.01
4,6.3,.23,0.,1.1E-06,0.01,0.,0.,0.,0.
0,0,0,0,0,0,0
1,0,0,1
0.0109, 4.27, 0.25, 7.0, 0.025, 24., 0.00001, 1., 0., 0.25

-- Input File:  BRCDCF.DAT
102,Antimony         0.00E+00,4.00E-04,0.00E+00,0.00E+00
104,Barium           0.00E+00,2.00E-01,0.00E+00,0.00E+00
106,Boron            0.00E+00,2.00E-01,0.00E+00,0.00E+00
109,Chromium-III     0.00E+00,0.00E+00,0.00E+00,0.00E+00
118,Lead             0.00E+00,0.00E+00,0.00E+00,0.00E+00
121,Manganese        0.00E+00,1.40E-01,0.00E+00,0.00E+00
123,Molybdenum       0.00E+00,5.00E-03,0.00E+00,0.00E+00
128,Selenium         0.00E+00,5.00E-03,0.00E+00,0.00E+00
131,Strontium        0.00E+00,6.00E-01,0.00E+00,0.00E+00
134,Tin              0.00E+00,6.00E-01,0.00E+00,0.00E+00
136,Vanadium         0.00E+00,5.00E-03,0.00E+00,0.00E+00
140,U-233            0.00E+00,3.00E-03,0.00E+00,0.00E+00
141,U-234            0.00E+00,3.00E-03,0.00E+00,0.00E+00
142,U-235            0.00E+00,3.00E-03,0.00E+00,0.00E+00
143,U-236            0.00E+00,3.00E-03,0.00E+00,0.00E+00
144,U-238            0.00E+00,3.00E-03,0.00E+00,0.00E+00
122,Mercury          0.00E+00,3.00E-04,0.00E+00,0.00E+00
704,Arsenic          0.00E+00,3.00E-04,0.00E+00,0.00E+00
705,Beryllium        0.00E+00,2.00E-03,0.00E+00,0.00E+00
706,Cadmium          0.00E+00,5.00E-04,0.00E+00,0.00E+00
707,Chromium-VI      0.00E+00,3.00E-03,0.00E+00,0.00E+00
708,Copper           0.00E+00,4.00E-02,0.00E+00,0.00E+00
709,Nickel           0.00E+00,2.00E-02,0.00E+00,0.00E+00
710,Silver           0.00E+00,5.00E-03,0.00E+00,0.00E+00
711,Zinc             0.00E+00,3.00E-01,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
102,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Antimony
104,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Barium
106,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Boron
109,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Chromium-III
118,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Lead
121,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Manganese
123,  1.00E+10, 1.910E+06,         0,         0, 7.660E+04,         0,        Molybdenum
128,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Selenium
131,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Strontium
134,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Tin
136,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Vanadium
140,  1.59E+05, 1.910E+06,         0,         0, 0.000E+00,         0,        U-233
141,  2.44E+05, 1.910E+06,         0,         0, 0.000E+00,         0,        U-234
142,  7.04E+08, 1.910E+06,         0,         0, 0.000E+00,         0,        U-235
143,  2.34E+07, 1.910E+06,         0,         0, 0.000E+00,         0,        U-236
144,  4.47E+09, 1.910E+06,         0,         0, 0.000E+00,         0,        U-238
122,  1.00E+10, 1.910E+06,         0,         0, 5.700E+01,         0,        Mercury
```

```
704,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Arsenic
705,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Beryllium
706,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Cadmium
707,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Chromium-VI
708,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Copper
709,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Nickel
710,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Silver
711,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Zinc

-- Input File:  RQSITE.DAT
102,-1.900E+01, 1.900E+00, 1.900E+01,       Antimony
104,-5.500E+01, 5.500E+00, 5.500E+01,       Barium
106,-3.000E+00, 3.000E-01, 3.000E+00,       Boron
109,-1.000E+01, 1.000E+00, 1.000E+01,       Chromium-III
118,-1.000E+02, 1.000E+01, 1.000E+02,       Lead
121,-2.000E+02, 2.000E+01, 2.000E+02,       Manganese
123,-2.000E+01, 2.000E+00, 2.000E+01,       Molybdenum
128,-1.500E+01, 1.500E+00, 1.500E+01,       Selenium
131,-1.350E+01, 0.000E+00, 1.350E+01,       Strontium
134,-2.500E+00, 2.500E-01, 2.500E+00,       Tin
136,-1.000E+02, 1.000E+01, 1.000E+02,       Vanadium
140,-5.000E+01, 5.000E+00, 5.000E+01,       U-233
141,-5.000E+01, 5.000E+00, 5.000E+01,       U-234
142,-5.000E+01, 5.000E+00, 5.000E+01,       U-235
143,-5.000E+01, 5.000E+00, 5.000E+01,       U-236
144,-5.000E+01, 5.000E+00, 5.000E+01,       U-238
122,-5.800E+02, 5.800E+01, 5.800E+02,       Mercury
704,-2.900E+01, 2.900E+00, 2.900E+01,       Arsenic
705,-7.900E+02, 7.900E+01, 7.900E+02,       Beryllium
706,-7.500E+01, 7.500E+00, 7.500E+01,       Cadmium
707,-1.000E+01, 1.000E+00, 1.000E+01,       Chromium-VI
708,-3.500E+01, 3.500E+00, 3.500E+01,       Copper
709,-6.500E+01, 6.500E+00, 6.500E+01,       Nickel
710,-8.300E+00, 8.300E-01, 8.300E+00,       Silver
711,-6.200E+01, 6.200E+00, 6.200E+01,       Zinc

-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
0.0,   2160.,  24.,     1440.,     1.,  0.83
50.,   6.,     48.,      480.,    48.
.05,  0.0008,  60.,        8.,    50.
14.,    176., 110.,        0.,    95.,   730., 0.0
Antimony              0.25,  5.00E-02,  5.00E-03,  2.50E-05,         0,  4.00E-05,  1.00E+02,        102
Barium                0.25,  1.00E-01,  1.00E-02,  4.80E-04,         0,  2.00E-04,  4.00E+00,        104
Boron                 0.25,  4.00E+00,  4.00E-01,  1.50E-03,         0,  8.00E-04,  0.00E+00,        106
Chromium-III          0.25,  4.00E-02,  4.00E-03,  1.00E-05,         0,  9.00E-03,  2.00E+02,        109
Lead                  0.25,  9.00E-02,  9.00E-03,  3.00E-04,         0,  4.00E-04,  3.00E+02,        118
Manganese             0.25,  6.80E-01,  6.80E-02,  3.00E-05,         0,  5.00E-04,  4.00E+02,        121
Molybdenum            0.25,  4.00E-01,  4.00E-02,  1.70E-03,         0,  1.00E-03,  0.00E+00,        123
Selenium              0.25,  5.00E-01,  5.00E-02,  1.00E-02,         0,  1.00E-01,  0.00E+00,        128
Strontium             0.25,  1.10E+00,  1.10E-01,  2.80E-03,         0,  8.00E-03,  0.00E+00,        131
Tin                   0.25,  1.00E+00,  1.00E-01,  1.00E-03,         0,  1.00E-02,  3.00E+03,        134
Vanadium              0.25,  5.50E-03,  5.50E-04,  2.00E-05,         0,  2.50E-03,  1.00E+01,        136
U-233                 0.25,  2.30E-02,  2.30E-03,  4.00E-04,         0,  3.00E-04,  1.00E+01,        140
U-234                 0.25,  2.30E-02,  2.30E-03,  4.00E-04,         0,  3.00E-04,  1.00E+01,        141
U-235                 0.25,  2.30E-02,  2.30E-03,  4.00E-04,         0,  3.00E-04,  1.00E+01,        142
U-236                 0.25,  2.30E-02,  2.30E-03,  4.00E-04,         0,  3.00E-04,  1.00E+01,        143
U-238                 0.25,  2.30E-02,  2.30E-03,  4.00E-04,         0,  3.00E-04,  1.00E+01,        144
Mercury               0.25,  1.00E+00,  1.00E-01,  4.70E-04,         0,  1.00E-02,  1.00E+03,        122
Arsenic               0.25,  4.00E-02,  4.00E-03,  6.00E-05,         0,  2.00E-03,  0.00E+00,        704
Beryllium             0.25,  1.00E-02,  1.00E-03,  9.00E-07,         0,  1.00E-03,  0.00E+00,        705
Cadmium               0.25,  5.50E-01,  5.50E-02,  1.00E-03,         0,  5.50E-04,  0.00E+00,        706
Chromium-VI           0.25,  7.50E-03,  7.50E-04,  1.50E-03,         0,  5.50E-03,  0.00E+00,        707
Copper                0.25,  4.00E-01,  4.00E-02,  1.50E-03,         0,  1.00E-02,  0.00E+00,        708
Nickel                0.25,  6.00E-02,  6.00E-03,  1.00E-03,         0,  6.00E-03,  0.00E+00,        709
Silver                0.25,  4.00E-01,  4.00E-02,  2.00E-02,         0,  3.00E-03,  0.00E+00,        710
Zinc                  0.25,  9.90E-01,  9.90E-02,  0.00E+00,         0,  1.00E-01,  0.00E+00,        711
1


**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  3
YEARS TO BE CALCULATED ARE ...

      .00  1000.00100000.00

THERE ARE  25 CONTAMINANTS IN THE INVENTORY FILE
```

```
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  1

          PATHWAY          TYPE OF USAGE
                          FOR UPTAKE FACTORS
   1  GROUNDWATER TO RIVER         2

TIME OF OPERATION OF WASTE FACILITY IN YEARS                    0.
LENGTH OF REPOSITORY (M)                                      243.
WIDTH OF REPOSITORY (M)                                       486.
RIVER FLOW RATE (M**3/YR)                                     4.91E+05
STREAM FLOW RATE (M**3/YR)                                    1.00E+00
DISTANCE TO RIVER (M)                                         476.

OPERATIONAL SPILLAGE FRACTION                                 0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                 1800.
LONGITUDINAL DISPERSIVITY (M)                                 6.00E+00
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)            0.00E+00
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION               20
FLAG FOR ATMOSPHERIC PATHWAY                                   0

COVER THICKNESS OVER WASTE (M)                                3.35
THICKNESS OF WASTE IN PITS (M)                               16.16
TOTAL WASTE VOLUME (M**3)                                     1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)                          476.
DISTANCE TO WELL -- Y COORDINATE (M)                          0.
DENSITY OF WASTE (KG/M**3)                                   1600.

FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE                .400
FRACTION OF YEAR CONTAMINANTS CONTACT SKIN                     .705
AREA OF SKIN IN CONTACT WITH CONTAMINANTS (M**2)               .0100
DEPTH OF PLANT ROOT ZONE (M)                                   .900
AREAL DENSITY OF PLANTS (KG/M**2)                             1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)                         1.00E-07

ANNUAL ADULT BREATHING RATE (M**3/YR)                        8000.
FRACTION OF YEAR EXPOSED TO DUST                               .705
CANISTER LIFETIME (YEARS)                                     0.
INVENTORY SCALING FACTOR                                      1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)                       240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)              5.56E-04

ATMOSPHERIC STABILITY CLASS                                   4
AVERAGE WIND SPEED (M/S)                                      6.30
FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR                    .2300
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)                  .0
DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)         1.10E-06
DEPOSITION VELOCITY (M/S)                                      .0100

STACK HEIGHT (M)                                               .0
STACK INSIDE DIAMETER (M)                                      .00
STACK GAS VELOCITY (M/S)                                       .0
HEAT EMISSION RATE FROM BURNING (CAL/S)                       0.00E+00
FLAGS FOR DEGRADATION SERIES              0   0   0   0   0   0   0

FLAG FOR INPUT SUMMARY PRINTOUT                               1
FLAG FOR DIRECTION OF TRENCH FILLING                          0
FLAG FOR GROUNDWATER PATHWAY OPTIONS                          1
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)        1.09E-02
DEGREE OF SOIL SATURATION                                     1.000
RESIDUAL SOIL SATURATION                                       .000

PERMEABILITY OF VERTICAL ZONE (M/YR)                           .32
SOIL NUMBER                                                    .000
POROSITY OF AQUIFER                                            .25
POROSITY OF UNSATURATED ZONE                                   .25
DISTANCE FROM AQUIFER TO WASTE (M)                            7.0
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)                  2.50E-02

HORIZONTAL VELOCITY OF AQUIFER (M/YR)                         4.27E+00
LENGTH OF PERFORATED WELL CASING (M)                         24.000
SURFACE EROSION RATE (M/YR)                                   1.000E-05
LEACH RATE SCALING FACTOR                                     1.000E+00
ANNUAL RUNOFF OF PRECIPITATION (M)                            0.00E+00


                      -------- INGESTION -----------   -------- INHALATION ----------
                        UNIT RISK    ALLOWABLE DAILY    UNIT RISK    ALLOWABLE DAILY
                         FACTORS         INTAKES         FACTORS         INTAKES          HALF
  CONTAMINANT          (KG-DAY/MG)     (MG/KG-DAY)     (KG-DAY/MG)     (MG/KG-DAY)     LIFE (YR)
```

| | | | | | |
|---|---|---|---|---|---|
| Antimony | 0.000E+00 | 4.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Barium | 0.000E+00 | 2.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Boron | 0.000E+00 | 2.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Chromium-III | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Lead | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Manganese | 0.000E+00 | 1.400E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Molybdenum | 0.000E+00 | 5.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Selenium | 0.000E+00 | 5.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Strontium | 0.000E+00 | 6.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Tin | 0.000E+00 | 6.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Vanadium | 0.000E+00 | 5.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| U-233 | 0.000E+00 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 1.590E+05 |
| U-234 | 0.000E+00 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 2.440E+05 |
| U-235 | 0.000E+00 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 7.040E+08 |
| U-236 | 0.000E+00 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 2.340E+07 |
| U-238 | 0.000E+00 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 4.470E+09 |
| Mercury | 0.000E+00 | 3.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Arsenic | 0.000E+00 | 3.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Beryllium | 0.000E+00 | 2.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Cadmium | 0.000E+00 | 5.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Chromium-VI | 0.000E+00 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Copper | 0.000E+00 | 4.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Nickel | 0.000E+00 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Silver | 0.000E+00 | 5.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Zinc | 0.000E+00 | 3.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |

| CONTAMINANT | VOLATILITY FRACTION | VAPORIZATION RATE (1/S) | SKIN ABSORPTION (M/HR) |
|---|---|---|---|
| Antimony | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Barium | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Boron | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Chromium-III | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Lead | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Manganese | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Molybdenum | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Selenium | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Strontium | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Tin | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Vanadium | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| U-233 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| U-234 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| U-235 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| U-236 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| U-238 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Mercury | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Arsenic | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Beryllium | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cadmium | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Chromium-VI | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Copper | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Nickel | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Silver | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Zinc | 0.000E+00 | 0.000E+00 | 0.000E+00 |

| CONTAMINANT | INPUT LEACH (1/YR) | FINAL LEACH (1/YR) | SOLUBILITY (MG/L) | INPUT INVENTORY (KG) |
|---|---|---|---|---|
| Antimony | -1.900E+01 | 2.201E-05 | 0.000E+00 | 1.910E+06 |
| Barium | -5.500E+01 | 7.643E-06 | 0.000E+00 | 1.910E+06 |
| Boron | -3.000E+00 | 1.336E-04 | 0.000E+00 | 1.910E+06 |
| Chromium-III | -1.000E+01 | 4.151E-05 | 0.000E+00 | 1.910E+06 |
| Lead | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| Manganese | -2.000E+02 | 2.106E-06 | 0.000E+00 | 1.910E+06 |
| Molybdenum | -2.000E+01 | 2.091E-05 | 7.660E+04 | 1.910E+06 |
| Selenium | -1.500E+01 | 2.781E-05 | 0.000E+00 | 1.910E+06 |
| Strontium | -1.350E+01 | 3.087E-05 | 0.000E+00 | 1.910E+06 |
| Tin | -2.500E+00 | 1.587E-04 | 0.000E+00 | 1.910E+06 |
| Vanadium | -1.000E+02 | 4.209E-06 | 0.000E+00 | 1.910E+06 |
| U-233 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-234 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-235 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-236 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| U-238 | -5.000E+01 | 8.405E-06 | 0.000E+00 | 1.910E+06 |
| Mercury | -5.800E+02 | 7.266E-07 | 5.700E+01 | 1.910E+06 |
| Arsenic | -2.900E+01 | 1.446E-05 | 0.000E+00 | 1.910E+06 |
| Beryllium | -7.900E+02 | 5.335E-07 | 0.000E+00 | 1.910E+06 |

| | | | | |
|---|---|---|---|---|
| Cadmium | -7.500E+01 | 5.609E-06 | 0.000E+00 | 1.910E+06 |
| Chromium-VI | -1.000E+01 | 4.151E-05 | 0.000E+00 | 1.910E+06 |
| Copper | -3.500E+01 | 1.199E-05 | 0.000E+00 | 1.910E+06 |
| Nickel | -6.500E+01 | 6.470E-06 | 0.000E+00 | 1.910E+06 |
| Silver | -8.300E+00 | 4.985E-05 | 0.000E+00 | 1.910E+06 |
| Zinc | -6.200E+01 | 6.782E-06 | 0.000E+00 | 1.910E+06 |

| CONTAMINANT | AQUIFER SORPTION | AQUIFER RETARDATION | VERTICAL SORPTION | VERTICAL RETARDATION |
|---|---|---|---|---|
| Antimony | 1.900E+00 | 1.468E+01 | 1.900E+01 | 1.378E+02 |
| Barium | 5.500E+00 | 4.060E+01 | 5.500E+01 | 3.970E+02 |
| Boron | 3.000E-01 | 3.160E+00 | 3.000E+00 | 2.260E+01 |
| Chromium-III | 1.000E+00 | 8.200E+00 | 1.000E+01 | 7.300E+01 |
| Lead | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| Manganese | 2.000E+01 | 1.450E+02 | 2.000E+02 | 1.441E+03 |
| Molybdenum | 2.000E+00 | 1.540E+01 | 2.000E+01 | 1.450E+02 |
| Selenium | 1.500E+00 | 1.180E+01 | 1.500E+01 | 1.090E+02 |
| Strontium | 0.000E+00 | 1.000E+00 | 1.350E+01 | 9.820E+01 |
| Tin | 2.500E-01 | 2.800E+00 | 2.500E+00 | 1.900E+01 |
| Vanadium | 1.000E+01 | 7.300E+01 | 1.000E+02 | 7.210E+02 |
| U-233 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-234 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-235 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-236 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| U-238 | 5.000E+00 | 3.700E+01 | 5.000E+01 | 3.610E+02 |
| Mercury | 5.800E+01 | 4.186E+02 | 5.800E+02 | 4.177E+03 |
| Arsenic | 2.900E+00 | 2.188E+01 | 2.900E+01 | 2.098E+02 |
| Beryllium | 7.900E+01 | 5.698E+02 | 7.900E+02 | 5.689E+03 |
| Cadmium | 7.500E+00 | 5.500E+01 | 7.500E+01 | 5.410E+02 |
| Chromium-VI | 1.000E+00 | 8.200E+00 | 1.000E+01 | 7.300E+01 |
| Copper | 3.500E+00 | 2.620E+01 | 3.500E+01 | 2.530E+02 |
| Nickel | 6.500E+00 | 4.780E+01 | 6.500E+01 | 4.690E+02 |
| Silver | 8.300E-01 | 6.976E+00 | 8.300E+00 | 6.076E+01 |
| Zinc | 6.200E+00 | 4.564E+01 | 6.200E+01 | 4.474E+02 |

| | BIOACCUMULATION FACTORS | | | |
|---|---|---|---|---|
| CONTAMINANT | SOIL-PLANT Bv | SOIL-PLANT Br | FORAGE-MILK Fm (D/L) | FORAGE-MEAT Ff (D/KG) |
| Antimony | 5.000E-02 | 5.000E-03 | 2.500E-05 | 4.000E-05 |
| Barium | 1.000E-01 | 1.000E-02 | 4.800E-04 | 2.000E-04 |
| Boron | 4.000E+00 | 4.000E-01 | 1.500E-03 | 8.000E-04 |
| Chromium-III | 4.000E-02 | 4.000E-03 | 1.000E-05 | 9.000E-03 |
| Lead | 9.000E-02 | 9.000E-03 | 3.000E-04 | 4.000E-04 |
| Manganese | 6.800E-01 | 6.800E-02 | 3.000E-05 | 5.000E-04 |
| Molybdenum | 4.000E-01 | 4.000E-02 | 1.700E-03 | 1.000E-03 |
| Selenium | 5.000E-01 | 5.000E-02 | 1.000E-02 | 1.000E-01 |
| Strontium | 1.100E+00 | 1.100E-01 | 2.800E-03 | 8.000E-03 |
| Tin | 1.000E+00 | 1.000E-01 | 1.000E-03 | 1.000E-02 |
| Vanadium | 5.500E-03 | 5.500E-04 | 2.000E-05 | 2.500E-03 |
| U-233 | 2.300E-02 | 2.300E-03 | 4.000E-04 | 3.000E-04 |
| U-234 | 2.300E-02 | 2.300E-03 | 4.000E-04 | 3.000E-04 |
| U-235 | 2.300E-02 | 2.300E-03 | 4.000E-04 | 3.000E-04 |
| U-236 | 2.300E-02 | 2.300E-03 | 4.000E-04 | 3.000E-04 |
| U-238 | 2.300E-02 | 2.300E-03 | 4.000E-04 | 3.000E-04 |
| Mercury | 1.000E+00 | 1.000E-01 | 4.700E-04 | 1.000E-02 |
| Arsenic | 4.000E-02 | 4.000E-03 | 6.000E-05 | 2.000E-03 |
| Beryllium | 1.000E-02 | 1.000E-03 | 9.000E-07 | 1.000E-03 |
| Cadmium | 5.500E-01 | 5.500E-02 | 1.000E-03 | 5.500E-04 |
| Chromium-VI | 7.500E-03 | 7.500E-04 | 1.500E-03 | 5.500E-03 |
| Copper | 4.000E-01 | 4.000E-02 | 1.500E-03 | 1.000E-02 |
| Nickel | 6.000E-02 | 6.000E-03 | 1.000E-03 | 6.000E-03 |
| Silver | 4.000E-01 | 4.000E-02 | 2.000E-02 | 3.000E-03 |
| Zinc | 9.900E-01 | 9.900E-02 | 0.000E+00 | 1.000E-01 |

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

| CONTAMINANT | PEAK CONCENTRATION (MG/L) | PEAK TIME (YR) | AVERAGE DOSE AT PEAK TIME (MG/KG-DAY) | AVERAGE RISK AT PEAK TIME (HE/LIFE) | FRACTION OF ADI |
|---|---|---|---|---|---|
| Antimony | 8.56E-02 | 50301.7 | 2.46E-03 | | 6.14E+00 |
| Barium | 2.97E-02 | 144679.6 | 8.58E-04 | | 4.29E-03 |

| | | | | |
|---|---|---|---|---|
| Boron | 5.20E-01 | 8356.0 | 1.52E-02 | 7.60E-02 |
| Chromium-III | 1.61E-01 | 26707.2 | 4.92E-03 | |
| Lead | 1.64E-02 | 262652.1 | 4.72E-04 | |
| Manganese | 8.19E-03 | 524813.0 | 2.36E-04 | 1.68E-03 |
| Molybdenum | 8.14E-02 | 52923.3 | 2.39E-03 | 4.78E-01 |
| Selenium | 1.08E-01 | 39815.3 | 5.56E-03 | 1.11E+00 |
| Strontium | 1.20E-01 | 34511.1 | 3.73E-03 | 6.22E-03 |
| Tin | 6.17E-01 | 7045.1 | 1.91E-02 | 3.18E-02 |
| Vanadium | 1.64E-02 | 262652.1 | 4.78E-04 | 9.56E-02 |
| U-233 | 2.03E-02 | 109368.9 | 5.85E-04 | 1.95E-01 |
| U-234 | 2.39E-02 | 109574.5 | 6.90E-04 | 2.30E-01 |
| U-235 | 3.27E-02 | 131571.6 | 9.43E-04 | 3.14E-01 |
| U-236 | 3.26E-02 | 111013.5 | 9.40E-04 | 3.13E-01 |
| U-238 | 3.27E-02 | 131571.6 | 9.43E-04 | 3.14E-01 |
| Mercury | | > 1000000.0 | | |
| Arsenic | 5.62E-02 | 76517.8 | 1.64E-03 | 5.45E+00 |
| Beryllium | | > 1000000.0 | | |
| Cadmium | 2.18E-02 | 197111.8 | 6.34E-04 | 1.27E+00 |
| Chromium-VI | 1.61E-01 | 26707.2 | 4.87E-03 | 1.62E+00 |
| Copper | 4.66E-02 | 92247.5 | 1.45E-03 | 3.62E-02 |
| Nickel | 2.52E-02 | 170895.7 | 7.59E-04 | 3.79E-02 |
| Silver | 1.94E-01 | 22250.5 | 6.74E-03 | 1.35E+00 |
| Zinc | 2.64E-02 | 163030.9 | 1.28E-03 | 4.28E-03 |

### 3.1.1.2 Remaining Contaminants of Concern (Organics)

PATHRAE-HAZ(PC) Version 2.3d January 1997
Date: 3-23-2015
Time: 14:44:26

pWAC HAZ – 2015 EMDF in UBCV

TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

| CONTAMINANT | UT(J,1) RIVER L/YR | UT(J,2) WELL L/YR | UT(J,3) EROSION L/YR | UT(J,4) BATHTUB L/YR | UT(J,5) SPILLAGE L/YR | UT(J,6) FOOD KG/YR |
|---|---|---|---|---|---|---|
| 24-D | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 5.498E+00 |
| 245-TP(silvex) | 7.342E+02 | 7.342E+02 | 7.342E+02 | 7.342E+02 | 7.342E+02 | 9.609E-01 |
| Acenaphthene | 7.365E+02 | 7.365E+02 | 7.365E+02 | 7.366E+02 | 7.366E+02 | 6.144E-01 |
| Acenaphthylene | 7.337E+02 | 7.337E+02 | 7.337E+02 | 7.338E+02 | 7.338E+02 | 1.201E+00 |
| Acetone | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 5.480E+01 |
| Acentonitrile | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.329E+02 | 2.529E+02 |
| acetophenone | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 1.645E+01 |
| Acrolien | 7.329E+02 | 7.329E+02 | 7.328E+02 | 7.329E+02 | 7.329E+02 | 1.813E+02 |
| Acylonitrle | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 1.138E+02 |
| Aldrin | 7.330E+02 | 7.330E+02 | 7.330E+02 | 7.335E+02 | 7.340E+02 | 2.940E+00 |
| Aroclor1221 | 7.351E+02 | 7.351E+02 | 7.351E+02 | 7.352E+02 | 7.354E+02 | 7.641E-01 |
| Aroclor1232 | 7.331E+02 | 7.331E+02 | 7.331E+02 | 7.332E+02 | 7.332E+02 | 2.273E+00 |
| Benzene | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 2.450E+00 |
| Benzoic-acid | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 1.266E+01 |
| Benzyl-alcohol | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 3.668E+01 |
| benzidine | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.333E+02 | 7.333E+02 | 2.825E+01 |
| Alpha-BHC | 7.342E+02 | 7.342E+02 | 7.342E+02 | 7.343E+02 | 7.343E+02 | 9.609E-01 |
| Beta-BHC | 7.346E+02 | 7.346E+02 | 7.346E+02 | 7.346E+02 | 7.346E+02 | 8.399E-01 |
| Delta-BHC | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.330E+02 | 7.330E+02 | 3.820E+00 |
| Bromodichloro | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 9.708E+00 |
| Bromoform | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 6.340E+00 |
| Bromometh | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 3.246E+01 |
| butylbenzene | 7.334E+02 | 7.334E+02 | 7.334E+02 | 7.334E+02 | 7.334E+02 | 1.525E+00 |
| Carbazole | 7.340E+02 | 7.340E+02 | 7.340E+02 | 7.340E+02 | 7.340E+02 | 1.081E+00 |
| CarbonDiS | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 8.445E+00 |
| Carbontetchl | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.329E+02 | 1.231E+00 |
| Chlordane | 7.905E+02 | 7.905E+02 | 7.905E+02 | 7.906E+02 | 7.908E+02 | 4.617E-01 |
| Chlorobenzene | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.329E+02 | 7.329E+02 | 3.820E+00 |
| Chloroform | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 2.955E+00 |
| Chlorometh | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 4.637E+01 |
| 0-ChloroTu | 7.332E+02 | 7.332E+02 | 7.332E+02 | 7.333E+02 | 7.333E+02 | 1.775E+00 |
| m-cresol | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 1.097E+01 |
| o-cresol | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 1.266E+01 |
| p-cresol | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.328E+02 | 1.266E+01 |
| Cumene | 7.334E+02 | 7.334E+02 | 7.334E+02 | 7.334E+02 | 7.334E+02 | 1.525E+00 |
| Cyanide | 7.328E+02 | 7.328E+02 | 7.328E+02 | 7.340E+02 | 7.341E+02 | 3.668E+01 |
| DDD | 8.493E+02 | 8.493E+02 | 8.493E+02 | 8.494E+02 | 8.494E+02 | 5.277E-01 |
| DDE | 8.270E+02 | 8.270E+02 | 8.270E+02 | 8.270E+02 | 8.270E+02 | 5.224E-01 |
| Dinbutylphthalat | 8.061E+02 | 8.061E+02 | 8.061E+02 | 8.061E+02 | 8.061E+02 | 1.249E-01 |

```
  Dibenz[ah]          1.898E+03 1.898E+03 1.898E+03 1.898E+03 1.905E+03 1.255E+00
  Dibenzofuran        7.352E+02 7.352E+02 7.352E+02 7.354E+02 7.357E+02 7.206E-01
  Dibromochloro       7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 8.445E+00
  12Dichloro          7.332E+02 7.332E+02 7.332E+02 7.333E+02 7.333E+02 1.775E+00
  13Dichloro          7.335E+02 7.335E+02 7.335E+02 7.336E+02 7.336E+02 1.362E+00
  14Dichlorobenzen    7.332E+02 7.332E+02 7.332E+02 7.333E+02 7.333E+02 1.775E+00
  12cisDichloro       7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.266E+01
  12transDichl        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 8.431E+01
  Dichlorodiflo       7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 8.445E+00
  12Dichlprop         7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.097E+01
  Dieldrin            8.286E+02 8.286E+02 8.283E+02 8.286E+02 8.286E+02 2.459E+00
  Diethylphth         7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 5.498E+00
  12DiMethylB         7.330E+02 7.330E+02 7.330E+02 7.330E+02 7.330E+02 2.566E+00
  24-Dimethylphe      7.328E+02 7.328E+02 7.328E+02 7.329E+02 7.329E+02 7.604E+00
  Dimethylphth        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.898E+01
  24Dinitrotoluene    7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.097E+01
  26Dinitrotoluene    7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.645E+01
  EndosulfanII        7.334E+02 7.334E+02 7.334E+02 7.334E+02 7.334E+02 1.444E+00
  Endrin              7.400E+02 7.400E+02 7.400E+02 7.401E+02 7.401E+02 4.928E-01
  Aldehyde            7.400E+02 7.400E+02 7.400E+02 7.401E+02 7.401E+02 4.928E-01
  Ketone              7.400E+02 7.400E+02 7.400E+02 7.401E+02 7.401E+02 4.928E-01
  Ethylbenz           7.330E+02 7.330E+02 7.330E+02 7.330E+02 7.330E+02 2.605E+00
  Ethylchlorid        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.488E+01
  Heptachlor          7.365E+02 7.365E+02 7.365E+02 7.365E+02 7.366E+02 6.144E-01
  Heptachlor-epoxd    7.789E+02 7.789E+02 7.789E+02 7.789E+02 7.789E+02 4.365E-01
  Hexachlorobenzen    7.695E+02 7.695E+02 7.695E+02 7.695E+02 7.696E+02 4.244E-01
  Hexachloroethane    7.342E+02 7.342E+02 7.342E+02 7.343E+02 7.343E+02 9.609E-01
  Nhexane             7.342E+02 7.342E+02 7.342E+02 7.342E+02 7.342E+02 9.609E-01
  1hexanol            7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.488E+01
  2hexanone           7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.488E+01
  Isophorone          7.329E+02 7.329E+02 7.328E+02 7.329E+02 7.329E+02 2.030E+00
  Lindane             7.337E+02 7.337E+02 7.337E+02 7.338E+02 7.338E+02 1.201E+00
  Methonal            7.330E+02 7.330E+02 7.329E+02 7.330E+02 7.330E+02 4.637E+02
  Methchloride        0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  Methylcyclo         7.329E+02 7.329E+02 7.329E+02 7.329E+02 7.329E+02 3.526E+00
  MethylIso           7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 3.246E+01
  MMetacrylate        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.825E+01
  MethylEthylB        7.334E+02 7.334E+02 7.334E+02 7.334E+02 7.334E+02 1.525E+00
  2Methylnaptha       7.342E+02 7.342E+02 7.342E+02 7.343E+02 7.343E+02 9.609E-01
  MethylPropylB       7.334E+02 7.334E+02 7.334E+02 7.334E+02 7.334E+02 1.525E+00
  Naphthalene         7.332E+02 7.332E+02 7.332E+02 7.333E+02 7.333E+02 1.981E+00
  4Nitrobenzenamin    7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.867E+01
  Nitrobenzene        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.434E+01
  2Nitrophenol        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.519E+01
  4Nitrophenol        7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 1.266E+01
  NnitroNpropyl       7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.488E+01
  NNitrosodiphen      7.330E+02 7.330E+02 7.330E+02 7.330E+02 7.330E+02 2.605E+00
  Phenol              7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.150E+01
  PropylB             7.334E+02 7.334E+02 7.334E+02 7.334E+02 7.334E+02 1.525E+00
  PropGlycol          7.334E+02 7.334E+02 7.332E+02 7.334E+02 7.334E+02 1.560E+03
  Pyridine            7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.825E+01
  Styrene             7.329E+02 7.329E+02 7.329E+02 7.330E+02 7.330E+02 3.358E+00
  1112Tetra           7.330E+02 7.330E+02 7.330E+02 7.330E+02 7.330E+02 2.940E+00
  1122Tetra           7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 6.340E+00
  Tetrachloroethen    7.329E+02 7.329E+02 7.329E+02 7.329E+02 7.329E+02 1.273E+00
  2346Tetrachlor      7.351E+02 7.351E+02 7.351E+02 7.353E+02 7.357E+02 7.641E-01
  Toluene             7.330E+02 7.330E+02 7.329E+02 7.330E+02 7.330E+02 1.106E+00
  124Trichlorb        7.339E+02 7.339E+02 7.339E+02 7.343E+02 7.343E+02 8.070E+01
  Trichloroethene     7.329E+02 7.329E+02 7.329E+02 7.329E+02 7.329E+02 1.735E+00
  TriChloFlo          7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 5.498E+00

**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC HAZ – 2015 EMDF in UBCV
2, 0., 1000.,
99,0,1
1,2
0.0, 243.19, 486.37, 4.91E+05, 1., 476., 0.
1800.,6.,0.,0.,0.,0.,0.315,0.
20,2,0,1,1
3.35, 16.16, 1.91E+06,476.,0.,1600.,.40,.705,0.90,1.
1.0E-7,8000.,.705,0.,1.0E+00,0.01
240.,5.56E-04,.22,.02,3.0E-4,20.,0.01
4,6.3,.23,0.,1.1E-06,0.01,0.,0.,0.,0.,0.
0,0,0,0,0,0,0
1,0,0,1
0.0109, 4.27, 0.25, 7.0, 0.025, 24., 0.00001, 1., 0., 0.25

-- Input File:  BRCDCF.DAT
501,24-D             0.00E+00,1.00E-02,0.00E+00,0.00E+00
```

```
502,245-TP(silvex)   0.00E+00,8.00E-03,0.00E+00,0.00E+00
503,Acenaphthene     0.00E+00,6.00E-02,0.00E+00,0.00E+00
504,Acenaphthylene   0.00E+00,6.00E-02,0.00E+00,0.00E+00
505,Acetone          0.00E+00,9.00E-01,0.00E+00,0.00E+00
506,Acentonitrile    0.00E+00,0.00E+00,0.00E+00,0.00E+00
507,acetophenone     0.00E+00,1.00E-01,0.00E+00,0.00E+00
508,Acrolien         0.00E+00,5.00E-04,0.00E+00,0.00E+00
509,Acylonitrle      5.40E-01,4.00E-02,0.00E+00,0.00E+00
510,Aldrin           1.70E+01,3.00E-05,0.00E+00,0.00E+00
513,Aroclor1221      2.00E+00,0.00E+00,0.00E+00,0.00E+00
514,Aroclor1232      2.00E+00,0.00E+00,0.00E+00,0.00E+00
520,Benzene          5.50E-02,4.00E-03,0.00E+00,0.00E+00
526,Benzoic-acid     0.00E+00,4.00E+00,0.00E+00,0.00E+00
527,Benzyl-alcohol   0.00E+00,1.00E-01,0.00E+00,0.00E+00
528,benzidine        2.30E+02,3.00E-03,0.00E+00,0.00E+00
529,Alpha-BHC        6.30E+00,8.00E-03,0.00E+00,0.00E+00
530,Beta-BHC         1.80E+00,0.00E+00,0.00E+00,0.00E+00
531,Delta-BHC        1.80E+00,0.00E+00,0.00E+00,0.00E+00
533,Bromodichloro    6.20E-02,2.00E-02,0.00E+00,0.00E+00
534,Bromoform        7.90E-03,2.00E-02,0.00E+00,0.00E+00
535,Bromometh        0.00E+00,1.40E-03,0.00E+00,0.00E+00
537,butylbenzene     0.00E+00,5.00E-02,0.00E+00,0.00E+00
539,Carbazole        2.00E-02,0.00E+00,0.00E+00,0.00E+00
540,CarbonDiS        0.00E+00,1.00E-01,0.00E+00,0.00E+00
541,Carbontetchl     7.00E-02,4.00E-03,0.00E+00,0.00E+00
542,Chlordane        3.50E-01,5.00E-04,0.00E+00,0.00E+00
543,Chlorobenzene    0.00E+00,2.00E-02,0.00E+00,0.00E+00
544,Chloroform       3.10E-02,1.00E-02,0.00E+00,0.00E+00
545,Chlorometh       0.00E+00,0.00E+00,0.00E+00,0.00E+00
548,0-ChloroTu       0.00E+00,2.00E-02,0.00E+00,0.00E+00
550,m-cresol         0.00E+00,5.00E-02,0.00E+00,0.00E+00
551,o-cresol         0.00E+00,5.00E-02,0.00E+00,0.00E+00
552,p-cresol         0.00E+00,1.00E-01,0.00E+00,0.00E+00
553,Cumene           0.00E+00,1.00E-01,0.00E+00,0.00E+00
554,Cyanide          0.00E+00,6.00E-04,0.00E+00,0.00E+00
555,DDD              2.40E-01,0.00E+00,0.00E+00,0.00E+00
556,DDE              3.40E-01,0.00E+00,0.00E+00,0.00E+00
558,Dinbutylphthalat 0.00E+00,1.00E-01,0.00E+00,0.00E+00
560,Dibenz[ah]       7.30E+00,0.00E+00,0.00E+00,0.00E+00
561,Dibenzofuran     0.00E+00,1.00E-03,0.00E+00,0.00E+00
562,Dibromochloro    8.40E-02,2.00E-02,0.00E+00,0.00E+00
563,12Dichloro       0.00E+00,9.00E-02,0.00E+00,0.00E+00
564,13Dichloro       0.00E+00,8.90E-02,0.00E+00,0.00E+00
565,14Dichlorobenzen 5.40E-03,7.00E-02,0.00E+00,0.00E+00
571,12cisDichloro    0.00E+00,2.00E-03,0.00E+00,0.00E+00
572,12transDichl     0.00E+00,2.00E-02,0.00E+00,0.00E+00
573,Dichlorodiflo    0.00E+00,2.00E-01,0.00E+00,0.00E+00
574,12Dichlprop      3.60E-02,9.00E-02,0.00E+00,0.00E+00
575,Dieldrin         1.60E+01,5.00E-05,0.00E+00,0.00E+00
576,Diethylphth      0.00E+00,8.00E-01,0.00E+00,0.00E+00
577,12DiMethylB      0.00E+00,2.00E-01,0.00E+00,0.00E+00
579,24-Dimethylphe   0.00E+00,2.00E-02,0.00E+00,0.00E+00
580,Dimethylphth     0.00E+00,1.00E+01,0.00E+00,0.00E+00
582,24Dinitrotoluene 3.10E-01,2.00E-03,0.00E+00,0.00E+00
583,26Dinitrotoluene 0.00E+00,1.00E-03,0.00E+00,0.00E+00
585,EndosulfanII     0.00E+00,6.00E-03,0.00E+00,0.00E+00
586,Endrin           0.00E+00,3.00E-04,0.00E+00,0.00E+00
587,Aldehyde         0.00E+00,3.00E-04,0.00E+00,0.00E+00
588,Ketone           0.00E+00,3.00E-04,0.00E+00,0.00E+00
589,Ethylbenz        1.10E-02,1.00E-01,0.00E+00,0.00E+00
590,Ethylchlorid     0.00E+00,0.00E+00,0.00E+00,0.00E+00
593,Heptachlor       4.50E+00,5.00E-04,0.00E+00,0.00E+00
594,Heptachlor-epoxd 9.10E+00,1.30E-05,0.00E+00,0.00E+00
595,Hexachlorobenzen 1.60E+00,8.00E-04,0.00E+00,0.00E+00
596,Hexachloroethane 4.00E-02,7.00E-04,0.00E+00,0.00E+00
597,Nhexane          0.00E+00,6.00E-02,0.00E+00,0.00E+00
598,1hexanol         0.00E+00,4.00E-02,0.00E+00,0.00E+00
599,2hexanone        0.00E+00,5.00E-03,0.00E+00,0.00E+00
601,Isophorone       9.50E-04,2.00E-01,0.00E+00,0.00E+00
602,Lindane          1.10E+00,3.00E-04,0.00E+00,0.00E+00
603,Methonal         0.00E+00,5.00E-01,0.00E+00,0.00E+00
605,Methchloride     2.00E-03,6.00E-03,0.00E+00,0.00E+00
606,Methylcyclo      0.00E+00,6.00E-02,0.00E+00,0.00E+00
607,MethylIso        0.00E+00,8.00E-02,0.00E+00,0.00E+00
608,MMetacrylate     0.00E+00,1.40E+00,0.00E+00,0.00E+00
609,MethylEthylB     0.00E+00,3.70E-02,0.00E+00,0.00E+00
610,2Methylnaptha    0.00E+00,4.00E-03,0.00E+00,0.00E+00
611,MethylPropylB    0.00E+00,3.70E-02,0.00E+00,0.00E+00
612,Naphthalene      0.00E+00,2.00E-02,0.00E+00,0.00E+00
614,4Nitrobenzenamin 2.00E-02,4.00E-03,0.00E+00,0.00E+00
615,Nitrobenzene     0.00E+00,2.00E-03,0.00E+00,0.00E+00
```

```
616,2Nitrophenol     0.00E+00,6.20E-02,0.00E+00,0.00E+00
617,4Nitrophenol     0.00E+00,6.20E-02,0.00E+00,0.00E+00
618,NnitroNpropyl    7.00E+00,0.00E+00,0.00E+00,0.00E+00
619,NNitrosodiphen   4.90E-03,0.00E+00,0.00E+00,0.00E+00
622,Phenol           0.00E+00,3.00E-01,0.00E+00,0.00E+00
623,PropylB          0.00E+00,3.70E-02,0.00E+00,0.00E+00
624,PropGlycol       0.00E+00,2.00E+01,0.00E+00,0.00E+00
626,Pyridine         0.00E+00,1.00E-03,0.00E+00,0.00E+00
627,Styrene          0.00E+00,2.00E-01,0.00E+00,0.00E+00
628,1112Tetra        2.60E-02,3.00E-02,0.00E+00,0.00E+00
629,1122Tetra        2.00E-01,2.00E-02,0.00E+00,0.00E+00
630,Tetrachloroethen 2.10E-03,6.00E-03,0.00E+00,0.00E+00
631,2346Tetrachlor   0.00E+00,3.00E-02,0.00E+00,0.00E+00
632,Toluene          0.00E+00,8.00E-02,0.00E+00,0.00E+00
634,124Trichlorb     2.90E-02,1.00E-02,0.00E+00,0.00E+00
637,Trichloroethene  4.60E-02,5.00E-04,0.00E+00,0.00E+00
639,TriChloFlo       0.00E+00,3.00E-01,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
501,  1.00E+10, 1.910E+06,         0,         0, 6.820E+02,         0,        24-D
502,  1.00E+10, 1.910E+06,         0,         0, 2.000E+02,         0,        245-TP(silvex)
503,  1.00E+10, 1.910E+06,         0,         0, 3.420E+00,         0,        Acenaphthene
504,  1.00E+10, 1.910E+06,         0,         0, 1.610E+01,         0,        Acenaphthylene
505,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Acetone
506,  1.00E+10, 1.910E+06,         0,         0, 1.000E+06,         0,        Acentonitrile
507,  1.00E+10, 1.910E+06,         0,         0, 6.130E+03,         0,        acetophenone
508,  1.00E+10, 1.910E+06,         0,         0, 1.200E+04,         0,        Acrolien
509,  1.00E+10, 1.910E+06,         0,         0, 7.450E+04,         0,        Acylonitrle
510,  1.00E+10, 1.910E+06,         0,         0, 1.700E-02,         0,        Aldrin
513,  1.00E+10, 1.910E+06,         0,         0, 4.830E+00,         0,        Aroclor1221
514,  1.00E+10, 1.910E+06,         0,         0, 4.830E+00,         0,        Aroclor1232
520,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Benzene
526,  1.00E+10, 1.910E+06,         0,         0, 3.400E+03,         0,        Benzolic
527,  1.00E+10, 1.910E+06,         0,         0, 4.290E+04,         0,        Benzyl
528,  1.00E+10, 1.910E+06,         0,         0, 3.220E+02,         0,        benzidine
529,  1.00E+10, 1.910E+06,         0,         0, 8.000E+00,         0,        Alpha-BHC
530,  1.00E+10, 1.910E+06,         0,         0, 8.000E+00,         0,        Beta-BHC
531,  1.00E+10, 1.910E+06,         0,         0, 8.000E+00,         0,        Delta-BHC
533,  1.00E+10, 1.910E+06,         0,         0, 3.030E+03,         0,        Bromodichloro
534,  1.00E+10, 1.910E+06,         0,         0, 1.000E+02,         0,        Bromoform
535,  1.00E+10, 1.910E+06,         0,         0, 5.200E+03,         0,        Bromometh
537,  1.00E+10, 1.910E+06,         0,         0, 6.130E+01,         0,        butylbenzene
539,  1.00E+10, 1.910E+06,         0,         0, 1.800E+00,         0,        Carbazole
540,  1.00E+10, 1.910E+06,         0,         0, 1.180E+03,         0,        CarbonDiS
541,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Carbontetchl
542,  1.00E+10, 1.910E+06,         0,         0, 5.600E-02,         0,        Chlordane
543,  1.00E+10, 1.910E+06,         0,         0, 4.980E+02,         0,        Chlorobenzene
544,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Chloroform
545,  1.00E+10, 1.910E+06,         0,         0, 5.320E+03,         0,        Chlorometh
548,  1.00E+10, 1.910E+06,         0,         0, 3.740E+02,         0,        0-ChloroTu
550,  1.00E+10, 1.910E+06,         0,         0, 2.270E+04,         0,        m-cresol
551,  1.00E+10, 1.910E+06,         0,         0, 2.590E+04,         0,        o-cresol
552,  1.00E+10, 1.910E+06,         0,         0, 2.150E+04,         0,        p-cresol
553,  1.00E+10, 1.910E+06,         0,         0, 6.130E+01,         0,        Cumene
554,  1.00E+10, 1.910E+06,         0,         0, 1.000E+06,         0,        Cyanide
555,  1.00E+10, 1.910E+06,         0,         0, 9.000E-02,         0,        DDD
556,  1.00E+10, 1.910E+06,         0,         0, 4.000E-02,         0,        DDE
558,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Dinbutylphthalat
560,  1.00E+10, 1.910E+06,         0,         0, 1.030E-03,         0,        Dibenz[ah]
561,  1.00E+10, 1.910E+06,         0,         0, 3.100E+00,         0,        Dibenzofuran
562,  1.00E+10, 1.910E+06,         0,         0, 2.700E+03,         0,        Dibromochloro
563,  1.00E+10, 1.910E+06,         0,         0, 8.000E+01,         0,        12Dichloro
564,  1.00E+10, 1.910E+06,         0,         0, 1.250E+02,         0,        13Dichloro
565,  1.00E+10, 1.910E+06,         0,         0, 8.130E+01,         0,        14Dichlorobenzen
571,  1.00E+10, 1.910E+06,         0,         0, 3.500E+03,         0,        12cisDichloro
572,  1.00E+10, 1.910E+06,         0,         0, 3.500E+03,         0,        12transDichl
573,  1.00E+10, 1.910E+06,         0,         0, 2.800E+02,         0,        Dichlorodiflo
574,  1.00E+10, 1.910E+06,         0,         0, 2.800E+03,         0,        12Dichlprop
575,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Dieldrin
576,  1.00E+10, 1.910E+06,         0,         0, 1.080E+03,         0,        Diethylphth
577,  1.00E+10, 1.910E+06,         0,         0, 2.200E+02,         0,        12DiMethylB
579,  1.00E+10, 1.910E+06,         0,         0, 7.870E+03,         0,        24-Dimethylphe
580,  1.00E+10, 1.910E+06,         0,         0, 4.000E+03,         0,        Dimethylphth
582,  1.00E+10, 1.910E+06,         0,         0, 2.700E+02,         0,        24Dinitrotoluene
583,  1.00E+10, 1.910E+06,         0,         0, 3.520E+02,         0,        26Dinitrotoluene
585,  1.00E+10, 1.910E+06,         0,         0, 4.500E-01,         0,        EndosufanII
586,  1.00E+10, 1.910E+06,         0,         0, 2.500E-01,         0,        Endrin
587,  1.00E+10, 1.910E+06,         0,         0, 2.500E-01,         0,        Aldehyde
588,  1.00E+10, 1.910E+06,         0,         0, 2.500E-01,         0,        Ketone
589,  1.00E+10, 1.910E+06,         0,         0, 1.690E+02,         0,        Ethylbenz
590,  1.00E+10, 1.910E+06,         0,         0, 6.700E+03,         0,        Ethylchlorid
```

```
593,  1.00E+10, 1.910E+06,         0,         0, 1.800E-01,         0,        Heptachlor
594,  1.00E+10, 1.910E+06,         0,         0, 2.000E-01,         0,        Heptachlor
595,  1.00E+10, 1.910E+06,         0,         0, 6.200E-03,         0,        Hexachlorobenzen
596,  1.00E+10, 1.910E+06,         0,         0, 5.000E+01,         0,        Hexachloroethane
597,  1.00E+10, 1.910E+06,         0,         0, 9.500E+00,         0,        Nhexane
598,  1.00E+10, 1.910E+06,         0,         0, 5.900E+03,         0,        1hexanol
599,  1.00E+10, 1.910E+06,         0,         0, 5.900E+03,         0,        2hexanone
601,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Isophorone
602,  1.00E+10, 1.910E+06,         0,         0, 8.000E+00,         0,        Lindane
603,  1.00E+10, 1.910E+06,         0,         0, 1.000E+06,         0,        Methonal
605,  1.00E+10, 1.910E+06,         0,         0, 1.300E+04,         0,        Methchloride
606,  1.00E+10, 1.910E+06,         0,         0, 1.400E+01,         0,        Methylcyclo
607,  1.00E+10, 1.910E+06,         0,         0, 1.900E+04,         0,        MethylIso
608,  1.00E+10, 1.910E+06,         0,         0, 1.500E+04,         0,        MMetacrylate
609,  1.00E+10, 1.910E+06,         0,         0, 6.100E+01,         0,        MethylEthylB
610,  1.00E+10, 1.910E+06,         0,         0, 2.460E+01,         0,        2Methylnaptha
611,  1.00E+10, 1.910E+06,         0,         0, 6.100E+01,         0,        MethylPropylB
612,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Naphthalene
614,  1.00E+10, 1.910E+06,         0,         0, 1.070E-05,         0,        4Nitrobenzenamin
615,  1.00E+10, 1.910E+06,         0,         0, 2.090E+03,         0,        Nitrobenzene
616,  1.00E+10, 1.910E+06,         0,         0, 2.500E+03,         0,        2Nitrophenol
617,  1.00E+10, 1.910E+06,         0,         0, 1.160E+04,         0,        4Nitrophenol
618,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        NnitroNpropyl
619,  1.00E+10, 1.910E+06,         0,         0, 3.500E+01,         0,        NNitrosodiphen
622,  1.00E+10, 1.910E+06,         0,         0, 9.300E+04,         0,        Phenol
623,  1.00E+10, 1.910E+06,         0,         0, 6.100E+01,         0,        PropylB
624,  1.00E+10, 1.910E+06,         0,         0, 1.000E+06,         0,        PropGlycol
626,  1.00E+10, 1.910E+06,         0,         0, 1.000E+06,         0,        Pyridine
627,  1.00E+10, 1.910E+06,         0,         0, 3.100E+02,         0,        Styrene
628,  1.00E+10, 1.910E+06,         0,         0, 1.070E+03,         0,        1112Tetra
629,  1.00E+10, 1.910E+06,         0,         0, 2.870E+03,         0,        1122Tetra
630,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Tetrachloroethen
631,  1.00E+10, 1.910E+06,         0,         0, 2.300E+01,         0,        2346Tetrachlor
632,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Toluene
634,  1.00E+10, 1.910E+06,         0,         0, 5.700E+01,         0,        124Trichlorb
637,  1.00E+10, 1.910E+06,         0,         0, 0.000E+00,         0,        Trichloroethene
639,  1.00E+10, 1.910E+06,         0,         0, 1.100E+03,         0,        TriChloFlo

-- Input File:  RQSITE.DAT
501,-5.880E-02, 5.880E-03, 5.880E-02,       24-D
502,-1.608E-01, 1.608E-02, 1.608E-01,       245-TP(silvex)
503,-9.200E+01, 9.200E+00, 9.200E+01,       Acenaphthene
504,-1.220E+01, 1.220E+00, 1.220E+01,       Acenaphthylene
505,-4.400E-02, 0.000E+00, 4.400E-02,       Acetone
506,-1.540E-03, 1.540E-04, 1.540E-03,       Acentonitrile
507,-9.240E-02, 9.240E-03, 9.240E-02,       acetophenone
508,-2.780E-03, 2.780E-04, 2.780E-03,       Acrolien
509,-4.440E-03, 4.440E-04, 4.440E-03,       Acylonitrle
510,-9.740E+01, 9.740E+00, 9.740E+01,       Aldrin
513,-1.200E+02, 1.200E+02, 1.200E+02,       Aroclor1221
514,-1.500E+01, 1.500E+01, 1.500E+01,       Aroclor1232
520,-1.700E+00, 0.000E+00, 1.700E+00,       Benzene
526,-1.200E-03, 1.200E-04, 1.200E-03,       Benzoic
527,-3.130E-02, 3.130E-03, 3.130E-02,       Benzyl
528,-5.480E+00, 5.480E-01, 5.480E+00,       benzidine
529,-3.520E+00, 3.520E-01, 3.520E+00,       Alpha-BHC
530,-4.280E+00, 4.280E-01, 4.280E+00,       Beta-BHC
531,-4.280E+00, 4.280E-01, 4.280E+00,       Delta-BHC
533,-1.080E-02, 1.080E-03, 1.080E-02,       Bromodichloro
534,-2.520E-01, 2.520E-02, 2.520E-01,       Bromoform
535,-2.830E-02, 2.830E-03, 2.830E-02,       Bromometh
537,-1.630E+00, 1.630E-01, 1.630E+00,       butylbenzene
539,-6.780E+00, 6.780E-01, 6.780E+00,       Carbazole
540,-1.030E-01, 1.030E-02, 1.030E-01,       CarbonDiS
541,-2.200E+00, 0.000E+00, 2.200E+00,       Carbontetchl
542,-1.730E+02, 1.730E+01, 1.730E+02,       Chlordane
543,-4.380E-01, 4.380E-02, 4.380E-01,       Chlorobenzene
544,-6.200E-01, 0.000E+00, 6.200E-01,       Chloroform
545,-2.860E-02, 2.860E-03, 2.860E-02,       Chlorometh
548,-8.860E-01, 8.860E-02, 8.860E-01,       0-ChloroTu
550,-9.560E-02, 9.560E-03, 9.560E-02,       m-cresol
551,-1.820E-01, 1.820E-02, 1.820E-01,       o-cresol
552,-9.220E-02, 9.220E-03, 9.220E-02,       p-cresol
553,-1.650E+00, 1.650E-01, 1.650E+00,       Cumene
554,-9.900E+00, 9.900E-01, 9.900E+00,       Cyanide
555,-9.160E+01, 9.160E+00, 9.160E+01,       DDD
556,-1.730E+00, 1.730E-01, 1.730E+00,       DDE
558,-1.000E-06, 0.000E+00, 1.000E-06,       Dinbutylphthalat
560,-3.580E+03, 3.580E+02, 3.580E+03,       Dibenz[ah]
561,-2.260E+02, 2.260E+01, 2.260E+02,       Dibenzofuran
562,-1.410E-01, 1.410E-02, 1.410E-01,       Dibromochloro
```

```
563,-7.580E-01, 7.580E-02, 7.580E-01,       12Dichloro
564,-1.606E+01, 1.606E+00, 1.606E+01,       13Dichloro
565,-1.232E+00, 1.232E-01, 1.232E+00,       14Dichlorobenzen
571,-9.960E-01, 9.960E-02, 9.960E-01,       12cisDichloro
572,-7.600E-02, 7.600E-03, 7.600E-02,       12transDichl
573,-1.370E-02, 1.370E-03, 1.370E-02,       Dichlorodiflo
574,-9.400E-02, 9.400E-03, 9.400E-02,       12Dichlprop
575,-3.400E+01, 0.000E+00, 3.400E+01,       Dieldrin
576,-2.520E-01, 2.520E-02, 2.520E-01,       Diethylphth
577,-4.800E-01, 4.800E-02, 4.800E-01,       12DiMethylB
579,-2.520E+00, 2.520E-01, 2.520E+00,       24-Dimethlphe
580,-7.420E-02, 7.420E-03, 7.420E-02,       Dimethylphth
582,-1.020E-01, 1.020E-02, 1.020E-01,       24Dinitrotoluene
583,-8.390E-02, 8.390E-03, 8.390E-02,       26Dinitrotoluene
585,-4.080E+00, 4.080E+00, 4.080E-01,       EndosulfanII
586,-2.160E+01, 2.160E+00, 2.160E+01,       Endrin
587,-2.160E+01, 2.160E+01, 2.160E+00,       Aldehyde
588,-2.160E+01, 2.160E+01, 2.160E+00,       Ketone
589,-4.080E-01, 4.080E-02, 4.080E-01,       Ethylbenz
590,-4.750E-02, 4.750E-03, 4.750E-02,       Ethylchlorid
593,-4.800E+01, 4.800E+00, 4.800E+01,       Heptachlor
594,-1.730E+01, 1.730E+00, 1.730E+01,       Heptachlor
595,-1.100E+02, 1.100E+01, 1.100E+02,       Hexachlorobenzen
596,-3.560E+00, 3.560E-01, 3.560E+00,       Hexachloroethane
597,-2.980E-01, 2.980E-02, 2.980E-01,       Nhexane
598,-2.600E-02, 2.600E-03, 2.600E-02,       1hexanol
599,-2.600E-02, 2.600E-03, 2.600E-02,       2hexanone
601,-1.700E+00, 0.000E+00, 1.700E+00,       Isophorone
602,-6.760E+00, 6.760E-01, 6.760E+00,       Lindane
603,-2.000E-03, 2.000E-04, 2.000E-03,       Methonal
605,-2.010E+03, 0.000E+00, 2.010E+03,       Methchloride
606,-1.990E-01, 0.000E+00, 0.000E+00,       Methylcyclo
607,-4.700E-03, 4.700E-04, 4.700E-03,       MethylIso
608,-2.000E-02, 2.000E-03, 2.000E-02,       MMetacrylate
609,-1.650E+00, 1.650E-01, 1.650E+00,       MethylEthylB
610,-5.940E+00, 5.940E-01, 5.940E+00,       2Methylnaptha
611,-1.650E+00, 1.650E-01, 1.650E+00,       MethylPropylB
612,-1.900E+01, 1.900E+00, 1.900E+01,       Naphthalene
614,-3.440E-01, 3.440E-02, 3.440E-01,       4Nitrobenzenamin
615,-1.290E-01, 1.290E-02, 1.290E-01,       Nitrobenzene
616,-7.100E-01, 7.100E-02, 7.100E-01,       2Nitrophenol
617,-8.740E-01, 8.740E-02, 8.740E-01,       4Nitrophenol
618,-3.000E-01, 3.000E-02, 3.000E-01,       NnitroNpropyl
619,-6.540E-01, 6.540E-02, 6.540E-01,       NNitrosodiphen
622,-2.800E-01, 2.800E-02, 2.800E-01,       Phenol
623,-1.650E+00, 1.650E-01, 1.650E+00,       PropylB
624,-2.000E-03, 2.000E-04, 2.000E-03,       PropGlycol
626,-1.380E-02, 1.380E-03, 1.380E-02,       Pyridine
627,-1.820E+00, 1.820E-01, 1.820E+00,       Styrene
628,-3.180E-01, 3.180E-02, 3.180E-01,       1112Tetra
629,-1.580E-01, 1.560E-02, 1.560E-01,       1122Tetra
630,-7.200E+00, 0.000E+00, 7.200E+00,       Tetrachloroethen
631,-2.490E+02, 2.490E+01, 2.490E+02,       2346Tetrachlor
632,-6.000E+00, 0.000E+00, 6.000E+00,       Toluene
634,-1.440E+00, 1.440E-01, 1.440E+00,       124Trichlorb
637,-2.600E+00, 0.000E+00, 2.600E+00,       Trichloroethene
639,-2.680E-01, 2.680E-02, 2.680E-01,       TriChloFlo



-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
0.0,   2160.,  24.,     1440.,     1.,  0.83
50.,   6.,     48.,      480.,    48.
.05,  0.0008,  60.,        8.,    50.
14.,    176., 110.,        0.,    95.,   730., 0.0
24-D                0.25,  1.30E+00,  1.30E-01,  2.50E-06,        0,  7.90E-06,  0.00E+00,        501
245-TP(silvex)      0.25,  2.10E-01,  2.10E-02,  6.30E-05,        0,  2.00E-04,  0.00E+00,        502
Acenaphthene        0.25,  1.20E-01,  1.20E-02,  1.60E-04,        0,  5.00E-04,  1.10E+03,        503
Acenaphthylene      0.25,  2.70E-01,  2.70E-02,  4.00E-05,        0,  1.30E-04,  0.00E+00,        504
Acetone             0.25,  1.30E+01,  1.30E+00,  1.50E-08,        0,  1.50E-08,  1.50E-08,        505
Acentonitrile       0.25,  6.00E+01,  6.00E+00,  3.60E-09,        0,  1.10E-08,  0.00E+00,        506
acetophenone        0.25,  3.90E+00,  3.90E-01,  4.00E-07,        0,  1.30E-06,  0.00E+00,        507
Acrolien            0.25,  4.30E+01,  4.30E+00,  6.30E-09,        0,  2.00E-08,  0.00E+00,        508
Acylonitrle         0.25,  2.70E+01,  2.70E+00,  1.40E-08,        0,  4.40E-08,  0.00E+00,        509
Aldrin              0.25,  6.90E-01,  6.90E-02,  7.90E-06,        0,  2.50E-05,  0.00E+00,        510
Aroclor1221         0.25,  1.60E-01,  1.60E-02,  9.90E-05,        0,  3.10E-04,  0.00E+00,        513
Aroclor1232         0.25,  5.30E-01,  5.30E-02,  1.30E-05,        0,  4.00E-05,  0.00E+00,        514
Benzene             0.25,  5.80E-01,  5.80E-02,  3.30E-06,        0,  3.30E-06,  3.30E-06,        520
```

```
Benzoic-acid        0.25,  3.00E+00,  3.00E-01,  6.30E-07,        0,  2.00E-06,  0.00E+00,        526
Benzyl-alcohol      0.25,  8.70E+00,  8.70E-01,  9.90E-08,        0,  3.10E-07,  0.00E+00,        527
benzidine           0.25,  6.70E+00,  6.70E-01,  1.60E-07,        0,  5.00E-07,  0.00E+00,        528
Alpha-BHC           0.25,  2.10E-01,  2.10E-02,  6.30E-05,        0,  2.00E-04,  0.00E+00,        529
Beta-BHC            0.25,  1.80E-01,  1.80E-02,  7.90E-05,        0,  2.50E-04,  0.00E+00,        530
Delta-BHC           0.25,  9.00E-01,  9.00E-02,  5.00E-06,        0,  1.60E-05,  0.00E+00,        531
Bromodichloro       0.25,  2.30E+00,  2.30E-01,  9.90E-07,        0,  3.10E-06,  0.00E+00,        533
Bromoform           0.25,  1.50E+00,  1.50E-01,  2.00E-06,        0,  6.30E-06,  0.00E+00,        534
Bromometh           0.25,  7.70E+00,  7.70E-01,  1.30E-07,        0,  4.00E-07,  0.00E+00,        535
butylbenzene        0.25,  3.50E-01,  3.50E-02,  2.50E-05,        0,  7.90E-05,  0.00E+00,        537
Carbazole           0.25,  2.40E-01,  2.40E-02,  5.00E-05,        0,  1.60E-04,  4.50E+02,        539
CarbonDiS           0.25,  2.00E+00,  2.00E-01,  1.30E-06,        0,  4.00E-06,  0.00E+00,        540
Carbontetchl        0.25,  2.90E-01,  2.90E-02,  1.10E-05,        0,  1.10E-05,  1.10E-05,        541
Chlordane           0.25,  2.50E-02,  2.50E-03,  2.50E-03,        0,  7.90E-03,  0.00E+00,        542
Chlorobenzene       0.25,  9.00E-01,  9.00E-02,  5.00E-06,        0,  1.60E-05,  0.00E+00,        543
Chloroform          0.25,  7.00E-01,  7.00E-02,  2.30E-06,        0,  2.30E-06,  2.30E-06,        544
Chlorometh          0.25,  1.10E+01,  1.10E+00,  6.40E-08,        0,  2.00E-07,  0.00E+00,        545
0-ChloroTu          0.25,  4.10E-01,  4.10E-02,  2.00E-05,        0,  6.30E-05,  0.00E+00,        548
m-cresol            0.25,  2.60E+00,  2.60E-01,  7.90E-07,        0,  2.50E-06,  0.00E+00,        550
o-cresol            0.25,  3.00E+00,  3.00E-01,  6.30E-07,        0,  2.00E-06,  0.00E+00,        551
p-cresol            0.25,  3.00E+00,  3.00E-01,  6.30E-07,        0,  2.00E-06,  0.00E+00,        552
Cumene              0.25,  3.50E-01,  3.50E-02,  2.50E-05,        0,  7.90E-05,  0.00E+00,        553
Cyanide             0.25,  8.70E+00,  8.70E-01,  9.90E-08,        0,  3.10E-07,  3.50E+00,        554
DDD                 0.25,  1.60E-02,  1.60E-03,  5.00E-03,        0,  1.60E-02,  0.00E+00,        555
DDE                 0.25,  1.90E-02,  1.90E-03,  4.00E-03,        0,  1.30E-02,  0.00E+00,        556
Dinbutylphthalat    0.25,  5.60E-03,  5.60E-04,  3.20E-03,        0,  1.00E-02,  0.00E+00,        558
Dibenz[ah]          0.25,  4.30E-03,  4.30E-04,  5.00E-02,        0,  1.60E-01,  6.30E+00,        560
Dibenzofuran        0.25,  1.50E-01,  1.50E-02,  1.00E-04,        0,  3.30E-04,  0.00E+00,        561
Dibromochloro       0.25,  2.00E+00,  2.00E-01,  1.30E-06,        0,  4.00E-06,  0.00E+00,        562
12Dichloro          0.25,  4.10E-01,  4.10E-02,  2.00E-05,        0,  6.30E-05,  8.70E+01,        563
13Dichloro          0.25,  3.10E-01,  3.10E-02,  3.10E-05,        0,  1.00E-04,  1.00E+02,        564
14Dichlorobenzen    0.25,  4.10E-01,  4.10E-02,  2.00E-05,        0,  6.30E-05,  0.00E+00,        565
12cisDichloro       0.25,  3.00E+00,  3.00E-01,  6.30E-07,        0,  2.00E-06,  0.00E+00,        571
12transDichl        0.25,  2.00E+01,  2.00E+00,  2.40E-08,        0,  7.50E-08,  0.00E+00,        572
Dichlorodiflo       0.25,  2.00E+00,  2.00E-01,  1.30E-06,        0,  4.00E-06,  0.00E+00,        573
12Dichlprop         0.25,  2.60E+00,  2.60E-01,  7.90E-07,        0,  2.50E-06,  0.00E+00,        574
Dieldrin            0.25,  9.20E-02,  9.20E-03,  7.90E-03,        0,  7.90E-03,  7.90E-03,        575
Diethylphth         0.25,  1.30E+00,  1.30E-01,  2.50E-06,        0,  7.90E-06,  0.00E+00,        576
12DiMethylB         0.25,  6.00E-01,  6.00E-02,  1.10E-05,        0,  3.40E-05,  0.00E+00,        577
24-Dimethylphe      0.25,  1.80E+00,  1.80E-01,  1.60E-06,        0,  5.00E-06,  0.00E+00,        579
Dimethylphth        0.25,  4.50E+00,  4.50E-01,  3.10E-07,        0,  1.00E-06,  0.00E+00,        580
24Dinitrotoluene    0.25,  2.60E+00,  2.60E-01,  7.90E-07,        0,  2.50E-06,  6.40E+00,        582
26Dinitrotoluene    0.25,  3.90E+00,  3.90E-01,  4.00E-07,        0,  1.30E-06,  6.20E+00,        583
EndosulfanII        0.25,  3.30E-01,  3.30E-02,  2.80E-05,        0,  8.90E-05,  0.00E+00,        585
Endrin              0.25,  8.20E-02,  8.20E-03,  3.10E-04,        0,  1.00E-03,  0.00E+00,        586
Aldehyde            0.25,  8.20E-02,  8.20E-03,  3.10E-04,        0,  1.00E-03,  0.00E+00,        587
Ketone              0.25,  8.20E-02,  8.20E-03,  3.10E-04,        0,  1.00E-03,  0.00E+00,        588
Ethylbenz           0.25,  6.10E-01,  6.10E-02,  9.90E-06,        0,  3.10E-05,  0.00E+00,        589
Ethylchlorid        0.25,  5.90E+00,  5.90E-01,  2.00E-07,        0,  6.30E-07,  0.00E+00,        590
Heptachlor          0.25,  1.20E-01,  1.20E-02,  1.60E-04,        0,  5.00E-04,  0.00E+00,        593
Heptachlor-epoxd    0.25,  2.80E-02,  2.80E-03,  2.00E-03,        0,  6.30E-03,  0.00E+00,        594
Hexachlorobenzen    0.25,  3.20E-02,  3.20E-03,  1.60E-03,        0,  5.00E-03,  0.00E+00,        595
Hexachloroethane    0.25,  2.10E-01,  2.10E-02,  6.30E-05,        0,  2.00E-04,  0.00E+00,        596
Nhexane             0.25,  2.10E-01,  2.10E-02,  6.30E-05,        0,  2.00E-04,  0.00E+00,        597
1hexanol            0.25,  5.90E+00,  5.90E-01,  2.00E-07,        0,  6.30E-07,  0.00E+00,        598
2hexanone           0.25,  5.90E+00,  5.90E-01,  2.00E-07,        0,  6.30E-07,  0.00E+00,        599
Isophorone          0.25,  4.80E-01,  4.80E-02,  4.60E-06,        0,  4.60E-06,  4.60E-06,        601
Lindane             0.25,  2.70E-01,  2.70E-02,  4.00E-05,        0,  1.30E-04,  0.00E+00,        602
Methonal            0.25,  1.10E+02,  1.10E+01,  1.30E-09,        0,  4.20E-09,  0.00E+00,        603
MethChoride         0.25,  6.70E+00,  6.70E-01,  1.60E-07,        0,  5.00E-07,  0.00E+00,        605
Methylcyclo         0.25,  8.30E-01,  8.30E-02,  5.70E-06,        0,  1.80E-05,  1.20E+02,        606
MethylIso           0.25,  7.70E+00,  7.70E-01,  1.30E-07,        0,  4.00E-07,  0.00E+00,        607
MMetacrylate        0.25,  6.70E+00,  6.70E-01,  1.60E-07,        0,  5.00E-07,  0.00E+00,        608
MethylEthylB        0.25,  3.50E-01,  3.50E-02,  2.50E-05,        0,  7.90E-05,  0.00E+00,        609
2Methylnaptha       0.25,  2.10E-01,  2.10E-02,  6.30E-05,        0,  2.00E-04,  0.00E+00,        610
MethylPropylB       0.25,  3.50E-01,  3.50E-02,  2.50E-05,        0,  7.90E-05,  0.00E+00,        611
Naphthalene         0.25,  4.60E-01,  4.60E-02,  1.60E-05,        0,  5.00E-05,  1.90E+02,        612
4Nitrobenzenamin    0.25,  6.80E+00,  6.80E-01,  2.00E-07,        0,  6.20E-07,  9.60E+02,        614
Nitrobenzene        0.25,  3.40E+00,  3.40E-01,  5.00E-07,        0,  1.60E-06,  0.00E+00,        615
2Nitrophenol        0.25,  3.60E+00,  3.60E-01,  4.90E-07,        0,  1.60E-06,  0.00E+00,        616
4Nitrophenol        0.25,  3.00E+00,  3.00E-01,  6.30E-07,        0,  2.00E-06,  3.10E+02,        617
NnitroNpropyl       0.25,  5.90E+00,  5.90E-01,  2.00E-07,        0,  6.30E-07,  6.80E+00,        618
NNitrosodiphen      0.25,  6.10E-01,  6.10E-02,  9.90E-06,        0,  3.00E-05,  5.30E+00,        619
Phenol              0.25,  5.10E+00,  5.10E-01,  2.50E-07,        0,  7.90E-07,  8.10E+00,        622
PropylB             0.25,  3.50E-01,  3.50E-02,  2.50E-05,        0,  7.90E-05,  0.00E+00,        623
PropGlycol          0.25,  3.70E+02,  3.70E+01,  1.60E-10,        0,  5.00E-10,  0.00E+00,        624
Pyridine            0.25,  6.70E+00,  6.70E-01,  1.60E-07,        0,  5.00E-07,  0.00E+00,        626
Styrene             0.25,  7.90E-01,  7.90E-02,  6.30E-06,        0,  2.00E-05,  0.00E+00,        627
1112Tetra           0.25,  6.90E-01,  6.90E-02,  7.90E-06,        0,  2.50E-05,  0.00E+00,        628
1122Tetra           0.25,  1.50E+00,  1.50E-01,  2.00E-06,        0,  6.30E-06,  0.00E+00,        629
Tetrachloroethen    0.25,  3.00E-01,  3.00E-02,  1.00E-05,        0,  1.00E-05,  1.00E-05,        630
```

```
2346Tetrachlor        0.25,  1.60E-01,  1.60E-02,  9.90E-05,         0,  3.10E-04,  0.00E+00,        631
Toluene               0.25,  2.60E-01,  2.60E-02,  1.30E-05,         0,  1.30E-05,  1.30E-05,        632
124Trichlorb          0.25,  2.44E-01,  2.44E+00,  4.80E-05,         0,  1.50E-04,  0.00E+00,        634
Trichloroethene       0.25,  4.10E-01,  4.10E-02,  6.00E-06,         0,  6.00E-06,  6.00E-06,        637
TriChloFlo            0.25,  1.30E+00,  1.30E-01,  2.50E-06,         0,  7.90E-06,  0.00E+00,        639

1



**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  2
YEARS TO BE CALCULATED ARE ...

      .00  1000.00

THERE ARE  99 CONTAMINANTS IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  1

           PATHWAY           TYPE OF USAGE
                           FOR UPTAKE FACTORS
   1  GROUNDWATER TO RIVER         2

TIME OF OPERATION OF WASTE FACILITY IN YEARS                    0.
LENGTH OF REPOSITORY (M)                                      243.
WIDTH OF REPOSITORY (M)                                       486.
RIVER FLOW RATE (M**3/YR)                                     4.91E+05
STREAM FLOW RATE (M**3/YR)                                    1.00E+00
DISTANCE TO RIVER (M)                                         476.

OPERATIONAL SPILLAGE FRACTION                                 0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                 1800.
LONGITUDINAL DISPERSIVITY (M)                                 6.00E+00
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)            0.00E+00
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION               20
FLAG FOR ATMOSPHERIC PATHWAY                                   0

COVER THICKNESS OVER WASTE (M)                                3.35
THICKNESS OF WASTE IN PITS (M)                               16.16
TOTAL WASTE VOLUME (M**3)                                     1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)                          476.
DISTANCE TO WELL -- Y COORDINATE (M)                          0.
DENSITY OF WASTE (KG/M**3)                                   1600.

FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE                .400
FRACTION OF YEAR CONTAMINANTS CONTACT SKIN                     .705
AREA OF SKIN IN CONTACT WITH CONTAMINANTS (M**2)               .0100
DEPTH OF PLANT ROOT ZONE (M)                                   .900
AREAL DENSITY OF PLANTS (KG/M**2)                             1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)                         1.00E-07

ANNUAL ADULT BREATHING RATE (M**3/YR)                        8000.
FRACTION OF YEAR EXPOSED TO DUST                               .705
CANISTER LIFETIME (YEARS)                                     0.
INVENTORY SCALING FACTOR                                      1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)                       240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)              5.56E-04

ATMOSPHERIC STABILITY CLASS                                   4
AVERAGE WIND SPEED (M/S)                                      6.30
FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR                    .2300
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)                  .0
DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)         1.10E-06
DEPOSITION VELOCITY (M/S)                                      .0100

STACK HEIGHT (M)                                               .0
STACK INSIDE DIAMETER (M)                                      .00
STACK GAS VELOCITY (M/S)                                       .0
HEAT EMISSION RATE FROM BURNING (CAL/S)                       0.00E+00
FLAGS FOR DEGRADATION SERIES              0   0   0   0   0   0   0

FLAG FOR INPUT SUMMARY PRINTOUT                               1
FLAG FOR DIRECTION OF TRENCH FILLING                          0
FLAG FOR GROUNDWATER PATHWAY OPTIONS                          1
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)        1.09E-02
DEGREE OF SOIL SATURATION                                     1.000
RESIDUAL SOIL SATURATION                                       .000
```

| | |
|---|---|
| PERMEABILITY OF VERTICAL ZONE (M/YR) | .32 |
| SOIL NUMBER | .000 |
| POROSITY OF AQUIFER | .25 |
| POROSITY OF UNSATURATED ZONE | .25 |
| DISTANCE FROM AQUIFER TO WASTE (M) | 7.0 |
| AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR) | 2.50E-02 |
| HORIZONTAL VELOCITY OF AQUIFER (M/YR) | 4.27E+00 |
| LENGTH OF PERFORATED WELL CASING (M) | 24.000 |
| SURFACE EROSION RATE (M/YR) | 1.000E-05 |
| LEACH RATE SCALING FACTOR | 1.000E+00 |
| ANNUAL RUNOFF OF PRECIPITATION (M) | 0.00E+00 |

| | INGESTION | | INHALATION | | |
|---|---|---|---|---|---|
| CONTAMINANT | UNIT RISK FACTORS (KG-DAY/MG) | ALLOWABLE DAILY INTAKES (MG/KG-DAY) | UNIT RISK FACTORS (KG-DAY/MG) | ALLOWABLE DAILY INTAKES (MG/KG-DAY) | HALF LIFE (YR) |
| 24-D | 0.000E+00 | 1.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 245-TP(silvex) | 0.000E+00 | 8.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Acenaphthene | 0.000E+00 | 6.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Acenaphthylene | 0.000E+00 | 6.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Acetone | 0.000E+00 | 9.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Acentonitrile | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| acetophenone | 0.000E+00 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Acrolien | 0.000E+00 | 5.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Acylonitrle | 5.400E-01 | 4.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Aldrin | 1.700E+01 | 3.000E-05 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Aroclor1221 | 2.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Aroclor1232 | 2.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Benzene | 5.500E-02 | 4.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Benzoic-acid | 0.000E+00 | 4.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Benzyl-alcohol | 0.000E+00 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| benzidine | 2.300E+02 | 3.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Alpha-BHC | 6.300E+00 | 8.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Beta-BHC | 1.800E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Delta-BHC | 1.800E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Bromodichloro | 6.200E-02 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Bromoform | 7.900E-03 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Bromometh | 0.000E+00 | 1.400E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| butylbenzene | 0.000E+00 | 5.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Carbazole | 2.000E-02 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| CarbonDiS | 0.000E+00 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Carbontetchl | 7.000E-02 | 4.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Chlordane | 3.500E-01 | 5.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Chlorobenzene | 0.000E+00 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Chloroform | 3.100E-02 | 1.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Chlorometh | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 0-ChloroTu | 0.000E+00 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| m-cresol | 0.000E+00 | 5.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| o-cresol | 0.000E+00 | 5.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| p-cresol | 0.000E+00 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Cumene | 0.000E+00 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Cyanide | 0.000E+00 | 6.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| DDD | 2.400E-01 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| DDE | 3.400E-01 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dinbutylphthalat | 0.000E+00 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dibenz[ah] | 7.300E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dibenzofuran | 0.000E+00 | 1.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dibromochloro | 8.400E-02 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 12Dichloro | 0.000E+00 | 9.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 13Dichloro | 0.000E+00 | 8.900E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 14Dichlorobenzen | 5.400E-03 | 7.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 12cisDichloro | 0.000E+00 | 2.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 12transDichl | 0.000E+00 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dichlorodiflo | 0.000E+00 | 2.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 12Dichlprop | 3.600E-02 | 9.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dieldrin | 1.600E+01 | 5.000E-05 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Diethylphth | 0.000E+00 | 8.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 12DiMethylB | 0.000E+00 | 2.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 24-Dimethylphe | 0.000E+00 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Dimethylphth | 0.000E+00 | 1.000E+01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 24Dinitrotoluene | 3.100E-01 | 2.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 26Dinitrotoluene | 0.000E+00 | 1.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| EndosulfanII | 0.000E+00 | 6.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Endrin | 0.000E+00 | 3.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Aldehyde | 0.000E+00 | 3.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Ketone | 0.000E+00 | 3.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Ethylbenz | 1.100E-02 | 1.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |

| | | | | | |
|---|---|---|---|---|---|
| Ethylchlorid | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Heptachlor | 4.500E+00 | 5.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Heptachlor-epoxd | 9.100E+00 | 1.300E-05 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Hexachlorobenzen | 1.600E+00 | 8.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Hexachloroethane | 4.000E-02 | 7.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Nhexane | 0.000E+00 | 6.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 1hexanol | 0.000E+00 | 4.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 2hexanone | 0.000E+00 | 5.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Isophorone | 9.500E-04 | 2.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Lindane | 1.100E+00 | 3.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Methonal | 0.000E+00 | 5.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Methchloride | 2.000E-03 | 6.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Methylcyclo | 0.000E+00 | 6.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| MethylIso | 0.000E+00 | 8.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| MMetacrylate | 0.000E+00 | 1.400E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| MethylEthylB | 0.000E+00 | 3.700E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 2Methylnaptha | 0.000E+00 | 4.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| MethylPropylB | 0.000E+00 | 3.700E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Naphthalene | 0.000E+00 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 4Nitrobenzenamin | 2.000E-02 | 4.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Nitrobenzene | 0.000E+00 | 2.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 2Nitrophenol | 0.000E+00 | 6.200E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 4Nitrophenol | 0.000E+00 | 6.200E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| NnitroNpropyl | 7.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| NNitrosodiphen | 4.900E-03 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Phenol | 0.000E+00 | 3.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| PropylB | 0.000E+00 | 3.700E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| PropGlycol | 0.000E+00 | 2.000E+01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Pyridine | 0.000E+00 | 1.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Styrene | 0.000E+00 | 2.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 1112Tetra | 2.600E-02 | 3.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 1122Tetra | 2.000E-01 | 2.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Tetrachloroethen | 2.100E-03 | 6.000E-03 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 2346Tetrachlor | 0.000E+00 | 3.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Toluene | 0.000E+00 | 8.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| 124Trichlorb | 2.900E-02 | 1.000E-02 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| Trichloroethene | 4.600E-02 | 5.000E-04 | 0.000E+00 | 0.000E+00 | 1.000E+10 |
| TriChloFlo | 0.000E+00 | 3.000E-01 | 0.000E+00 | 0.000E+00 | 1.000E+10 |

| CONTAMINANT | VOLATILITY FRACTION | VAPORIZATION RATE (1/S) | SKIN ABSORPTION (M/HR) |
|---|---|---|---|
| 24-D | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 245-TP(silvex) | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Acenaphthene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Acenaphthylene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Acetone | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Acentonitrile | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| acetophenone | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Acrolien | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Acylonitrle | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Aldrin | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Aroclor1221 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Aroclor1232 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Benzene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Benzoic-acid | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Benzyl-alcohol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| benzidine | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Alpha-BHC | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Beta-BHC | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Delta-BHC | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Bromodichloro | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Bromoform | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Bromometh | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| butylbenzene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Carbazole | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| CarbonDiS | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Carbontetchl | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Chlordane | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Chlorobenzene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Chloroform | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Chlorometh | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 0-ChloroTu | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| m-cresol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| o-cresol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| p-cresol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cumene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Cyanide | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| DDD | 0.000E+00 | 0.000E+00 | 0.000E+00 |

| | | | |
|---|---|---|---|
| DDE | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dinbutylphthalat | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dibenz[ah] | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dibenzofuran | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dibromochloro | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 12Dichloro | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 13Dichloro | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 14Dichlorobenzen | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 12cisDichloro | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 12transDichl | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dichlorodiflo | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 12Dichlprop | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dieldrin | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Diethylphth | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 12DiMethylB | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 24-Dimethylphe | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Dimethylphth | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 24Dinitrotoluene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 26Dinitrotoluene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| EndosulfanII | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Endrin | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Aldehyde | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ketone | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ethylbenz | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Ethylchlorid | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Heptachlor | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Heptachlor-epoxd | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Hexachlorobenzen | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Hexachloroethane | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Nhexane | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 1hexanol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 2hexanone | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Isophorone | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Lindane | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Methonal | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Methchloride | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Methylcyclo | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| MethylIso | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| MMetacrylate | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| MethylEthylB | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 2Methylnaptha | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| MethylPropylB | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Naphthalene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 4Nitrobenzenamin | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Nitrobenzene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 2Nitrophenol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 4Nitrophenol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| NnitroNpropyl | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| NNitrosodiphen | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Phenol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| PropylB | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| PropGlycol | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Pyridine | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Styrene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 1112Tetra | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 1122Tetra | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Tetrachloroethen | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 2346Tetrachlor | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Toluene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 124Trichlorb | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Trichloroethene | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| TriChloFlo | 0.000E+00 | 0.000E+00 | 0.000E+00 |

| CONTAMINANT | INPUT LEACH (1/YR) | FINAL LEACH (1/YR) | SOLUBILITY (MG/L) | INPUT INVENTORY (KG) |
|---|---|---|---|---|
| 24-D | -5.880E-02 | 4.604E-04 | 6.820E+02 | 1.910E+06 |
| 245-TP(silvex) | -1.608E-01 | 1.350E-04 | 2.000E+02 | 1.910E+06 |
| Acenaphthene | -9.200E+01 | 2.309E-06 | 3.420E+00 | 1.910E+06 |
| Acenaphthylene | -1.220E+01 | 1.087E-05 | 1.610E+01 | 1.910E+06 |
| Acetone | -4.400E-02 | 2.105E-03 | 0.000E+00 | 1.910E+06 |
| Acentonitrile | -1.540E-03 | 2.672E-03 | 1.000E+06 | 1.910E+06 |
| acetophenone | -9.240E-02 | 1.695E-03 | 6.130E+03 | 1.910E+06 |
| Acrolien | -2.780E-03 | 2.651E-03 | 1.200E+04 | 1.910E+06 |
| Acylonitrle | -4.440E-03 | 2.623E-03 | 7.450E+04 | 1.910E+06 |
| Aldrin | -9.740E+01 | 1.148E-08 | 1.700E-02 | 1.910E+06 |
| Aroclor1221 | -1.200E+02 | 3.260E-06 | 4.830E+00 | 1.910E+06 |
| Aroclor1232 | -1.500E+01 | 3.260E-06 | 4.830E+00 | 1.910E+06 |
| Benzene | -1.700E+00 | 2.271E-04 | 0.000E+00 | 1.910E+06 |
| Benzoic-acid | -1.200E-03 | 2.295E-03 | 3.400E+03 | 1.910E+06 |

| | | | | |
|---|---|---|---|---|
| Benzyl-alcohol | -3.130E-02 | 2.248E-03 | 4.290E+04 | 1.910E+06 |
| benzidine | -5.480E+00 | 7.480E-05 | 3.220E+02 | 1.910E+06 |
| Alpha-BHC | -3.520E+00 | 5.400E-06 | 8.000E+00 | 1.910E+06 |
| Beta-BHC | -4.280E+00 | 5.400E-06 | 8.000E+00 | 1.910E+06 |
| Delta-BHC | -4.280E+00 | 5.400E-06 | 8.000E+00 | 1.910E+06 |
| Bromodichloro | -1.080E-02 | 2.045E-03 | 3.030E+03 | 1.910E+06 |
| Bromoform | -2.520E-01 | 6.750E-05 | 1.000E+02 | 1.910E+06 |
| Bromometh | -2.830E-02 | 2.284E-03 | 5.200E+03 | 1.910E+06 |
| butylbenzene | -1.630E+00 | 4.138E-05 | 6.130E+01 | 1.910E+06 |
| Carbazole | -6.780E+00 | 1.215E-06 | 1.800E+00 | 1.910E+06 |
| CarbonDiS | -1.030E-01 | 7.965E-04 | 1.180E+03 | 1.910E+06 |
| Carbontetchl | -2.200E+00 | 1.789E-04 | 0.000E+00 | 1.910E+06 |
| Chlordane | -1.730E+02 | 3.780E-08 | 5.600E-02 | 1.910E+06 |
| Chlorobenzene | -4.380E-01 | 3.362E-04 | 4.980E+02 | 1.910E+06 |
| Chloroform | -6.200E-01 | 5.431E-04 | 0.000E+00 | 1.910E+06 |
| Chlorometh | -2.860E-02 | 2.281E-03 | 5.320E+03 | 1.910E+06 |
| 0-ChloroTu | -8.860E-01 | 2.525E-04 | 3.740E+02 | 1.910E+06 |
| m-cresol | -9.560E-02 | 1.674E-03 | 2.270E+04 | 1.910E+06 |
| o-cresol | -1.820E-01 | 1.246E-03 | 2.590E+04 | 1.910E+06 |
| p-cresol | -9.220E-02 | 1.697E-03 | 2.150E+04 | 1.910E+06 |
| Cumene | -1.650E+00 | 4.138E-05 | 6.130E+01 | 1.910E+06 |
| Cyanide | -9.900E+00 | 4.192E-05 | 1.000E+06 | 1.910E+06 |
| DDD | -9.160E+01 | 6.075E-08 | 9.000E-02 | 1.910E+06 |
| DDE | -1.730E+00 | 2.700E-08 | 4.000E-02 | 1.910E+06 |
| Dinbutylphthalat | -1.000E-06 | 2.698E-03 | 0.000E+00 | 1.910E+06 |
| Dibenz[ah] | -3.580E+03 | 6.953E-10 | 1.030E-03 | 1.910E+06 |
| Dibenzofuran | -2.260E+02 | 1.864E-06 | 3.100E+00 | 1.910E+06 |
| Dibromochloro | -1.410E-01 | 1.418E-03 | 2.700E+03 | 1.910E+06 |
| 12Dichloro | -7.580E-01 | 5.400E-05 | 8.000E+01 | 1.910E+06 |
| 13Dichloro | -1.606E+01 | 2.600E-05 | 1.250E+02 | 1.910E+06 |
| 14Dichlorobenzen | -1.232E+00 | 5.488E-05 | 8.130E+01 | 1.910E+06 |
| 12cisDichloro | -9.960E-01 | 3.659E-04 | 3.500E+03 | 1.910E+06 |
| 12transDichl | -7.600E-02 | 1.815E-03 | 3.500E+03 | 1.910E+06 |
| Dichlorodiflo | -1.370E-02 | 1.890E-04 | 2.800E+02 | 1.910E+06 |
| 12Dichlprop | -9.400E-02 | 1.685E-03 | 2.800E+03 | 1.910E+06 |
| Dieldrin | -3.400E+01 | 1.234E-05 | 0.000E+00 | 1.910E+06 |
| Diethylphth | -2.520E-01 | 7.290E-04 | 1.080E+03 | 1.910E+06 |
| 12DiMethylB | -4.800E-01 | 1.485E-04 | 2.200E+02 | 1.910E+06 |
| 24-Dimethylphe | -2.520E+00 | 1.575E-04 | 7.870E+03 | 1.910E+06 |
| Dimethylphth | -7.420E-02 | 1.829E-03 | 4.000E+03 | 1.910E+06 |
| 24Dinitrotoluene | -1.020E-01 | 1.823E-04 | 2.700E+02 | 1.910E+06 |
| 26Dinitrotoluene | -8.390E-02 | 2.376E-04 | 3.520E+02 | 1.910E+06 |
| EndosulfanII | -4.080E+00 | 3.038E-07 | 4.500E-01 | 1.910E+06 |
| Endrin | -2.160E+01 | 1.688E-07 | 2.500E-01 | 1.910E+06 |
| Aldehyde | -2.160E+01 | 1.688E-07 | 2.500E-01 | 1.910E+06 |
| Ketone | -2.160E+01 | 1.688E-07 | 2.500E-01 | 1.910E+06 |
| Ethylbenz | -4.080E-01 | 1.141E-04 | 1.690E+02 | 1.910E+06 |
| Ethylchlorid | -4.750E-02 | 2.069E-03 | 6.700E+03 | 1.910E+06 |
| Heptachlor | -4.800E+01 | 1.215E-07 | 1.800E-01 | 1.910E+06 |
| Heptachlor-epoxd | -1.730E+01 | 1.350E-07 | 2.000E-01 | 1.910E+06 |
| Hexachlorobenzen | -1.100E+02 | 4.185E-09 | 6.200E-03 | 1.910E+06 |
| Hexachloroethane | -3.560E+00 | 3.375E-05 | 5.000E+01 | 1.910E+06 |
| Nhexane | -2.980E-01 | 6.413E-06 | 9.500E+00 | 1.910E+06 |
| 1hexanol | -2.600E-02 | 2.313E-03 | 5.900E+03 | 1.910E+06 |
| 2hexanone | -2.600E-02 | 2.313E-03 | 5.900E+03 | 1.910E+06 |
| Isophorone | -1.700E+00 | 2.271E-04 | 0.000E+00 | 1.910E+06 |
| Lindane | -6.760E+00 | 5.400E-06 | 8.000E+00 | 1.910E+06 |
| Methonal | -2.000E-03 | 2.664E-03 | 1.000E+06 | 1.910E+06 |
| Methchloride | -2.010E+03 | 2.097E-07 | 1.300E+04 | 1.910E+06 |
| Methylcyclo | -1.990E-01 | 9.450E-06 | 1.400E+01 | 1.910E+06 |
| MethylIso | -4.700E-03 | 2.619E-03 | 1.900E+04 | 1.910E+06 |
| MMetacrylate | -2.000E-02 | 2.392E-03 | 1.500E+04 | 1.910E+06 |
| MethylEthylB | -1.650E+00 | 4.118E-05 | 6.100E+01 | 1.910E+06 |
| 2Methylnaptha | -5.940E+00 | 1.661E-05 | 2.460E+01 | 1.910E+06 |
| MethylPropylB | -1.650E+00 | 4.118E-05 | 6.100E+01 | 1.910E+06 |
| Naphthalene | -1.900E+01 | 2.201E-05 | 0.000E+00 | 1.910E+06 |
| 4Nitrobenzenamin | -3.440E-01 | 7.223E-12 | 1.070E-05 | 1.910E+06 |
| Nitrobenzene | -1.290E-01 | 1.411E-03 | 2.090E+03 | 1.910E+06 |
| 2Nitrophenol | -7.100E-01 | 4.867E-04 | 2.500E+03 | 1.910E+06 |
| 4Nitrophenol | -8.740E-01 | 4.092E-04 | 1.160E+04 | 1.910E+06 |
| NnitroNpropyl | -3.000E-01 | 9.240E-04 | 0.000E+00 | 1.910E+06 |
| NNitrosodiphen | -6.540E-01 | 2.363E-05 | 3.500E+01 | 1.910E+06 |
| Phenol | -2.800E-01 | 9.663E-04 | 9.300E+04 | 1.910E+06 |
| PropylB | -1.650E+00 | 4.118E-05 | 6.100E+01 | 1.910E+06 |
| PropGlycol | -2.000E-03 | 2.664E-03 | 1.000E+06 | 1.910E+06 |
| Pyridine | -1.380E-02 | 2.479E-03 | 1.000E+06 | 1.910E+06 |
| Styrene | -1.820E+00 | 2.093E-04 | 3.100E+02 | 1.910E+06 |
| 1112Tetra | -3.180E-01 | 7.223E-04 | 1.070E+03 | 1.910E+06 |
| 1122Tetra | -1.580E-01 | 1.341E-03 | 2.870E+03 | 1.910E+06 |
| Tetrachloroethen | -7.200E+00 | 5.731E-05 | 0.000E+00 | 1.910E+06 |
| 2346Tetrachlor | -2.490E+02 | 1.692E-06 | 2.300E+01 | 1.910E+06 |

| | | | | |
|---|---|---|---|---|
| Toluene | -6.000E+00 | 6.848E-05 | 0.000E+00 | 1.910E+06 |
| 124Trichlorb | -1.440E+00 | 3.848E-05 | 5.700E+01 | 1.910E+06 |
| Trichloroethene | -2.600E+00 | 1.529E-04 | 0.000E+00 | 1.910E+06 |
| TriChloFlo | -2.680E-01 | 7.425E-04 | 1.100E+03 | 1.910E+06 |

| CONTAMINANT | AQUIFER SORPTION | AQUIFER RETARDATION | VERTICAL SORPTION | VERTICAL RETARDATION |
|---|---|---|---|---|
| 24-D | 5.880E-03 | 1.042E+00 | 5.880E-02 | 1.423E+00 |
| 245-TP(silvex) | 1.608E-02 | 1.116E+00 | 1.608E-01 | 2.158E+00 |
| Acenaphthene | 9.200E+00 | 6.724E+01 | 9.200E+01 | 6.634E+02 |
| Acenaphthylene | 1.220E+00 | 9.784E+00 | 1.220E+01 | 8.884E+01 |
| Acetone | 0.000E+00 | 1.000E+00 | 4.400E-02 | 1.317E+00 |
| Acentonitrile | 1.540E-04 | 1.001E+00 | 1.540E-03 | 1.011E+00 |
| acetophenone | 9.240E-03 | 1.067E+00 | 9.240E-02 | 1.665E+00 |
| Acrolien | 2.780E-04 | 1.002E+00 | 2.780E-03 | 1.020E+00 |
| Acylonitrle | 4.440E-04 | 1.003E+00 | 4.440E-03 | 1.032E+00 |
| Aldrin | 9.740E+00 | 7.113E+01 | 9.740E+01 | 7.023E+02 |
| Aroclor1221 | 1.200E+02 | 8.650E+02 | 1.200E+02 | 8.650E+02 |
| Aroclor1232 | 1.500E+01 | 1.090E+02 | 1.500E+01 | 1.090E+02 |
| Benzene | 0.000E+00 | 1.000E+00 | 1.700E+00 | 1.324E+01 |
| Benzoic-acid | 1.200E-04 | 1.001E+00 | 1.200E-03 | 1.009E+00 |
| Benzyl-alcohol | 3.130E-03 | 1.023E+00 | 3.130E-02 | 1.225E+00 |
| benzidine | 5.480E-01 | 4.946E+00 | 5.480E+00 | 4.046E+01 |
| Alpha-BHC | 3.520E-01 | 3.534E+00 | 3.520E+00 | 2.634E+01 |
| Beta-BHC | 4.280E-01 | 4.082E+00 | 4.280E+00 | 3.182E+01 |
| Delta-BHC | 4.280E-01 | 4.082E+00 | 4.280E+00 | 3.182E+01 |
| Bromodichloro | 1.080E-03 | 1.008E+00 | 1.080E-02 | 1.078E+00 |
| Bromoform | 2.520E-02 | 1.181E+00 | 2.520E-01 | 2.814E+00 |
| Bromometh | 2.830E-03 | 1.020E+00 | 2.830E-02 | 1.204E+00 |
| butylbenzene | 1.630E-01 | 2.174E+00 | 1.630E+00 | 1.274E+01 |
| Carbazole | 6.780E-01 | 5.882E+00 | 6.780E+00 | 4.982E+01 |
| CarbonDiS | 1.030E-02 | 1.074E+00 | 1.030E-01 | 1.742E+00 |
| Carbontetchl | 0.000E+00 | 1.000E+00 | 2.200E+00 | 1.684E+01 |
| Chlordane | 1.730E+01 | 1.256E+02 | 1.730E+02 | 1.247E+03 |
| Chlorobenzene | 4.380E-02 | 1.315E+00 | 4.380E-01 | 4.154E+00 |
| Chloroform | 0.000E+00 | 1.000E+00 | 6.200E-01 | 5.464E+00 |
| Chlorometh | 2.860E-03 | 1.021E+00 | 2.860E-02 | 1.206E+00 |
| 0-ChloroTu | 8.860E-02 | 1.638E+00 | 8.860E-01 | 7.379E+00 |
| m-cresol | 9.560E-03 | 1.069E+00 | 9.560E-02 | 1.688E+00 |
| o-cresol | 1.820E-02 | 1.131E+00 | 1.820E-01 | 2.310E+00 |
| p-cresol | 9.220E-03 | 1.066E+00 | 9.220E-02 | 1.664E+00 |
| Cumene | 1.650E-01 | 2.188E+00 | 1.650E+00 | 1.288E+01 |
| Cyanide | 9.900E-01 | 8.128E+00 | 9.900E+00 | 7.228E+01 |
| DDD | 9.160E+00 | 6.695E+01 | 9.160E+01 | 6.605E+02 |
| DDE | 1.730E-01 | 2.246E+00 | 1.730E+00 | 1.346E+01 |
| Dinbutylphthalat | 0.000E+00 | 1.000E+00 | 1.000E-06 | 1.000E+00 |
| Dibenz[ah] | 3.580E+02 | 2.579E+03 | 3.580E+03 | 2.578E+04 |
| Dibenzofuran | 2.260E+01 | 1.637E+02 | 2.260E+02 | 1.628E+03 |
| Dibromochloro | 1.410E-02 | 1.102E+00 | 1.410E-01 | 2.015E+00 |
| 12Dichloro | 7.580E-02 | 1.546E+00 | 7.580E-01 | 6.458E+00 |
| 13Dichloro | 1.606E+00 | 1.256E+01 | 1.606E+01 | 1.166E+02 |
| 14Dichlorobenzen | 1.232E-01 | 1.887E+00 | 1.232E+00 | 9.870E+00 |
| 12cisDichloro | 9.960E-02 | 1.717E+00 | 9.960E-01 | 8.171E+00 |
| 12transDichl | 7.600E-03 | 1.055E+00 | 7.600E-02 | 1.547E+00 |
| Dichlorodiflo | 1.370E-03 | 1.010E+00 | 1.370E-02 | 1.099E+00 |
| 12Dichlprop | 9.400E-03 | 1.068E+00 | 9.400E-02 | 1.677E+00 |
| Dieldrin | 0.000E+00 | 1.000E+00 | 3.400E+01 | 2.458E+02 |
| Diethylphth | 2.520E-02 | 1.181E+00 | 2.520E-01 | 2.814E+00 |
| 12DiMethylB | 4.800E-02 | 1.346E+00 | 4.800E-01 | 4.456E+00 |
| 24-Dimethylphe | 2.520E-01 | 2.814E+00 | 2.520E+00 | 1.914E+01 |
| Dimethylphth | 7.420E-03 | 1.053E+00 | 7.420E-02 | 1.534E+00 |
| 24Dinitrotoluene | 1.020E-02 | 1.073E+00 | 1.020E-01 | 1.734E+00 |
| 26Dinitrotoluene | 8.390E-03 | 1.060E+00 | 8.390E-02 | 1.604E+00 |
| EndosulfanII | 4.080E+00 | 3.038E+01 | 4.080E-01 | 3.938E+00 |
| Endrin | 2.160E+00 | 1.655E+01 | 2.160E+01 | 1.565E+02 |
| Aldehyde | 2.160E+01 | 1.565E+02 | 2.160E+00 | 1.655E+01 |
| Ketone | 2.160E+01 | 1.565E+02 | 2.160E+00 | 1.655E+01 |
| Ethylbenz | 4.080E-02 | 1.294E+00 | 4.080E-01 | 3.938E+00 |
| Ethylchlorid | 4.750E-03 | 1.034E+00 | 4.750E-02 | 1.342E+00 |
| Heptachlor | 4.800E+00 | 3.556E+01 | 4.800E+01 | 3.466E+02 |
| Heptachlor-epoxd | 1.730E+00 | 1.346E+01 | 1.730E+01 | 1.256E+02 |
| Hexachlorobenzen | 1.100E+01 | 8.020E+01 | 1.100E+02 | 7.930E+02 |
| Hexachloroethane | 3.560E-01 | 3.563E+00 | 3.560E+00 | 2.663E+01 |
| Nhexane | 2.980E-02 | 1.215E+00 | 2.980E-01 | 3.146E+00 |
| 1hexanol | 2.600E-03 | 1.019E+00 | 2.600E-02 | 1.187E+00 |
| 2hexanone | 2.600E-03 | 1.019E+00 | 2.600E-02 | 1.187E+00 |
| Isophorone | 0.000E+00 | 1.000E+00 | 1.700E+00 | 1.324E+01 |
| Lindane | 6.760E-01 | 5.867E+00 | 6.760E+00 | 4.967E+01 |
| Methonal | 2.000E-04 | 1.001E+00 | 2.000E-03 | 1.014E+00 |

| | | | | |
|---|---|---|---|---|
| Methchloride | 0.000E+00 | 1.000E+00 | 2.010E+03 | 1.447E+04 |
| Methylcyclo | 0.000E+00 | 1.000E+00 | 0.000E+00 | 1.000E+00 |
| MethylIso | 4.700E-04 | 1.003E+00 | 4.700E-03 | 1.034E+00 |
| MMetacrylate | 2.000E-03 | 1.014E+00 | 2.000E-02 | 1.144E+00 |
| MethylEthylB | 1.650E-01 | 2.188E+00 | 1.650E+00 | 1.288E+01 |
| 2Methylnaptha | 5.940E-01 | 5.277E+00 | 5.940E+00 | 4.377E+01 |
| MethylPropylB | 1.650E-01 | 2.188E+00 | 1.650E+00 | 1.288E+01 |
| Naphthalene | 1.900E+00 | 1.468E+01 | 1.900E+01 | 1.378E+02 |
| 4Nitrobenzenamin | 3.440E-02 | 1.248E+00 | 3.440E-01 | 3.477E+00 |
| Nitrobenzene | 1.290E-02 | 1.093E+00 | 1.290E-01 | 1.929E+00 |
| 2Nitrophenol | 7.100E-02 | 1.511E+00 | 7.100E-01 | 6.112E+00 |
| 4Nitrophenol | 8.740E-02 | 1.629E+00 | 8.740E-01 | 7.293E+00 |
| NnitroNpropyl | 3.000E-02 | 1.216E+00 | 3.000E-01 | 3.160E+00 |
| NNitrosodiphen | 6.540E-02 | 1.471E+00 | 6.540E-01 | 5.709E+00 |
| Phenol | 2.800E-02 | 1.202E+00 | 2.800E-01 | 3.016E+00 |
| PropylB | 1.650E-01 | 2.188E+00 | 1.650E+00 | 1.288E+01 |
| PropGlycol | 2.000E-04 | 1.001E+00 | 2.000E-03 | 1.014E+00 |
| Pyridine | 1.380E-03 | 1.010E+00 | 1.380E-02 | 1.099E+00 |
| Styrene | 1.820E-01 | 2.310E+00 | 1.820E+00 | 1.410E+01 |
| 1112Tetra | 3.180E-02 | 1.229E+00 | 3.180E-01 | 3.290E+00 |
| 1122Tetra | 1.560E-02 | 1.112E+00 | 1.560E-01 | 2.123E+00 |
| Tetrachloroethen | 0.000E+00 | 1.000E+00 | 7.200E+00 | 5.284E+01 |
| 2346Tetrachlor | 2.490E+01 | 1.803E+02 | 2.490E+02 | 1.794E+03 |
| Toluene | 0.000E+00 | 1.000E+00 | 6.000E+00 | 4.420E+01 |
| 124Trichlorb | 1.440E-01 | 2.037E+00 | 1.440E+00 | 1.137E+01 |
| Trichloroethene | 0.000E+00 | 1.000E+00 | 2.600E+00 | 1.972E+01 |
| TriChloFlo | 2.680E-02 | 1.193E+00 | 2.680E-01 | 2.930E+00 |

| | BIOACCUMULATION FACTORS | | | |
|---|---|---|---|---|
| | SOIL-PLANT | SOIL-PLANT | FORAGE-MILK | FORAGE-MEAT |
| CONTAMINANT | Bv | Br | Fm (D/L) | Ff (D/KG) |
| 24-D | 1.300E+00 | 1.300E-01 | 2.500E-06 | 7.900E-06 |
| 245-TP(silvex) | 2.100E-01 | 2.100E-02 | 6.300E-05 | 2.000E-04 |
| Acenaphthene | 1.200E-01 | 1.200E-02 | 1.600E-04 | 5.000E-04 |
| Acenaphthylene | 2.700E-01 | 2.700E-02 | 4.000E-05 | 1.300E-04 |
| Acetone | 1.300E+01 | 1.300E+00 | 1.500E-08 | 1.500E-08 |
| Acentonitrile | 6.000E+01 | 6.000E+00 | 3.600E-09 | 1.100E-08 |
| acetophenone | 3.900E+00 | 3.900E-01 | 4.000E-07 | 1.300E-06 |
| Acrolien | 4.300E+01 | 4.300E+00 | 6.300E-09 | 2.000E-08 |
| Acylonitrle | 2.700E+01 | 2.700E+00 | 1.400E-08 | 4.400E-08 |
| Aldrin | 6.900E-01 | 6.900E-02 | 7.900E-06 | 2.500E-05 |
| Aroclor1221 | 1.600E-01 | 1.600E-02 | 9.900E-05 | 3.100E-04 |
| Aroclor1232 | 5.300E-01 | 5.300E-02 | 1.300E-05 | 4.000E-05 |
| Benzene | 5.800E-01 | 5.800E-02 | 3.300E-06 | 3.300E-06 |
| Benzoic-acid | 3.000E+00 | 3.000E-01 | 6.300E-07 | 2.000E-06 |
| Benzyl-alcohol | 8.700E+00 | 8.700E-01 | 9.900E-08 | 3.100E-07 |
| benzidine | 6.700E+00 | 6.700E-01 | 1.600E-07 | 5.000E-07 |
| Alpha-BHC | 2.100E-01 | 2.100E-02 | 6.300E-05 | 2.000E-04 |
| Beta-BHC | 1.800E-01 | 1.800E-02 | 7.900E-05 | 2.500E-04 |
| Delta-BHC | 9.000E-01 | 9.000E-02 | 5.000E-06 | 1.600E-05 |
| Bromodichloro | 2.300E+00 | 2.300E-01 | 9.900E-07 | 3.100E-06 |
| Bromoform | 1.500E+00 | 1.500E-01 | 2.000E-06 | 6.300E-06 |
| Bromometh | 7.700E+00 | 7.700E-01 | 1.300E-07 | 4.000E-07 |
| butylbenzene | 3.500E-01 | 3.500E-02 | 2.500E-05 | 7.900E-05 |
| Carbazole | 2.400E-01 | 2.400E-02 | 5.000E-05 | 1.600E-04 |
| CarbonDiS | 2.000E+00 | 2.000E-01 | 1.300E-06 | 4.000E-06 |
| Carbontetchl | 2.900E-01 | 2.900E-02 | 1.100E-05 | 1.100E-05 |
| Chlordane | 2.500E-02 | 2.500E-03 | 2.500E-03 | 7.900E-03 |
| Chlorobenzene | 9.000E-01 | 9.000E-02 | 5.000E-06 | 1.600E-05 |
| Chloroform | 7.000E-01 | 7.000E-02 | 2.300E-06 | 2.300E-06 |
| Chlorometh | 1.100E+01 | 1.100E+00 | 6.400E-08 | 2.000E-07 |
| 0-ChloroTu | 4.100E-01 | 4.100E-02 | 2.000E-05 | 6.300E-05 |
| m-cresol | 2.600E+00 | 2.600E-01 | 7.900E-07 | 2.500E-06 |
| o-cresol | 3.000E+00 | 3.000E-01 | 6.300E-07 | 2.000E-06 |
| p-cresol | 3.000E+00 | 3.000E-01 | 6.300E-07 | 2.000E-06 |
| Cumene | 3.500E-01 | 3.500E-02 | 2.500E-05 | 7.900E-05 |
| Cyanide | 8.700E+00 | 8.700E-01 | 9.900E-08 | 3.100E-07 |
| DDD | 1.600E-02 | 1.600E-03 | 5.000E-03 | 1.600E-02 |
| DDE | 1.900E-02 | 1.900E-03 | 4.000E-03 | 1.300E-02 |
| Dinbutylphthalat | 5.600E-03 | 5.600E-04 | 3.200E-03 | 1.000E-02 |
| Dibenz[ah] | 4.300E-03 | 4.300E-04 | 5.000E-02 | 1.600E-01 |
| Dibenzofuran | 1.500E-01 | 1.500E-02 | 1.000E-04 | 3.300E-04 |
| Dibromochloro | 2.000E+00 | 2.000E-01 | 1.300E-06 | 4.000E-06 |
| 12Dichloro | 4.100E-01 | 4.100E-02 | 2.000E-05 | 6.300E-05 |
| 13Dichloro | 3.100E-01 | 3.100E-02 | 3.100E-05 | 1.000E-04 |
| 14Dichlorobenzen | 4.100E-01 | 4.100E-02 | 2.000E-05 | 6.300E-05 |
| 12cisDichloro | 3.000E+00 | 3.000E-01 | 6.300E-07 | 2.000E-06 |
| 12transDichl | 2.000E+01 | 2.000E+00 | 2.400E-08 | 7.500E-08 |
| Dichlorodiflo | 2.000E+00 | 2.000E-01 | 1.300E-06 | 4.000E-06 |

| | | | | |
|---|---|---|---|---|
| 12Dichlprop | 2.600E+00 | 2.600E-01 | 7.900E-07 | 2.500E-06 |
| Dieldrin | 9.200E-02 | 9.200E-03 | 7.900E-03 | 7.900E-03 |
| Diethylphth | 1.300E+00 | 1.300E-01 | 2.500E-06 | 7.900E-06 |
| 12DiMethylB | 6.000E-01 | 6.000E-02 | 1.100E-05 | 3.400E-05 |
| 24-Dimethylphe | 1.800E+00 | 1.800E-01 | 1.600E-06 | 5.000E-06 |
| Dimethylphth | 4.500E+00 | 4.500E-01 | 3.100E-07 | 1.000E-06 |
| 24Dinitrotoluene | 2.600E+00 | 2.600E-01 | 7.900E-07 | 2.500E-06 |
| 26Dinitrotoluene | 3.900E+00 | 3.900E-01 | 4.000E-07 | 1.300E-06 |
| EndosulfanII | 3.300E-01 | 3.300E-02 | 2.800E-05 | 8.900E-05 |
| Endrin | 8.200E-02 | 8.200E-03 | 3.100E-04 | 1.000E-03 |
| Aldehyde | 8.200E-02 | 8.200E-03 | 3.100E-04 | 1.000E-03 |
| Ketone | 8.200E-02 | 8.200E-03 | 3.100E-04 | 1.000E-03 |
| Ethylbenz | 6.100E-01 | 6.100E-02 | 9.900E-06 | 3.100E-05 |
| Ethylchlorid | 5.900E+00 | 5.900E-01 | 2.000E-07 | 6.300E-07 |
| Heptachlor | 1.200E-01 | 1.200E-02 | 1.600E-04 | 5.000E-04 |
| Heptachlor-epoxd | 2.800E-02 | 2.800E-03 | 2.000E-03 | 6.300E-03 |
| Hexachlorobenzen | 3.200E-02 | 3.200E-03 | 1.600E-03 | 5.000E-03 |
| Hexachloroethane | 2.100E-01 | 2.100E-02 | 6.300E-05 | 2.000E-04 |
| Nhexane | 2.100E-01 | 2.100E-02 | 6.300E-05 | 2.000E-04 |
| 1hexanol | 5.900E+00 | 5.900E-01 | 2.000E-07 | 6.300E-07 |
| 2hexanone | 5.900E+00 | 5.900E-01 | 2.000E-07 | 6.300E-07 |
| Isophorone | 4.800E-01 | 4.800E-02 | 4.600E-06 | 4.600E-06 |
| Lindane | 2.700E-01 | 2.700E-02 | 4.000E-05 | 1.300E-04 |
| Methonal | 1.100E+02 | 1.100E+01 | 1.300E-09 | 4.200E-09 |
| Methchloride | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| Methylcyclo | 8.300E-01 | 8.300E-02 | 5.700E-06 | 1.800E-05 |
| MethylIso | 7.700E+00 | 7.700E-01 | 1.300E-07 | 4.000E-07 |
| MMetacrylate | 6.700E+00 | 6.700E-01 | 1.600E-07 | 5.000E-07 |
| MethylEthylB | 3.500E-01 | 3.500E-02 | 2.500E-05 | 7.900E-05 |
| 2Methylnaptha | 2.100E-01 | 2.100E-02 | 6.300E-05 | 2.000E-04 |
| MethylPropylB | 3.500E-01 | 3.500E-02 | 2.500E-05 | 7.900E-05 |
| Naphthalene | 4.600E-01 | 4.600E-02 | 1.600E-05 | 5.000E-05 |
| 4Nitrobenzenamin | 6.800E+00 | 6.800E-01 | 2.000E-07 | 6.200E-07 |
| Nitrobenzene | 3.400E+00 | 3.400E-01 | 5.000E-07 | 1.600E-06 |
| 2Nitrophenol | 3.600E+00 | 3.600E-01 | 4.900E-07 | 1.600E-06 |
| 4Nitrophenol | 3.000E+00 | 3.000E-01 | 6.300E-07 | 2.000E-06 |
| NnitroNpropyl | 5.900E+00 | 5.900E-01 | 2.000E-07 | 6.300E-07 |
| NNitrosodiphen | 6.100E-01 | 6.100E-02 | 9.900E-06 | 3.000E-05 |
| Phenol | 5.100E+00 | 5.100E-01 | 2.500E-07 | 7.900E-07 |
| PropylB | 3.500E-01 | 3.500E-02 | 2.500E-05 | 7.900E-05 |
| PropGlycol | 3.700E+02 | 3.700E+01 | 1.600E-10 | 5.000E-10 |
| Pyridine | 6.700E+00 | 6.700E-01 | 1.600E-07 | 5.000E-07 |
| Styrene | 7.900E-01 | 7.900E-02 | 6.300E-06 | 2.000E-05 |
| 1112Tetra | 6.900E-01 | 6.900E-02 | 7.900E-06 | 2.500E-05 |
| 1122Tetra | 1.500E+00 | 1.500E-01 | 2.000E-06 | 6.300E-06 |
| Tetrachloroethen | 3.000E-01 | 3.000E-02 | 1.000E-05 | 1.000E-05 |
| 2346Tetrachlor | 1.600E-01 | 1.600E-02 | 9.900E-05 | 3.100E-04 |
| Toluene | 2.600E-01 | 2.600E-02 | 1.300E-05 | 1.300E-05 |
| 124Trichlorb | 2.440E-01 | 2.440E+00 | 4.800E-05 | 1.500E-04 |
| Trichloroethene | 4.100E-01 | 4.100E-02 | 6.000E-06 | 6.000E-06 |
| TriChloFlo | 1.300E+00 | 1.300E-01 | 2.500E-06 | 7.900E-06 |

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

| CONTAMINANT | PEAK CONCENTRATION (MG/L) | | PEAK TIME (YR) | AVERAGE DOSE AT PEAK TIME (MG/KG-DAY) | AVERAGE RISK AT PEAK TIME (HE/LIFE) | FRACTION OF ADI |
|---|---|---|---|---|---|---|
| 24-D | 1.79E+00 | | 774.3 | 5.14E-02 | | 5.14E+00 |
| 245-TP(silvex) | 5.25E-01 | | 1095.2 | 1.51E-02 | | 1.89E+00 |
| Acenaphthene | | > | 10000.0 | | | |
| Acenaphthylene | | > | 10000.0 | | | |
| Acetone | 8.19E+00 | | 722.4 | 2.35E-01 | | 2.61E-01 |
| Acentonitrile | 1.04E+01 | | 693.2 | 2.98E-01 | | |
| acetophenone | 6.60E+00 | | 880.0 | 1.89E-01 | | 1.89E+00 |
| Acrolien | 1.03E+01 | | 647.9 | 2.96E-01 | | 5.92E+02 |
| Acylonitrle | 1.02E+01 | | 703.9 | 2.93E-01 | 1.58E-01 | 7.32E+00 |
| Aldrin | | > | 10000.0 | | | |
| Aroclor1221 | | > | 10000.0 | | | |
| Aroclor1232 | | > | 10000.0 | | | |
| Benzene | 8.83E-01 | | 4775.1 | 2.53E-02 | 1.39E-03 | 6.33E+00 |
| Benzoic-acid | 8.93E+00 | | 692.0 | 2.56E-01 | | 6.40E-02 |
| Benzyl-alcohol | 8.74E+00 | | 687.8 | 2.51E-01 | | 2.51E+00 |
| benzidine | | > | 10000.0 | | | |
| Alpha-BHC | 2.10E-02 | | 9719.2 | 6.04E-04 | 3.80E-03 | 7.55E-02 |
| Beta-BHC | 2.10E-02 | | 11711.6 | 6.04E-04 | 1.09E-03 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Delta-BHC | 2.10E-02 | | 11711.6 | 6.03E-04 | 1.08E-03 | |
| Bromodichloro | 7.96E+00 | | 623.3 | 2.28E-01 | 1.41E-02 | 1.14E+01 |
| Bromoform | 2.63E-01 | | 1382.1 | 7.53E-03 | 5.95E-05 | 3.77E-01 |
| Bromometh | 8.89E+00 | | 678.4 | 2.55E-01 | | 1.82E+02 |
| butylbenzene | 1.61E-01 | | 4764.3 | 4.62E-03 | | 9.24E-02 |
| Carbazole | | > | 10000.0 | | | |
| CarbonDiS | 3.10E+00 | | 913.4 | 8.89E-02 | | 8.89E-01 |
| Carbontetchl | 6.96E-01 | | 6035.1 | 2.00E-02 | 1.40E-03 | 4.99E+00 |
| Chlordane | | > | 10000.0 | | | |
| Chlorobenzene | 1.31E+00 | | 1967.3 | 3.75E-02 | | 1.88E+00 |
| Chloroform | 2.11E+00 | | 2053.5 | 6.06E-02 | 1.88E-03 | 6.06E+00 |
| Chlorometh | 8.87E+00 | | 679.3 | 2.54E-01 | | |
| 0-ChloroTu | 9.82E-01 | | 2813.9 | 2.82E-02 | | 1.41E+00 |
| m-cresol | 6.51E+00 | | 890.1 | 1.87E-01 | | 3.74E+00 |
| o-cresol | 4.85E+00 | | 1161.9 | 1.39E-01 | | 2.78E+00 |
| p-cresol | 6.60E+00 | | 879.4 | 1.89E-01 | | 1.89E+00 |
| Cumene | 1.61E-01 | | 4816.8 | 4.62E-03 | | 4.62E-02 |
| Cyanide | | > | 10000.0 | | | |
| DDD | | > | 10000.0 | | | |
| DDE | 1.05E-04 | | 5026.5 | 3.40E-06 | 1.16E-06 | |
| Dinbutylphthalat | 1.05E+01 | | 687.6 | 3.31E-01 | | 3.31E+00 |
| Dibenz[ah] | | > | 10000.0 | | | |
| Dibenzofuran | | > | 10000.0 | | | |
| Dibromochloro | 5.52E+00 | | 1032.9 | 1.58E-01 | 1.33E-02 | 7.91E+00 |
| 12Dichloro | 2.10E-01 | | 2478.3 | 6.03E-03 | | 6.70E-02 |
| 13Dichloro | | > | 10000.0 | | | |
| 14Dichlorobenzen | 2.13E-01 | | 3720.9 | 6.13E-03 | 3.31E-05 | 8.75E-02 |
| 12cisDichloro | 1.42E+00 | | 3722.7 | 4.08E-02 | | 2.04E+01 |
| 12transDichl | 7.06E+00 | | 828.4 | 2.03E-01 | | 1.01E+01 |
| Dichlorodiflo | 7.35E-01 | | 737.9 | 2.11E-02 | | 1.05E-01 |
| 12Dichlprop | 6.55E+00 | | 885.1 | 1.88E-01 | 6.77E-03 | 2.09E+00 |
| Dieldrin | | > | 10000.0 | | | |
| Diethylphth | 2.84E+00 | | 1382.1 | 8.13E-02 | | 1.02E-01 |
| 12DiMethylB | 5.78E-01 | | 1749.5 | 1.66E-02 | | 8.29E-02 |
| 24-Dimethylphe | 6.13E-01 | | 7097.6 | 1.76E-02 | | 8.79E-01 |
| Dimethylphth | 7.12E+00 | | 822.8 | 2.04E-01 | | 2.04E-02 |
| 24Dinitrotoluene | 7.09E-01 | | 910.2 | 2.03E-02 | 6.30E-03 | 1.02E+01 |
| 26Dinitrotoluene | 9.24E-01 | | 853.3 | 2.65E-02 | | 2.65E+01 |
| EndosulfanII | 1.18E-03 | | 11329.9 | 3.39E-05 | | 5.65E-03 |
| Endrin | | > | 10000.0 | | | |
| Aldehyde | | > | 10000.0 | | | |
| Ketone | | > | 10000.0 | | | |
| Ethylbenz | 4.44E-01 | | 1872.9 | 1.27E-02 | 1.40E-04 | 1.27E-01 |
| Ethylchlorid | 8.05E+00 | | 738.8 | 2.31E-01 | | |
| Heptachlor | | > | 10000.0 | | | |
| Heptachlor-epoxd | | > | 10000.0 | | | |
| Hexachlorobenzen | | > | 10000.0 | | | |
| Hexachloroethane | 1.31E-01 | | 9824.1 | 3.77E-03 | 1.51E-04 | 5.39E+00 |
| Nhexane | 2.49E-02 | | 1526.8 | 7.17E-04 | | 1.19E-02 |
| 1hexanol | 9.00E+00 | | 671.1 | 2.58E-01 | | 6.45E+00 |
| 2hexanone | 9.00E+00 | | 671.1 | 2.58E-01 | | 5.16E+01 |
| Isophorone | 8.83E-01 | | 4775.1 | 2.53E-02 | 2.41E-05 | 1.27E-01 |
| Lindane | | > | 10000.0 | | | |
| Methonal | 1.04E+01 | | 694.9 | 2.97E-01 | | 5.95E-01 |
| Methchloride | | > | 10000.0 | | | |
| Methylcyclo | 3.68E-02 | | 589.3 | 1.05E-03 | | 1.76E-02 |
| MethylIso | 1.02E+01 | | 604.1 | 2.92E-01 | | 3.65E+00 |
| MMetacrylate | 9.30E+00 | | 652.3 | 2.67E-01 | | 1.91E-01 |
| MethylEthylB | 1.60E-01 | | 5780.1 | 4.60E-03 | | 1.24E-01 |
| 2Methylnaptha | | > | 10000.0 | | | |
| MethylPropylB | 1.60E-01 | | 5780.1 | 4.60E-03 | | 1.24E-01 |
| Naphthalene | | > | 10000.0 | | | |
| 4Nitrobenzenamin | 2.81E-08 | | 1671.5 | 8.06E-10 | 1.61E-11 | 2.01E-07 |
| Nitrobenzene | 5.49E+00 | | 995.2 | 1.57E-01 | | 7.87E+01 |
| 2Nitrophenol | 1.89E+00 | | 2352.5 | 5.43E-02 | | 8.76E-01 |
| 4Nitrophenol | 1.59E+00 | | 3338.9 | 4.57E-02 | | 7.36E-01 |
| NnitroNpropyl | 3.59E+00 | | 1533.1 | 1.03E-01 | 7.22E-01 | |
| NNitrosodiphen | 9.19E-02 | | 2646.8 | 2.64E-03 | 1.29E-05 | |
| Phenol | 3.76E+00 | | 1470.2 | 1.08E-01 | | 3.59E-01 |
| PropylB | 1.60E-01 | | 5780.1 | 4.60E-03 | | 1.24E-01 |
| PropGlycol | 1.04E+01 | | 694.9 | 2.97E-01 | | 1.49E-02 |
| Pyridine | 9.64E+00 | | 632.8 | 2.77E-01 | | 2.77E+02 |
| Styrene | 8.14E-01 | | 5262.5 | 2.34E-02 | | 1.17E-01 |
| 1112Tetra | 2.81E+00 | | 1589.8 | 8.06E-02 | 2.10E-03 | 2.69E+00 |
| 1122Tetra | 5.22E+00 | | 1080.1 | 1.50E-01 | 2.99E-02 | 7.48E+00 |
| Tetrachloroethen | | > | 10000.0 | | | |
| 2346Tetrachlor | | > | 10000.0 | | | |
| Toluene | | > | 10000.0 | | | |
| 124Trichlorb | 1.50E-01 | | 4266.2 | 4.30E-03 | 1.25E-04 | 4.30E-01 |
| Trichloroethene | 5.95E-01 | | 7043.1 | 1.71E-02 | 7.85E-04 | 3.41E+01 |
| TriChloFlo | 2.89E+00 | | 1432.5 | 8.28E-02 | | 2.76E-01 |

This page intentionally left blank.

# APPENDIX I:
# COST ESTIMATES FOR ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES

This page intentionally left blank.

# CONTENTS


ACRONYMS ..... I-4
1. INTRODUCTION ..... I-5
1.1 ALTERNATIVE DESCRIPTIONS ..... I-7
1.1.1 On-site Disposal Alternative ..... I-7
1.1.2 Off-site Disposal Alternative ..... I-9
1.1.3 Project Schedules ..... I-11
2. ELEMENTS COMMON TO THE ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES ..... I-11
3. ON-SITE DISPOSAL ALTERNATIVE COST ESTIMATE ..... I-13
3.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS ..... I-13
3.2 ON-SITE DISPOSAL ALTERNATIVE ESTIMATE DEVELOPMENT ..... I-15
3.2.1 Financial Basis of Estimate ..... I-15
3.2.1.1 Material and Labor Pricing ..... I-15
3.2.1.2 Wage Rates ..... I-15
3.2.1.3 Material, Equipment, and Production ..... I-15
3.2.1.4 Indirect Markups ..... I-21
3.2.1.5 Contingency and Risk ..... I-21
3.2.2 Descriptions of Estimate Activities and Assumptions ..... I-21
3.2.2.1 Pre-construction Activities and Design (Elements 1 and 4 in Table I-3) ..... I-21
3.2.2.2 Site Development and Phase I, II, and III Construction (Elements 5, 6, 7, 8, and 9 in Table I-3) ..... I-23
3.2.2.3 Operations (Element 2 in Table I-3) ..... I-25
3.2.2.4 Post-closure Care Operations (Element 3 in Table I-3) ..... I-26
3.2.2.5 Final Capping and Facility Closure (Elements 10 and 11 in Table I-3) ..... I-27
3.2.2.6 Post-closure (Element 12 in Table I-3) ..... I-28
3.2.3 Present Worth ..... I-28
3.2.4 Construction of Five Cells ..... I-29
4. OFF-SITE DISPOSAL ALTERNATIVE COST ESTIMATE ..... I-31
4.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS ..... I-31
4.2 FINANCIAL BASIS OF ESTIMATE ..... I-34
4.3 CONTINGENCY AND RISK ..... I-37
4.4 PRESENT WORTH ..... I-37
5. REFERENCES ..... I-40

# FIGURES

Figure I-1. On-site EMDF Conceptual Site Layout Plan ..... I-10
Figure I-2. On-site Disposal Alternative Schedule ..... I-12
Figure I-3. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative ..... I-32
Figure I-4. Schematic of Responsibilities for Waste Shipments of Mercury-contaminated Waste to Energy*Solutions* or WCS in Off-site Disposal Alternative ..... I-33

# TABLES

Table I-1. As-generated Waste Volume Estimate with Uncertainty ..... I-6
Table I-2. Summary of Estimated Costs for CERCLA Waste Disposal Alternatives ..... I-8
Table I-3. Summary of EMDF Conceptual Design Cost Estimate ..... I-16
Table I-4. Estimated Annual S&M Costs in FY 2012 Dollars ..... I-27
Table I-5. Summary of Cost Reductions for Landfill Construction of Five Cells versus Six Cells ..... I-30
Table I-6. On-site Disposal Alternative Landfill Estimated Costs, Conceptual Design and Five Cells ..... I-30
Table I-7. As-generated Waste Volume Estimate (FY 2022 – FY 2043) for Off-site Disposal Alternative ..... .I-31
Table I-8. Transportation and Treatment/Disposal Costs for Off-site Disposal Alternative ..... I-36
Table I-9. Off-site Disposal Alternative Estimated Cost, Option 1 Disposal at NNSS ..... I-38
Table I-10. Off-site Disposal Alternative Estimated Cost, Option 2 Disposal at Energy*Solutions* ..... I-39

# ACRONYMS

| | |
|---|---|
| ABC | articulated built container |
| CD | Critical Decision |
| CEES | Cost Engineering Estimating System |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| DOE | U.S. Department of Energy |
| EMDF | Environmental Management Disposal Facility |
| EMWMF | Environmental Management Waste Management Facility |
| EPA | U.S. Environmental Protection Agency |
| ETTP | East Tennessee Technology Park |
| FFS | Focused Feasibility Study |
| FY | Fiscal Year |
| G&A | General and Administrative |
| IWM | Integrated Water Management |
| K | Thousand |
| LF | linear feet |
| LLW | low-level waste |
| M | Million |
| NNSS | Nevada National Security Site |
| NT | Northern Tributary |
| OMB | Office of Management and Budget |
| ORR | Oak Ridge Reservation |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RAWP | Remedial Action Work Plan |
| RDR | Remedial Design Report |
| RI/FS | Remedial Investigation/Feasibility Study |
| S&M | surveillance and maintenance |
| TSCA | Toxic Substances Control Act of 1976 |
| UCOR | URS\|CH2M Oak Ridge LLC |
| U.S. | United States |
| WAC | waste acceptance criteria |
| WBS | Work Breakdown Structure |
| WCS | Waste Control Specialists |
| WFG | Waste Forecast Generation |
| Y-12 | Y-12 National Security Complex |

This page intentionally left blank.

# 1. INTRODUCTION

This Appendix provides cost estimates, supporting assumptions, summary cost information, and material pricing for the disposal of future-generated Oak Ridge Reservation (ORR) Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste after the existing Environmental Management Waste Management Facility (EMWMF) reaches maximum capacity. Under the On-site Disposal Alternative, waste would be disposed in a newly constructed on-site disposal facility at ORR referred to as the Environmental Management Disposal Facility (EMDF). Under the Off-site Disposal Alternative, waste would be disposed at existing off-site facilities. Two options were defined for off-site disposal:

**Option 1 (Major Destination NNSS):**

- All classified waste disposed by Nevada National Security Site (NNSS).
- All mixed waste treated and disposed by Energy*Solutions* and/or Waste Control Specialists (WCS).
- All low-level waste (LLW) and LLW/Toxic Substances Control Act of 1976 (TSCA) disposed by NNSS.

**Option 2 (Major Destination Energy*Solutions*):**

- All classified waste disposed by NNSS.
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS.
- All LLW and LLW/TSCA disposed by Energy*Solutions.*

CERCLA waste will be generated from environmental restoration activities on the ORR and associated sites. Individual demolition and remediation projects are responsible for transport of waste to the new disposal facility for the On-site Disposal Alternative or to a centrally located transfer station for the Off-site Disposal Alternative. The cost of this transportation is therefore not included in either estimate as it is currently assumed this cost is equivalent for either alternative. An unfunded risk to the Off-site Disposal Alternative has been identified concerning transportation to the rail transloading station at the East Tennessee Technology Park (ETTP), which will become a public industrial park in the future. As a public site, stringent transportation requirements would become applicable to this transfer (from demolition site to transloading station) with associated costs.

Candidate waste streams addressed under these disposal alternatives are LLW and mixed waste with components of radiological and other regulated waste such as Resource Conservation and Recovery Act of 1976 (RCRA) hazardous waste and TSCA-regulated waste (LLW/RCRA, LLW/TSCA). For the Remedial Investigation/Feasibility Study (RI/FS) evaluation, material types are defined as either soil or debris. See Chapter 2 of the RI/FS for additional information about candidate waste streams.

Major cost elements for the On-site Disposal Alternative are design and construction of the landfill and supporting infrastructure, operation and management of the disposal cells (including mercury macroencapsulation treatment), capping and closure, and post-closure monitoring and maintenance. Major cost elements of the Off-site Disposal Alternative are packaging and transportation of waste to the off-site facilities and fees for disposal (and treatment in the case of mercury-contaminated debris). Waste volumes estimated to be generated and disposed are fundamental assumptions in determining the cost for both disposal alternatives. Details about the as-generated and as-disposed waste volume estimates that are used in the cost estimates are provided in Chapter 2 and Appendix A of the RI/FS. A summary of those volumes is given in Table I-1.

Contingency has been added for both the On-site and Off-site Disposal Alternative cost estimates based on guidance provided in the United States (U.S.) Environmental Protection Agency's (EPA's) *A Guide to*

*Developing and Documenting Cost Estimates During the Feasibility Study*, July 2000. Contingency on a cost estimate is typically applied as two elements: scope contingency and bid contingency. Scope contingency accounts for unknowns concerning the design: costs that are unforeseen/undocumented at the time of estimating due to lack of clarity/granularity. Bid contingency accounts for unforeseen conditions: weather, material cost increases, and situations outside the control of a project.

**Table I-1. As-generated Waste Volume Estimate with Uncertainty**

| Material Type | Waste Type | | TOTAL by Material Type ($yd^3$) |
|---|---|---|---|
| | LLW (includes LLW/TSCA) | Mixed (LLW/RCRA, LLW/RCRA/TSCA) | |
| ***25% Uncertainty applied to As-generated Estimates*** | | | |
| Debris | 1,151,440 | 149,418 | 1,300,858 |
| Debris/Classified[a] | 35,612 | 4,621 | 40,233 |
| Soil | 540,115 | 67,353 | 607,468 |
| **Total** | **1,727,167** | **221,391** | **1,948,559** |

[a] Some percentage of debris waste is expected to be classified, but is currently not specified as such in the Waste Generation Forecast. Three percent of generated debris is assumed to be classified for purposes of off-site disposal evaluation (based on 3% of waste from ETTP considered classified in the WGF).

For the On-site cost estimate a 22% contingency was applied to all elements except operations – 7% scope contingency, and 15% bid contingency. EPA recommends a 5–10% scope contingency for clay caps, 5–10% scope contingency for surface grading/diking, and 10–20% scope contingency for synthetic caps. A 7% scope contingency was selected based on the fact that needed design considerations have been readily available from the existing EMWMF design. A mid-range bid contingency (EPA recommends 10–20%) was applied, 15%, to account for changing conditions (e.g. material pricing and weather disruptions). Contingency on operations was held to 5% since U.S. Department of Energy (DOE) currently operates an existing and very similar landfill, and those costs are very well known. Operations that have not previously been performed (e.g., macroencapsulation) carry the 22% contingency.

For the Off-site estimate, the scope contingency was estimated at 12%, toward the higher value recommended by EPA (off-site disposal 5–15% contingency range) since the scope (e.g., disposal cost per volume of waste) used in the estimate is not adjusted for surcharges that are likely to be leveled (e.g., those for fuel, over-sized equipment disposal, water content of soils). A mid-value bid contingency of 15% is applied due to the significant risk inherent in an alternative that might be affected by external uncontrollable influences such as travel across state lines, potential for modified off-site availability, and the unusually long timeframe in which waste is expected to be generated. Therefore a total 27% contingency is applied to the off-site alternative.

Additionally, the waste volume contingency of 25% that is accounted for in both on-site and off-site alternatives is part of the analysis, and therefore is present in both estimates as additional contingency. Table I-1 summarizes the volumes considered for either alternative including the 25% volume contingency. For the On-site Disposal Alternative, this 1.95 Million (M) $yd^3$ as-generated volume results

in 2.18 M $yd^3$ as-disposed volume (required disposal capacity) as demonstrated in Chapter 2 (see Tables 2-3 and 2-4 in Chapter 2). This is the capacity provided by five cells, whereas the conceptual design is a six cell design. The cost developed for the EMDF throughout this Appendix is for the whole design of six cells. However, as only five cells are currently projected to be required (per the volume estimate), and that is the volume of waste assumed for the Off-site Disposal Alternative, a five cell estimated cost for the On-site Disposal Alternative is used to compare to the Off-site Disposal Alternative cost.

Table I-2 summarizes the cost for the On-site and Off-site Disposal Alternatives in Fiscal Year (FY) 2012 dollars, future (escalated) cost, and present worth project cost for FY 2015. Note that the estimated costs for mercury treatment and disposal for both on-site and off-site alternatives are included in the table as well, for comparison purposes, but are part of the total base cost of the alternatives as reported. Details regarding the estimates are found in the subsequent sections. In terms of comparing costs, it is best to compare the Present Worth estimates, which are given in FY 2015 dollars; and on a cost basis of dollars per $yd^3$ of waste, those numbers are the last entries in Table I-2. As shown, the on-site disposal cost, for the given volume of waste (which would occupy the 5 cell build-out) is $447 per $yd^3$, while the lowest off-site cost is approximately double at $986 per $yd^3$.

## 1.1 ALTERNATIVE DESCRIPTIONS

A summary description of the On-site and Off-site Disposal Alternatives that were developed for analysis in the RI/FS is provided below.

### 1.1.1 On-site Disposal Alternative

The On-site Disposal Alternative proposes the consolidated disposal of CERCLA waste in a newly constructed disposal facility on the ORR. The scope of actions for this alternative includes early actions (i.e., pre-design investigations and required CERCLA and DOE order documentation and reviews); design and construction of all facilities; design support during construction, quality assurance, quality controls; operations for receiving waste, meeting the waste acceptance criteria (WAC), unloading the waste and placing it into the disposal cells; decontaminating any containers, equipment, or vehicles leaving the site; managing the waste and the disposal cells during construction, operations, closure, and post-closure; and final capping (design and construction) and closure of the facility.

The envisioned on-site EMDF would consist of an engineered waste disposal facility (i.e., landfill) with sufficient capacity to accept the anticipated volume of CERCLA waste and ancillary facilities to support operations. As discussed in Chapter 2 of the RI/FS, the estimated needed future capacity varies with changes in actual disposed volumes and future waste volume projections, as well as projected uncertainty. EMDF is estimated to receive waste for approximately 22 years (i.e., FY 2022 through FY 2043) followed by closure (through FY 2047). Support facilities required for initial operations would include those needed for staging of waste, receiving and unloading waste, treatment by macroencapsulation, and management of landfill wastewater. Siting near EMWMF would allow many of the support facilities already constructed for EMWMF to be shared with EMDF (see Section 6.2.2.5 of the RI/FS). The conceptual design of EMDF would provide a disposal capacity of approximately 2.5 M[1] $yd^3$, and it is projected that only five cells will be filled based on the current waste generation forecast (WGF).

[1] A projected disposal capacity need of approximately 2.5 M $yd^3$ is based on an assumed allowance of 25% uncertainty applied to waste volume estimates as described in Chapter 2 of the RI/FS.

**Table I-2. Summary of Estimated Costs for CERCLA Waste Disposal Alternatives**

| Description of Cost | Estimated Cost | | | |
|---|---|---|---|---|
| | On-site Disposal Alternative | | Off-site Disposal Alternative | |
| | Conceptual Design (Six Cells) | On-site Disposal Alternative (Five Cells) | NNSS Option 1 | Energy*Solutions* Option 2 |
| Mercury-contaminated debris costs [a] | $ 80,030,876 | | $ 216,740,474 | |
| **On-site Disposal Alternative:**<br>• 1,948,559 $yd^3$ of waste disposed<br>• DOE Order and CERCLA compliance<br>• 22 years of operation (base operations, in-cell macroencapsulation; leachate treatment; security)<br>• Treatment of Mercury-contaminated debris<br>• All capital costs for three phases of construction (Phase I cells 1&2; Phase II cells 3&4; and Phase III cells 5&6)<br>• Capital costs for final capping of landfill<br>• Perpetual care fee (covers post-closure care and monitoring (100 yr))<br>• Demolition of structures | | | **Off-site Disposal Alternative:**<br>• 1,948,559 $yd^3$ of waste disposed<br>• Packaging in Intermodal/sealands<br>• Transloading to Rail<br>• Transporting to Disposal Site<br>• Treatment of Mercury-contaminated Debris<br>• Disposal | |
| Life-cycle Cost (FY 2012 Dollars) | $ 704.1M | $ 679.4M | $ 1,473.4M | $ 1,337.5M |
| Contingency | $ 103.1M | $ 97.7M | $ 397.8M | $ 267.5M |
| Life-cycle Cost with Contingency (FY 2012 Dollars) | $ 807.2M | $ 777.1M | $ 1,871.2M | $1,605.0M |
| Escalated Cost with Contingency | $ 1,280.9M | $ 1,226.9M | $ 3,122.0M | $ 2,793.6M |
| Present Worth[b] Cost with Contingency | $ 905.6M | $ 871.1M | $ 2,119.7M | $ 1,920.5M |
| Disposal Cost ($/$yd^3$) FY 2012 Dollars with Contingency | $414 | $399 | $960 | $824 |
| Disposal Cost ($/$yd^3$) Escalated Cost with Contingency | $657 | $630 | $1,602 | $1,434 |
| **Disposal Cost ($/$yd^3$) Present Worth[b] with Contingency** | **$465** | **$447** | **$1,088** | **$986** |

[a] Costs provided for comparison purposes. Mercury-contaminated debris treatment and disposal costs are the same regardless of the on-site facility size (6 versus 5 cells). Likewise, mercury-contaminated debris in both off-site options is transported and disposed by either Energy*Solutions* or Waste Control Specialists, same cost for either option.

[b] Present Worth in FY 2015 dollars.

The representative process option for the On-site Disposal Alternative is construction of an engineered waste disposal facility for on-site disposal of radioactive or mixed wastes and implementation of long-term institutional controls for this EMDF. Key elements of the proposed disposal facility include an underdrain beneath the landfill to intercept and drain ground water; a compacted clay geobuffer; a multilayer liner with a double leachate collection detection system; a dike constructed of clean fill material to contain the waste laterally; upgradient geomembrane-lined diversion ditch with shallow french drain to divert upgradient surface water and shallow perched ground water around the landfill; and a multilayer cap that contains layers of clay, geosynthetic liner, sand, and cobblestones to minimize infiltration and isolate the waste from human and environmental receptors. Section 6.2 of the RI/FS provides a more-detailed description of this alternative. The conceptual site layout plan for EMDF is shown in Figure I-1.

### 1.1.2 Off-site Disposal Alternative

This alternative provides for the transportation of future candidate waste streams off the ORR to approved disposal facilities and placement of the wastes in those facilities. For purposes of the cost estimate, two options are examined: non-classified LLW and LLW/TSCA waste would be shipped to either NNSS in Nye County, Nevada, or Energy*Solutions* in Clive, Utah. Any classified LLW or LLW/TSCA waste would be shipped for disposal at NNSS in Nye County. Classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS. Any mixed (LLW/RCRA) waste requiring treatment (e.g., the mercury-contaminated debris) is assumed to go to either Energy*Solutions* or WCS in Andrews, Texas, where it would undergo treatment to meet land disposal restrictions and be disposed. Waste generator costs for treatment of waste to meet the facility WAC are not included in the Off-site Disposal Alternative estimate. All non-classified waste would be shipped by rail to Energy*Solutions* or NNSS. For transfer to NNSS, rail transport would end in Kingman, Arizona, where intermodals would be transferred to trucks for the final transport to NNSS. Thus two options are considered. Volume reduction, in a facility assumed to be located close to the transloading station at ETTP, would be implemented for Option 1 only, as Option 2 is a weight-limited transportation scenario (e.g., reducing volume will not change the weight transport analysis). Appendix B contains the details regarding the assumed volume reduction. The cost savings is applied within this Appendix (see Chapter 4). The two options are:

**Option 1 (Major Destination NNSS):**

- All classified waste disposed by NNSS.
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS.
- All LLW and LLW/TSCA disposed by NNSS.

**Option 2 (Major Destination Energy*Solutions*):**

- All classified waste disposed by NNSS.
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS.
- All LLW and LLW/TSCA disposed by Energy*Solutions*.

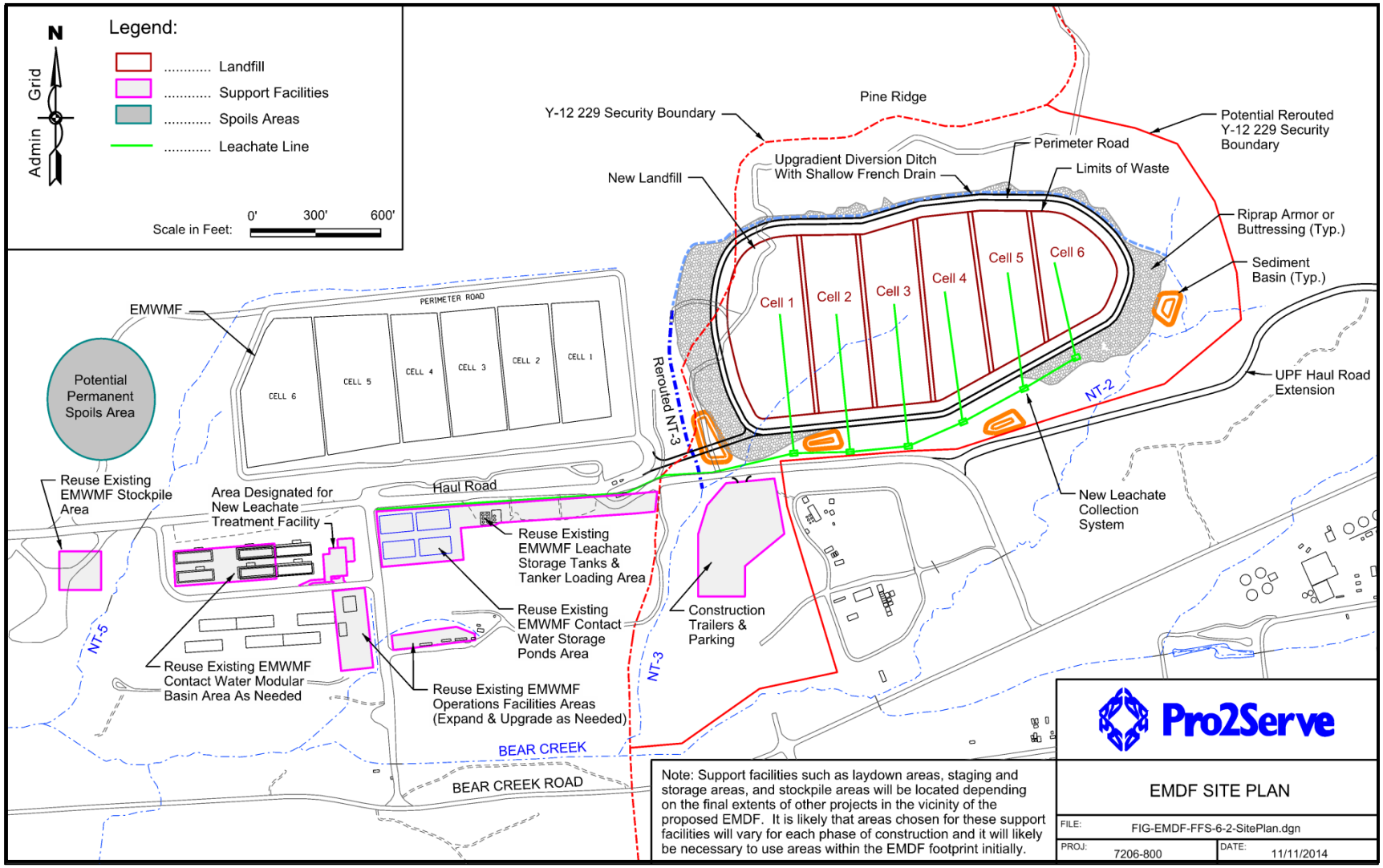



**Figure I-1. On-site EMDF Conceptual Site Layout Plan**

### 1.1.3 Project Schedules

Project schedules for the On- and Off-site Disposal Alternatives are based on the estimated future waste-generation rates. It is assumed that waste would be disposed of on-site or off-site in the same year it is generated. The schedule for the Off-site Disposal Alternative is directly linked to the as-generated waste volume estimate, and occurs from FY 2022 to FY 2043.

Figure I-2 shows the project schedule for the On-site Disposal Alternative. Operation of the on-site disposal facility would be expected to continue through FY 2043 with closure activities completed by FY 2047. Long-term surveillance and maintenance (S&M) and monitoring would continue after facility closure.

# 2. ELEMENTS COMMON TO THE ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES

Key elements common to the On- and Off-site Disposal Alternatives that affect cost estimates include contractual mechanisms, assumptions about excluding cost of the DOE activities, and assumptions regarding responsibilities of the waste generators. Volumes, and therefore costs for off-site shipment of waste not meeting an on-site disposal facility WAC or shipped off-site due to other project-specific factors, are excluded for both disposal alternatives (see Section 2.1.3 of the RI/FS).

For purposes of the estimates for both alternatives, costs for DOE activities are excluded from the estimates for both disposal alternatives as they would be comparable. Cost contingency was added to both the On-site or Off-site Disposal Alternative cost estimates, 22% for the on-site estimate applied to all elements except active operations (which received a 5% contingency) and 27% applied to the off-site estimate. Integrating prime contractor General and Administrative (G&A) and fee is applied to the on-site estimate at 15%.

The waste generators are considered to be responsible for removal of waste during cleanup actions; waste characterization and certification; waste segregation, compaction, or shredding; transport of waste to treatment facilities (with the exception of mercury-contaminated debris); treatment as necessary to meet disposal-facility WAC; placement of waste into containers; transport to either the on-site disposal facility or the transfer station at ETTP for off-site shipment; and interim storage, if required, for waste not meeting the disposal facilities' WAC. As waste generator responsibilities that are required regardless of the destination, the costs of these activities are not included in either estimate as they would not represent a discriminating element between the alternatives. Discriminating costs, such as purchasing waste containers and liners for transport to off-site facilities, are included. For classified waste and hazardous waste to be treated at the disposal facility, purchase and single use of containers is assumed. Purchase of liners and a limited number of containers for LLW and LLW/TSCA waste disposal at off-site facilities is assumed for the off-site alternative; containers are assumed to be reused for a 10-year lifetime.

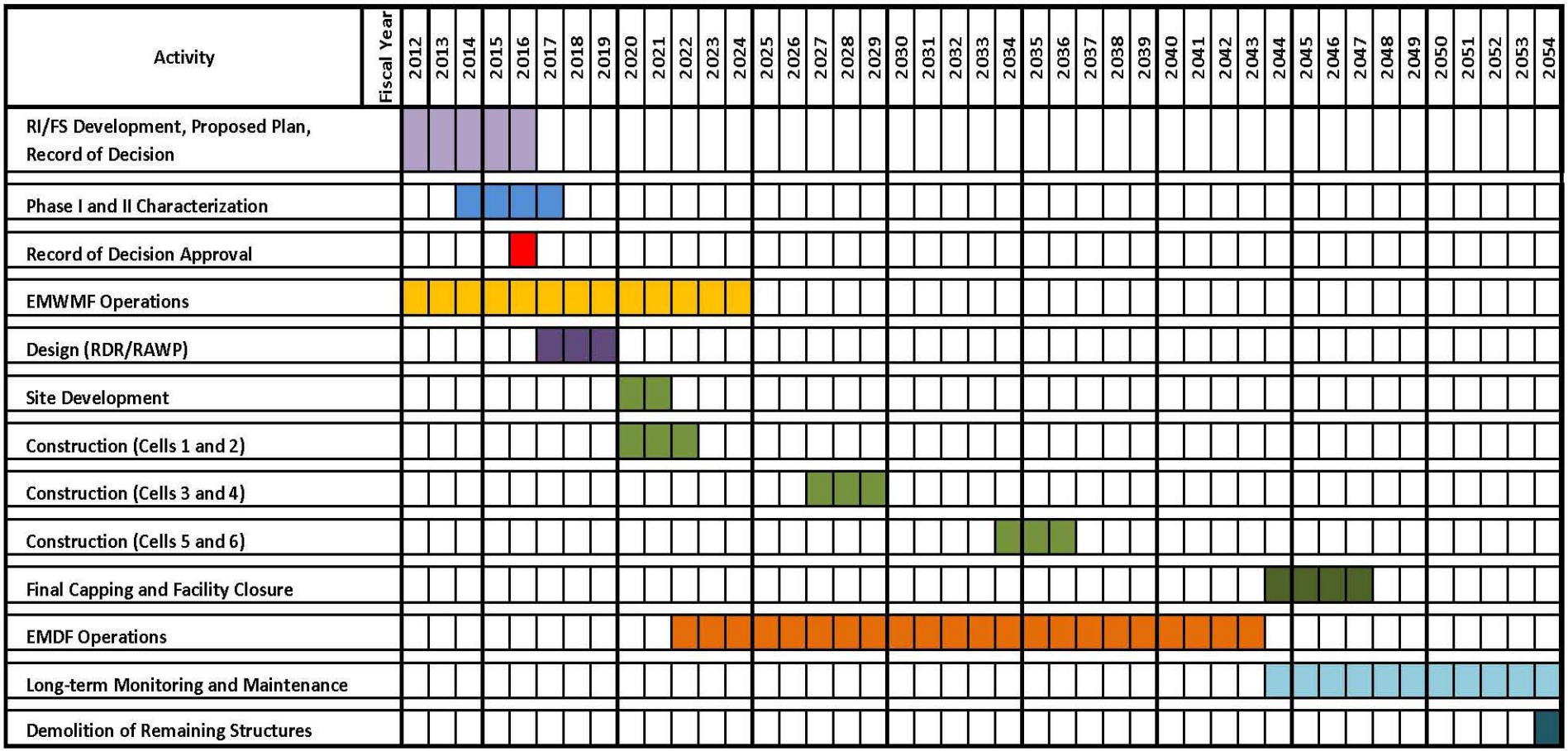



**Figure I-2. On-site Disposal Alternative Schedule**

# 3. ON-SITE DISPOSAL ALTERNATIVE COST ESTIMATE

This chapter provides the key assumptions for the On-site Disposal Alternative cost estimate, the basis for the estimate, and summary results.

## 3.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS

A cost estimate was prepared for the On-site Disposal Alternative with a proposed EMDF sited in East Bear Creek Valley immediately east of EMWMF (see Figure I-1). This section provides the conditions and assumptions for the on-site EMDF estimate. Elements common to both the On-site and Off-site Disposal Alternative (see Chapter 2 above) are not included in the On-site Disposal Alternative cost estimate.

The On-site Disposal Alternative would be implemented and managed by a prime contractor to DOE. This contractor would self-perform a portion of the work such as operations and subcontract other work activities as needed. Cost estimates for the On-site Disposal Alternative include early actions, including pre-design characterization and engineering studies along with CERCLA and DOE required documentation/review; remedial design; site development; construction for the entire facility, including waste cell and support facilities; receiving, unloading, and placing of waste into the disposal cell; all operations including placement of waste, daily cover, landfill water management and treatment as needed, and site monitoring; final capping and closure of the landfill; post-closure monitoring and maintenance; and management of all aspects and phases of the project. A Cost Engineering Estimating System (CEES) project value file for materials and labor was used to develop the estimate. No allowance is included for overtime during any phase of the project.

The key assumptions for the On-site Disposal Alternative cost estimate are as follows:

- Costs for DOE activities are not included.
- Waste is sequenced and the facility built and operated under the FY 2016 Target Funding Baseline Case ($420M).
- DOE funds all activities for the On-site Disposal Alternative (e.g., construction, operation, and closure).
- Management and Operations Contractor fees and G&A are assumed for all elements at 15%.
- All costs are presented in FY 2012 dollars, escalated dollars, and present worth (present worth given in FY 2015 dollars).
- Escalation of 2.3% per year is assumed.
- Assume EMWMF capacity is filled in FY 2024. EMDF would have an operational lifespan of approximately 22 years from FY 2022 through FY 2043 and waste would be generated during the 22 years of operation. This schedule assumes approximately two years of operational overlap of the two facilities.
- Activities for the On-site Disposal Alternative began in FY 2012, and will complete in FY 2054 in the current schedule; this is a total life-cycle of 43 years.
- No remediation would be required to construct the new facility.
- The site would be free of radiological materials/contamination during construction activities.
- Review and approval protocols for CERCLA documents would be per the ORR Federal Facility Agreement.
- The total capacity of EMDF would be approximately 2.5M $yd^3$. The disposal facility would be constructed in three phases. Each phase would include the construction of two disposal cells; the entire facility would include six cells.

- Site development activities would be performed to prepare the site and provide/modify support facilities and utilities prior to landfill construction. These activities are described in Section 3.2.2.2. Some support facilities would be shared with the existing EMWMF.
- The first phase of landfill construction would include the construction of two waste disposal cells (Cells 1 and 2) and the associated structural features necessary for operation of Cells 1 and 2, and future disposal cells. Construction of the first phase would be implemented so that the EMDF is ready to receive waste for approximately two years prior to reaching capacity at EMWMF.
- Phase II construction would include the construction of two waste disposal cells (Cells 3 and 4) and the soil contour layer for interim capping of Cells 1 and 2. This construction would occur simultaneously with the operation of the disposal cells.
- Phase III construction would include the construction of two waste disposal cells (Cells 5 and 6) and the soil contour layer for interim capping of Cells 3 and 4. This construction would occur simultaneously with the operation of the disposal cells.
- The EMDF would be closed with a final cap that would be placed at the conclusion of operation in Cells 5 and 6 including an interim cap (soil contour layer) on Cells 5 and 6 placed as part of Phase III construction.
- The new disposal facility would be a stand-alone facility. Complete self-supporting infrastructure (e.g., access roads, utilities, disposal cells, leachate collection, treatment facilities, staging, truck scales, etc.) would be constructed or shared with EMWMF (see Section 6.2.2.5 of the RI/FS).
- Waste would be transported from the Y-12 National Security Complex (Y-12) and Oak Ridge National Laboratory to the EMDF on dedicated Haul Roads and not over state maintained roadways.
- EMDF and support facilities would be located in close proximity to one another. Mobile fire and safety equipment/services would be provided by existing DOE ORR facilities.
- All monitoring and alarms would be maintained on-site.
- Davis-Bacon Act regulations regarding local prevailing wage rates would be in effect for all construction and operation activities.
- Borrow areas within 25 miles of the project site would be used for landfill construction and to provide suitable clean fill material for void space reduction in the waste cells.
- No additional verification, sampling, or analysis of incoming waste would be required other than visual inspection, review of manifest, and waste fingerprinting. Verification and documenting meeting WAC attainment requirements is considered part of operations.
- New storage capacity for landfill wastewater is provided, as well as bypass piping for the existing EMWMF and new EMDF.
- Landfill wastewater would be managed by collecting in existing leachate collection tanks and contact water basins located at the EMWMF site as well as new tanks. The Integrated Water Management (IWM) Focused Feasibility Study (FFS) (UCOR 2015) contains the details as to the proposed system for treatment. Existing collection systems would be maintained as necessary for EMDF utilization.
- Operation of the leachate collection system would continue three years after disposal operations cease. Reduced operation of the leachate collection system would continue for ten years after closure.
- Waste would not be highly radioactive; therefore, would not require personnel shielding or special handling.
- Operations costs are based on actual EMWMF operations data.

- The long-term monitoring and maintenance for EMDF would continue after closure of the facility. Estimates for this cost are based on the current perpetual care fee approach in place for EMWMF. A perpetual care fee of $1M per year for each year of operation of EMDF (e.g., 22 years) would be paid by DOE into an escrow account to be used for long-term monitoring and maintenance.
- No assumption as to the performer of the long-term maintenance is made in this document.

## 3.2 ON-SITE DISPOSAL ALTERNATIVE ESTIMATE DEVELOPMENT

The key components of the On-site Disposal Alternative cost estimate include pre-construction activities (includes design); site development and construction; operations (including security); final capping and facility closure; and long-term, post-closure care. A detailed basis of estimate has been prepared (P2S 2015), with references and vendor quotes. The detailed estimate was developed in CEES. This document summarizes costs and assumptions taken from that CEES detailed estimate and Basis of Estimate document with references.

Table I-3 is a summary of the EMDF Conceptual Design (six cells) estimate. The following sections summarize the activities/elements of the estimate and give major assumptions. Each section points to the specific elements of Table I-3 that are described.

### 3.2.1 Financial Basis of Estimate

#### 3.2.1.1 Material and Labor Pricing

The site development and construction estimates are based on preliminary bills of materials developed for each anticipated activity. Each activity was estimated with regard to the material cost and labor cost. Material and labor rates productivity were based on similar recent job history, as applicable, and R.S. Means cost data (Means 2012). Special work situations and job conditions that would result in additional material and/or labor work hours were identified and included in the estimate. Examples of special considerations include safety requirements, special materials, specialized training, supporting items, and cleanup.

#### 3.2.1.2 Wage Rates

Labor crafts that are expected to perform the tasks have been identified and appropriate wage rates applied. Labor rates used in the estimate are based on construction labor agreement rates for the Oak Ridge area. Fixed-price construction labor rates were based on average crew sizes with necessary foremen, general foremen, etc. All fringe benefits, payroll taxes, and worker's compensation insurance were included.

#### 3.2.1.3 Material, Equipment, and Production

The material, equipment, and production rates were generated using national averages obtained from nationally recognized cost references such as R. S. Means. The estimators used their experience to modify national average production rates for remedial action work. Special equipment and special facilities costs were obtained from vendors or from similar projects. Vendor quotes are used in the estimate for certain activities, which are not commonly found in cost references. These vendor quotes could change based on final engineering.

**Table I-3. Summary of EMDF Conceptual Design Cost Estimate**

| Element Number | WBS Element | Cost (FY 2012 Dollars) |
|---|---|---|
| **1** | **Pre-Construction and Engineering** | **$31,946,437** |
| | **Project Management** | **$1,692,070** |
| | **Site Characterization** | **$6,064,500** |
| | **Engineering (DOE Order/CERCLA compliance; Design) pre-ROD[a]** | **$3,537,686** |
| | **Engineering (DOE Order/CERCLA compliance; Design) post-ROD** | **$20,652,181** |
| **2** | **Operations** | **$365,495,038** |
| | **Base Operations** | **$265,650,000** |
| | **Interim Capping (all cells, material only)** | **$749,602** |
| | **Water Treatment Operations** | **$17,825,000** |
| | **In-cell Macroencapsulation Operations** | **$77,613,391** |
| | **Security Operations** | **$3,657,045** |
| **3** | **Post-closure Care Operations** | **$28,999,475** |
| | **Perpetual Care Fee[a]** | **$22,000,000** |
| | **Post-closure Care Operations** | **$6,999,475** |
| **4** | **EMDF Engineering Phase I** | **$1,946,798** |
| | **Engineering** | **$1,946,798** |
| | *Requests for proposals/review/award* | *$696,162* |
| | *Documentation* | *$502,313* |
| | *Operational readiness and startup* | *$715,014* |
| **5** | **EMDF Construction Phase I (Cells 1 and 2)** | **$102,626,951** |
| | **Project Management** | **$6,149,114** |
| | **Site Development** | **$11,495,076** |
| | *Construction Management* | *$852,225* |
| | *Mobilization/demobilization* | *$1,658,851* |
| | *Work packages/lift plan* | *$136,499* |
| | *Wetlands/stream replacement* | *$841,101* |
| | *Clearing/grading* | *$353,964* |
| | *Initial sediment control* | *$123,579* |
| | *Access roads/laydown areas* | *$338,228* |
| | *229 Boundary* | *$312,775* |
| | *Utility install/distribute* | *$2,711,472* |
| | *Prefabricated bridge* | *$4,131,536* |
| | *NT-3 culvert* | *$34,846* |
| | **Support Facilities** | **$9,553,055** |
| | *Personnel facilities* | *$462,743* |
| | *Truck scale* | *$147,732* |
| | *Guard station* | *$107,972* |
| | *Leachate/contact water treatment facilities* | *$2,347,352* |
| | *Leachate storage and transfer systems* | *$4,069,770* |
| | *In-cell macroencapsulation facilities* | *$2,417,485* |

**Table I-3. Summary of On-site Disposal Alternative Cost Estimate (Continued)**

| Element Number | WBS Element | Cost (FY 2012 Dollars) |
|---|---|---|
| **5 (cont.)** | **EMDF Construction Phase I (Cells 1 and 2)** | **(continued)** |
| | **Construct Cells 1 and 2** | **$75,429,706** |
| | *Construction Management* | ***$4,713,300*** |
| | *Oversight and Quality Assurance* | ***$5,406,093*** |
| | *Mobilization/demobilization* | ***$1,852,349*** |
| | · Pre-mob submittals | $245,824 |
| | · Work packages & lift plan | $136,499 |
| | · Personnel training | $164,275 |
| | · Temporary facilities | $215,472 |
| | · Support equipment and services | $634,533 |
| | · Site restoration | $42,522 |
| | · Mobilization/demobilization | $413,223 |
| | *Cell 1 & 2 Preparations* | ***$21,445,582*** |
| | · Clearing/grading | $661,815 |
| | · Underdrain construction | $1,400,575 |
| | · Excavation and fill | $18,846,701 |
| | · Test pads | $536,491 |
| | *Cells 1 & 2 Buffer and Liner Systems* | ***$26,952,075*** |
| | · Geologic buffer | $13,119,253 |
| | · Compacted clay liner | $9,676,967 |
| | · Secondary geomembrane liner | $470,250 |
| | · Geocomposite leak detection | $92,377 |
| | · Primary geomembrane liner | $516,099 |
| | · Geotextile cushion layer | $50,717 |
| | · Geosynthetic clay liner | $569,368 |
| | · Leachate collection drainage layer | $637,075 |
| | · Geotextile separator layer | $33,510 |
| | · Geocomposite drainage leachate collection | $377,642 |
| | · Protective soil layer | $665,610 |
| | · Leachate collection window | $258,948 |
| | · Liner trench/penetration boxes | $484,259 |
| | *Cells 1 & 2 Construction* | ***$15,060,308*** |
| | · Side slope riprap buttress | $9,789,721 |
| | · Perimeter road/ditch construction | $524,207 |
| | · Upgradient ditch/French drain | $432,516 |
| | · Sediment basin construction | $61,179 |
| | · Security fencing/lighting | $524,326 |
| | · Drainage and erosion controls | $619,902 |
| | · Leachate piping | $540,482 |
| | · Lift stations | $73,600 |
| | · Power to alarm controls | $66,004 |
| | · Engineering & Testing | $2,428,371 |

**Table I-3. Summary of On-site Disposal Alternative Cost Estimate (Continued)**

| Element Number | WBS Element | Cost (FY 2012 Dollars) |
|---|---|---|
| **6** | **EMDF Engineering Phase II (Cells 3 and 4)** | **$2,102,443** |
| | **Engineering** | **$2,102,443** |
| | *Requests for proposals/review/award* | *$418,357* |
| | *DOE Order, CERCLA compliance; design addendum* | *$1,558,506* |
| **7** | **EMDF Construction Phase II (Cells 3 and 4)** | **$42,225,701** |
| | **Project Management** | **$5,319,745** |
| | **Construct Cells 3 and 4** | **$36,905,956** |
| | *Construction Management* | ***$4,538,734*** |
| | *Oversight and Quality Assurance* | ***$2,969,512*** |
| | *Mobilization/demobilization* | ***$1,609,267*** |
| | · Pre-mob submittals | $245,824 |
| | · Work packages & lift plan | $136,673 |
| | · Personnel training | $164,275 |
| | · Temporary facilities | $190,703 |
| | · Support equipment and services | $423,108 |
| | · Site restoration | $38,547 |
| | · Mobilization/demobilization | $410,137 |
| | *Cell 3 & 4 Preparations* | ***$1,816,538*** |
| | · Clearing/grading | $201,113 |
| | · Underdrain construction | $126,002 |
| | · Excavation and fill | $975,895 |
| | · Test pads | $513,528 |
| | *Cells 3 & 4 Buffer and Liner Systems* | ***$22,328,541*** |
| | · Geologic buffer | $8,265,033 |
| | · Compacted clay liner | $9,603,239 |
| | · Secondary geomembrane liner | $449,885 |
| | · Geocomposite leak detection | $179,976 |
| | · Primary geomembrane liner | $409,918 |
| | · Geotextile cushion layer | $98,810 |
| | · Geosynthetic clay liner | $496,278 |
| | · Leachate collection drainage layer | $1,239,329 |
| | · Geotextile separator layer | $65,286 |
| | · Geocomposite drainage leachate collection | $229,740 |
| | · Protective soil layer | $584,000 |
| | · Leachate collection window | $237,459 |
| | · Liner trench/penetration boxes | $469,590 |
| | *Cells 3 & 4 Construction* | ***$3,643,364*** |
| | · Side slope riprap buttress | $151,195 |
| | · Perimeter road/ditch construction | $153,044 |
| | · Upgradient ditch/french drain | $46,828 |
| | · Sediment basin construction | $57,514 |
| | · Security fencing/lighting | $306,566 |
| | · Drainage and erosion controls | $327,967 |
| | · Leachate piping | $407,812 |
| | · Power to alarm controls | $66,004 |
| | · Engineering & Testing | $2,126,434 |

**Table I-3. Summary of On-site Disposal Alternative Cost Estimate (Continued)**

| Element Number | WBS Element | Cost (FY 2012 Dollars) |
|---|---|---|
| **8** | **EMDF Engineering Phase III (Cells 5 and 6)** | **$2,102,443** |
| | **Engineering** | **$2,102,443** |
| | *Requests for proposals/review/award* | *$418,357* |
| | *DOE Order, CERCLA compliance; design addendum* | *$1,684,085* |
| **9** | **EMDF Construction Phase III (Cells 5 and 6)** | **$47,649,458** |
| | **Project Management** | **$5,327,856** |
| | **Construct Cells 5 and 6** | **$42,321,602** |
| | *Construction Management* | ***$3,142,200*** |
| | *Oversight and Quality Assurance* | ***$2,969,358*** |
| | *Mobilization/demobilization* | ***$1,613,176*** |
| | · Pre-mob submittals | $245,824 |
| | · Work packages & lift plan | $136,673 |
| | · Personnel training | $164,275 |
| | · Temporary facilities | $191,277 |
| | · Support equipment and services | $423,108 |
| | · Site restoration | $38,833 |
| | · Mobilization/demobilization | $413,186 |
| | *Cell 5 & 6 Preparations* | ***$5,443,382*** |
| | · Clearing/grading | $334,722 |
| | · Underdrain construction | $544,568 |
| | · Excavation and fill | $4,027,601 |
| | · Test pads | $536,491 |
| | *Cells 5 & 6 Buffer and Liner Systems* | ***$18,938,029*** |
| | · Geologic buffer | $8,870,563 |
| | · Compacted clay liner | $6,669,006 |
| | · Secondary geomembrane liner | $349,301 |
| | · Geocomposite leak detection | $118,726 |
| | · Primary geomembrane liner | $349,301 |
| | · Geotextile cushion layer | $65,183 |
| | · Geosynthetic clay liner | $385,350 |
| | · Leachate collection drainage layer | $753,802 |
| | · Geotextile separator layer | $43,068 |
| | · Geocomposite drainage leachate collection | $199,387 |
| | · Protective soil layer | $418,057 |
| | · Leachate collection window | $236,374 |
| | · Liner trench/penetration boxes | $479,910 |
| | *Cells 5 & 6 Construction* | ***$10,215,457*** |
| | · Side slope riprap buttress | $6,091,335 |
| | · Perimeter road/ditch construction | $325,740 |
| | · Upgradient ditch/french drain | $224,696 |
| | · Security fencing/lighting | $305,923 |
| | · Drainage and erosion controls | $618,795 |
| | · Leachate piping | $381,044 |
| | · Power to alarm controls | $66,004 |
| | · Engineering & Testing | $2,201,919 |

**Table I-3. Summary of On-site Disposal Alternative Cost Estimate (continued)**

| Element Number | WBS Element | Cost (FY 2012 Dollars) |
|---|---|---|
| **10** | **EMDF Engineering Final Cap** | **$2,046,565** |
| | **Engineering** | **$2,046,565** |
| | *Requests for proposals/review/award* | *$346,610* |
| | *DOE Order, CERCLA compliance; design addendum* | *$1,699,955* |
| **11** | **EMDF Construction Final Cap** | **$69,219,039** |
| | **Project Management** | **$7,072,992** |
| | **Construct Final Cap** | **$62,146,047** |
| | *Construction Management and Oversight* | ***$6,665,242*** |
| | *Oversight and Quality Assurance* | ***$6,498,415*** |
| | *Mobilization/demobilization* | ***$3,271,078*** |
| | · Pre-mob submittals | $317,658 |
| | · Work packages | $136,673 |
| | · Personnel training | $250,608 |
| | · Temporary facilities | $366,416 |
| | · Support equipment and services | $1,245,471 |
| | · Site restoration/erosion control | $802,342 |
| | · Mobilization/demobilization | $151,910 |
| | *Final Cap Construction* | ***$45,711,311*** |
| | · Test pads | $536,491 |
| | · Compacted clay layer | $4,199,258 |
| | · Amended compacted clay layer | $9,477,385 |
| | · Geomembrane liner | $1,189,287 |
| | · Geotextile cushion layer | $756,820 |
| | · Lateral drainage layer | $3,493,778 |
| | · Biointrusion layer | $6,951,997 |
| | · Geotextile separator layer | $500,042 |
| | · Granular filter layer | $3,380,403 |
| | · Erosion control layer | $12,910,005 |
| | · Engineering & Testing | $2,315,845 |
| **12** | **Support Facilities Demolition** | **$7,718,800** |
| | **Water Treatment System Demolition** | **$3,680,000** |
| | **Leachate Storage Demolition** | **$4,038,800** |
| | **SUBTOTAL ON-SITE DISPOSAL FACILITY (FY 2012 Dollars)** | $704,079,148 |
| | CONTINGENCY (22% on all but Base & Security Operations and completed work scope; Base and Security Operations 5%) | $103,098,612 |
| | **TOTAL with Contingency (FY 2012 Dollars)** | **$807,177,760** |
| | *Purple indicates Capital portions of scope and cost.* | |
| | *Orange indicates Operations portions of scope and cost.* | |

#### 3.2.1.5 Indirect Markups

Indirect markups for construction have been applied according to DOE guidelines. Indirect markups for fixed price construction used in the estimates cover expenses incurred by the subcontractor such as overhead (e.g., home office support, G&A expenses) profit, bond, and markup on subcontractors utilized for various specialty construction services. A compounded rate of 28% has been applied to both material and labor to account for these activities.

A prime contractor to DOE is assumed to oversee all work elements, including design, operations, and construction. A 15% overhead rate to cover G&A expenses and fee is assumed on all elements.

#### 3.2.1.6 Contingency and Risk

For the On-site cost estimate a 22% contingency was applied to all elements except operations – 22% is the sum of 7% scope contingency and 15% bid contingency. EPA recommends a 5–10% scope contingency for clay caps, 5–10% scope contingency for surface grading/diking, and 10–20% scope contingency for synthetic caps. A 7% scope contingency was selected based on the fact that needed design considerations have been readily available from the existing EMWMF design. A mid-range bid contingency (EPA recommends 10–20%) was applied, 15%, to account for changing conditions (e.g. material pricing and weather disruptions). Therefore, a 22% contingency is calculated and applied to all construction and design elements, pre-construction elements, and operations that have not previously been performed at EMWMF (e.g., the water treatment operations and macroencapsulation operations). Contingency on base operations (includes base operations and security) was held to 5% since DOE currently operates an existing and very similar landfill, and those costs are very well known. No contingency was added on completed work scope (e.g., preparation of the RI/FS and Phase I Characterization).

Risks identified for the on-site alternative were identified along with cost implications and probability of occurrence. Contingency was assumed based on these risks:

| Risk | Cost Implications | Probability of Occurrence |
|---|---|---|
| • Material and/or labor cost increases during construction or operation | Moderate cost | Moderate |
| • Waste not meeting facility WAC and requiring off-site disposal | Moderate cost | Unlikely |
| • Compliance issues/operational issues requiring corrective actions | Low cost | Unlikely |
| • Increased long-term S&M costs | Moderate cost | Moderate |
| • Disposal site shutdown during operations | High cost | Unlikely |
| • Post-closure, extreme maintenance issues | High cost | Unlikely |

### 3.2.2 Descriptions of Estimate Activities and Assumptions

#### 3.2.2.1 Pre-construction Activities and Design (Elements 1 and 4 in Table I-3)

Early actions to support remedial design include activities under site characterization such as construction of new ground water monitoring wells and surface water weirs, upgrading existing down-gradient ground water monitoring wells (if required), ground water monitoring, hydrogeological and geotechnical investigations, and wetland delineation activities. Topography and threatened and endangered species surveys are completed. (Note that some of these activities have been completed and are summarized in this RI/FS. Others such as the topographic survey have not been completed as of this writing.) These early

actions would be completed prior to design and issuance of the draft Remedial Design Report (RDR)/ Remedial Action Work Plan (RAWP). Characterization is completed in two Phases.

Included in pre-construction activities are the efforts to produce and review CERCLA documents (e.g., this RI/FS, a Proposed Plan, Record of Decision, and Remedial Design Work Plan). Compliance with DOE orders (e.g., DOE O 435.1 and 413.3B) are assumed to be completed under pre-construction and engineering activities.

Remedial design for the On-site Disposal Alternative includes development of a RDR/RAWP (required by CERCLA) and Title I and Title II design engineering. Title I and Title II design activities include preparation of design drawings, specifications, reports, calculations, etc., required to construct and operate the new disposal facility and support facilities. In addition, remedial design includes preparation of design documents for site development activities. Procurement activities include development, issuance of request for proposals, review, and award of contracts for the different phases of facility design and construction.

For Phase I construction only (Cells 1 and 2), operational readiness and startup is part of the pre-construction activities.

Assumptions include (note that some of these activities have been completed as of the writing of this document, others are planned/assumed):

- Two phases of characterization: Phase I (mostly complete; hydrology monitoring is ongoing), and Phase II to be completed.
- Phase I Sampling and Analysis Plan development and request for proposal are completed.
- Phase I characterization: Five ground water well pairs, one deep and one shallow, are installed. Three flume locations will be monitored.
- Phase I access roads are built.
- Continued hydrological monitoring in the five Phase I well pairs for one year.
- Limited geotechnical data summaries in Phase I characterization.
- No contingency applied to completed scope of Phase I characterization.
- Extensive Phase II characterization, including the Data Quality Objectives, development of a Sampling and Analysis Plan, and Quality Assurance Plan.
- Phase II characterization to include: One deep well, six intermediate wells, six shallow wells, one flume.
- Phase II includes sampling and characterization to develop background constituent levels; a total of 1,777 samples are collected and laboratory analyses included.
- Phase II includes a topographical survey.
- Phase II includes geotechnical borings and analyses.
- Phase I and II reporting included.
- Oversight of field work included.
- Completion of the RI/FS and other required CERCLA documentation (proposed plan and record of decision) is part of pre-construction.
- No contingency is applied to the RI/FS development; no contractor G&A and fee is applied to the RI/FS preparation.
- Compliance with DOE O 435.1 is in pre-construction.

- Compliance with DOE O 413.3B (Critical Decision [CD]-0, 1, and 2/3A, CD-4A and completion report at completion of Cells 1 and 2 construction]. Includes all document development and reviews. Pre-construction includes this effort for Phase I Cells 1 and 2 only, for CD-2/3A and CD-4A. CD-0 and CD-1 are all inclusive of the whole landfill (all six cells).
- Engineering design procurement activities for a contractor to complete a full design are included.
- Engineering design: preparation of design drawings, design specifications, design calculations, final WAC, final WAC Attainment Plan, and the RDR/RAWP; development of operating plans, regulatory review, and project management for the landfill and for the water treatment system.

#### 3.2.2.2 Site Development and Phase I, II, and III Construction (Elements 5, 6, 7, 8, and 9 in Table I-3)

Site development activities described in Section 6.2.2.3 of the RI/FS would be performed as a separate early phase of construction prior to construction of Phase I (Cells 1 and 2). Site development activities would include constructing access roads to the landfill site; preparing additional parking, laydown, spoil, and staging areas; creating/expanding wetlands as required; extending utilities to the landfill site; relocating the Y-12 229 security boundary and installing new guard stations; clearing and grubbing, and installing initial sediment and erosion controls for site development activities; upgrading and installing new weigh scales; and setting up construction trailers. Purchase and installation of a pre-fabricated bridge for the access road is included. A new Northern Tributary (NT)-3 culvert purchase and installation is included.

Elements of the estimate and pertinent assumptions for site development include:

- Mobilization/demobilization of subcontractor with appropriate work packages and lift plan.
- Mobilization and rental of construction equipment.
- Wetlands/stream replacement: construct 2.5 acres of replacement wetlands and 1,607 linear ft (LF) of replacement streams at the East Bear Creek Valley (Site to mitigate impact on any wetlands and streams that would be disturbed during early actions, construction, operation, or closure of EMDF. Develop Wetlands Design Report and drawing of wetlands boundary and data collection points. Assume a cost of $100,000 per acre for wetland development per EPA guidance. Assume a cost of $200/LF for an estimated 1,607 LF of impacted stream.
- Clearing, grubbing of 13 acres, topsoil removal (10 acres), excavating, off-site borrow, and grading for site development activities.
- Installation of sediment controls include installation of silt fence, erosion control matting, and construct sediment basins 1 (5,516 $yd^3$) and 2 (1,867 $yd^3$). Silt fence will be installed along down-gradient slopes of NT-3 stream.
- Construction of access roads and laydown areas includes constructing a laydown and parking area south of the Haul Road and a gravel access road and staging area north of the Haul Road. Both areas are assumed to need minimal grading due to existing site conditions, but are assumed to need culverts installed prior to placing geotextile and gravel.
- Relocation of the 229 Boundary, assumes 4,350 LF of fencing demolished and 5,842 LF of fencing installed.
- Utility installation and distribution, includes water, communications, and associated equipment installation and connection. Assume EMWMF overhead power line can be extended for use. Water line extended from Bear Creek. Communications lines extended from EMWMF.
- Project oversight and reporting (engineering, health and safety, regulatory review, field services, document control, and project management)

Construction activities for all phases would include construction of the disposal facility cells (clearing/grubbing, hydrogeologic buffer, liner system, berms, etc.). Construction of six disposal cells of the facility would be in three phases (two cells in each phase [Phases I, II, and III]). Support facilities, including construction of the landfill wastewater treatment system described in Section 6.2.2.5 of the RI/FS, are part of Phase I construction. Placement of interim covers is part of operations and not included in construction; however, the interim cover materials are noted in Table I-3.

Support facilities, to be constructed as part of Phase I (Cells 1 and 2) only include:

- Installation of personnel facilities and parking. Includes purchase and installation of six trailers to support construction personnel. Site preparation not required (already provided at EMWMF). Installation of two septic tanks, 2,000 gallons each.
- Installation of truck scales and three guard stations. Includes preparations (concrete pads and communications).
- Landfill wastewater treatment system (estimate from IWM FFS).
- Leachate storage tanks (new) to provide for 1,500,000 gallons of storage. Assumes three new tanks at 500,000 gallons each. Includes site preparation and concrete pads installed.
- Bypass pipelines for EMWMF and EMDF to allow for direct discharge.
- In-cell macroencapsulation batch plant (from URS|CH2M Oak Ridge LLC [UCOR] provided estimate).
- Elements 6 and 8 in Table I-3 contain efforts to develop requests for proposal for update of design and construction, and review/award of the contracts. Effort to complete the design addendum, and DOE O 413.3B requirements (Critical Decision-2/3 at the start and CD-4 at completion of each phase) is included.

Phase I, II, and III construction includes:

- Elements 5, 7, and 9 in Table I-3 summarize costs for construction of Phases I, II and III.
- Material (soil layer) for contouring of previous cells (e.g., Phase II includes soil contour for Cells 1 and 2; Phase III includes soil contour for cells 3 and 4; Capping includes soil contour for Cells 5 and 6). Placement of all interim covers (enhanced operational cover) is assumed to be part of ongoing cell operations, and therefore the material (soil layer) is not considered capital cost.
- Mobilization/demobilization of construction subcontractor includes development of pre-mobilization submittals, work packages and lift plan; personnel training, construction of temporary facilities, support equipment and services, and site restoration upon completion of construction phase.
- Preparations for construction include clearing, grubbing of area for cell placement, topsoil removal, excavating, off-site borrow, and grading for site development activities.
- Excavation and fill costs for Cells 1 and 2 assume grading, filling, and installation of underdrain system below areas of Cells 3 and 4 to control surface water in upper areas of Northern Tributary-3 watershed.
- Landfill Construction Project Management includes project manager (includes managing subcontracts); project controls; scheduling and estimating; project engineer (includes Change Order reviews and engineering design modifications); health and safety officer; field engineers (construction observation); administrative support; development of preliminary hazard analysis reports, hazard acceptance and safety assessments documents; request for proposal efforts; document production/reproduction; procurement efforts for different design phases; and development of operation and maintenance manuals and record drawings.

- Actual construction of cells includes the following, significant materials (synthetic layers) were based on vendor quotes (P2S 2015) listed below:
  - Installation of sediment controls.
  - Installation of security fencing, lighting, and alarms.
  - Site restoration.
  - Engineering and testing.
  - Support equipment services.
  - Underdrain construction.
  - Rough grading for under landfill liner (includes excavation and off-site borrow costs).
  - Test pads.
  - Construction of clean fill dike.
  - Construction of liner layers.
  - Installation of liner trenches and excavation boxes.
  - Armoring side slopes.
  - Construction of perimeter road and ditch.
  - Construction of upgradient ditch and French drain.
  - Installation of leachate and leak detection piping and equipment.
  - Installation of landfill waste water manholes.
- At the conclusion of design of each Phase, As-Built drawings/specs are finalized.

#### 3.2.2.3 Operations (Element 2 in Table I-3)

It is assumed that all operations activities would be performed by a prime contractor to DOE. Transition of most equipment from the existing EMWMF to use at EMDF is assumed. Minimal equipment purchase is included. Operations activities would consist of waste record-keeping, receipt and inspection, WAC attainment, placement of wastes into the disposal cell, decontamination of waste packaging and transport vehicles, and maintenance of the disposal facility. Facility maintenance includes providing daily cover over the emplaced waste, landfill wastewater collection and management, equipment maintenance, support facility (e.g., roads and buildings) maintenance, and record keeping. Interim capping of filled cells is included in operations scope. Interim capping, with an enhanced operational cover, is considered part of ongoing operations; materials are included in operations with the exception of the contour layer (1 ft of soil). This contour layer is included in construction of cells (see Section 3.3.2.2). Disposal facility operations costs are based on actual EMWMF operations cost data as provided by UCOR, the current EMWMF operating contractor. Annual operations costs are taken from actual costs at EMWMF, estimated at $10.5M per year.

Treatment of waste to meet the disposal-facility WAC would remain the responsibility of the waste generator and is not included in this alternative.

Collected landfill wastewater would be stored in the existing EMWMF leachate storage tanks and contact water collection basins/modular tanks as well as new storage tanks. The landfill wastewater will be sampled and characterized. It will be managed as specified in the IWM FFS. The estimate for landfill wastewater treatment operations is taken from the IWM FFS. It includes all labor and materials to operate a 60 gallon per minute facility as described in the IWM FFS. Sampling and analysis are included. The lifetime is assumed to be 22 years of active cell operations plus an additional three years until final capping of the landfill is completed for a total of 25 years of operation.

In-cell macroencapsulation operations costs were estimated by UCOR. A capital cost for installation of a batch plant to provide the flowable fill is shown under support facilities, and the operations cost to form the 30 ft × 30 ft × 10 ft structures, place the waste, and macroencapsulate the waste is included as a line item under cell operations.

Security operations were estimated based on the volume of classified waste predicted for receipt over the 22 year active life of the facility. Assumptions include:

- **Cell Security:** Assume classified waste will be received at the start of operations. Assume ½ day per week for a security guard to be on duty at the cell when classified waste is received. This is 5 hour/week or 260 hour/year for 22 years.
- **Drive by Security Checks:** Assume one drive-by per shift each day (there are three shifts in a day). Assume each drive-by is two hours. This totals 2 hours × 3 shifts/day × 7 days/week = 42 hours/week or 2,184 hours per year for 22 years.

#### 3.2.2.4 Post-closure Care Operations (Element 3 in Table I-3)

This element includes the $1M per year Perpetual Care Fee. This fee will be paid into an escrow account for 22 years of active operations or $22M total life-cycle cost.

Leachate post-closure costs include the cost to run the leachate treatment system for ten years following final capping of the landfill. This estimate includes sampling and analysis of the leachate. The annual estimate is from the IWM FFS; however, the FFS assumes a 30-year duration while this RI/FS assumes a ten year duration, after which the leachate generation is assumed to cease.

The perpetual care fee is paid annually. This amount ($1M) is assumed to be invested annually, so that at the end of operation these funds have been earning interest for that entire time period. At an estimated 3% return, the base amount ($22M, $1M annually invested) will have grown to $32,452,884. Interest alone on this amount provides an annual income of $973,587 in its 23$^{rd}$ year. Annual costs for S&M are estimated in Table I-4 as approximately $420,000 per year for the first three years, and $288,000 for the remaining years (year 3 through 100). The first year of post-closure care is assumed to be 2047, which would result in an estimated $ 953,000 in fees for that year (based on an escalation rate of 2.3%), within the estimated $973,587 that would be provided by interest on the perpetual care fee. Provided investments keep up with inflation, the perpetual care fee could be expected to fund the S&M of the landfill through the 100-year period following closure.

Assumptions for long-term maintenance include:

- Annual mowing and fertilizing (40 acres).
- Watering to occur only the first three years.
- Annual weed control in specific areas.
- Annual surface water drainage maintenance.
- Quarterly ground water monitoring of 12 wells. Includes sampling, analysis, and reporting. Personnel include: Two Technicians, one Supervisor, one Radcon, one Health and Safety, one Engineer.
- Quarterly records maintenance and CERCLA reporting.
- Yearly inspections, quarterly for the first three years.
- Cap maintenance annual repair. Reseeding for first three years until vegetation is established.
- Project management of effort and contingency at 27%.

- For volume reduction estimation, annual mowing; watering (for initial three years); and annual weed control were removed for 7 of the 40 acres. This resulted in years 1 -3 cost of $389,190 and subsequent years annual cost of $278,820 (years 4-100). Over a period of 100 years of post-closure care, this is approximately $1M.

**Table I-4. Estimated Annual S&M Costs in FY 2012 Dollars**

| Surveillance & Maintenance Item | FY 2012 Dollars Annual Cost ($K) | Additional Annual Cost for First 3 Years ($K) |
|---|---|---|
| Cap Maintenance | | |
| Mowing and fertilizing | $ 12.55 | |
| Watering | | $ 115.70 |
| Weed control; Pest control | $ 0.88 | |
| Surface water drainage maintenance | $ 15.00 | |
| Ground Water Monitoring | | |
| Sampling and analysis | $ 100.60 | |
| Records and planning | $ 18.56 | |
| Post Closure Inspections (non-security related) | | |
| Engineering | $ 0.63 | $ 1.90 |
| Other (wells, etc.) | $ 8.11 | |
| Minor Cap Maintenance | | |
| Additional soil cover, reseeding for erosion | $ 30.00 | |
| Combine tilling/reseeding to establish cover | | $ 14.46 |
| Management | | |
| Management | $ 40.50 | |
| Contingency | | |
| Contingency at 27% | $ 61.20 | |
| | | |
| **Annual Cost (Years 1–3)** | **$ 420.13 K** | |
| **Annual Cost (Years 4 and later)** | **$ 288.07 K** | |

### 3.2.2.5 Final Capping and Facility Closure (Elements 10 and 11 in Table I-3)

Final capping and facility closure would include final design of the cover system, placement of the final cover system and quality assurance procedures associated with cover placement, removal of support facilities, and site restoration (see Section 6.2.8 of the RI/FS).

The final cap includes placing multiple layers over all filled waste cells. All overlying cap layers will tie into the clean-fill dikes. Site restoration will include seeding and mulching cap and dikes with native grasses and maintaining this until vegetative cover is established.

The final cover system (11 ft) is described in Section 6.2.2.4.7 of the RI/FS. It consists of multiple layers, beginning with the 1 ft contour layer that is added as part of the enhanced operational cover during the

phased construction of Cells 3 and 4, and 5, and 6. A 1 ft thick compacted clay layer (native or amended to achieve specifications) is the first layer of the final cap. Subsequent layers include an amended clay layer, geomembrane layer (40 mil), geotextile cushion layer, lateral drainage layer (1 ft of #57 siliceous stone), biointrusion layer (2 ft 4–12 in. diameter riprap), geotextile separator layer, and final layer is the erosion control layer (4 ft vegetated soil/rock matrix), which includes a seed mix specially designed for this application. The final cover system would tie into the top of the perimeter clean-fill dike. The drainage and overlying layers would discharge water into perimeter ditches that would carry runoff away from the landfill.

Assumptions include:

- Mobilization/demobilization of construction subcontractor includes development of pre-mobilization submittals, work packages and lift plan; personnel training, construction of temporary facilities, support equipment and services, and site restoration upon completion of construction phase.
- Two test pads, each 100 ft × 100 ft for compacted clay liner and amended compacted clay liner.
- Purchase and installation of the compacted clay liner layer (67,600 $yd^3$).
- Purchase and installation of the amended (bentonite) compacted clay liner layer (67,600 $yd^3$).
- Geomembrane (40 mil) purchase and installation (1,673,100 $ft^2$).
- Geotextile (16 $oz/yd^2$) purchase and installation (1,673,100 $ft^2$).
- Lateral drainage layer purchase, constructed at 1 ft thick. Assumes stone density of 1.6 $ton/yd^3$ and 108,160 tons. Equipment and labor to construct.
- Biointrusion layer, purchase, construct at 4 ft thick. Assumes stone density of 1.5 $ton/yd^3$ and 202,800 tons. Equipment and labor to construct.
- Geotextile separator layer (8 $oz/yd^2$) purchase and installation (1,673,100 $ft^2$).
- Granular filter layer (1 ft thick, consisting of 6 in. thick #57 stone siliceous layer and 6 in thick sand layer) purchase and installation, 33,800 $yd^3$ of each layer.
- Erosion control layer 4 ft thick, purchase and build, soil and rock mixture 1:1, 270,400 $yd^3$.
- Erosion control matting, 9 mil thick, to be placed over erosion control layer, 169,000 $yd^2$.
- All oversight and construction quality assurance and control, testing, is assumed.
- Construction management is assumed.
- Development of As-Builts.

#### 3.2.2.6 Post-closure (Element 12 in Table I-3)

Post-closure is assumed to be funded by the Perpetual Care Fee (see Section 3.3.2.4 above). As discussed, post-closure care is assumed to be carried out for 100 years. After 10 years, it is assumed that leachate from the landfill in the leachate collection system has ceased. The demolition of the water treatment system and support systems (tanks, ponds, etc.) is completed.

### 3.2.3 Present Worth

Present worth cost for the cost estimates were calculated based on EPA guidance (EPA 2000) using a real discount rate of 2.0% according to published 2012 Discount rates for Office of Management and Budget (OMB) Circular No. A-94 (OMB 2012). The present worth cost is based on discounting cost of escalated dollars over the period of activity as determined by the project schedule. For the On-site Disposal Alternative, the period of activity is FY 2015 through FY 2047, with long-term maintenance extending for 100 years post-closure.

### 3.2.4 Construction of Five Cells

As stated in the Introduction of this Appendix, for the On-site Disposal Alternative, the 1.95 M $yd^3$ as-generated waste volume results in 2.18 M $yd^3$ as-disposed volume (required disposal capacity) as demonstrated in Chapter 2 (see Tables 2-3 and 2-4 in Chapter 2). This is the capacity provided by five cells, whereas the conceptual design is a six-cell design. The cost developed for the EMDF and given in Table I-3 is for the whole design of six cells. However, as only five cells are currently projected to be required (per the volume estimate), and that is the volume of waste assumed for the Off-site Disposal Alternative, a five cell estimated cost for the On-site Disposal Alternative is used to compare to the Off-site Disposal Alternative cost. Table I-5 summarizes the reduction in costs if Cell 6 is not constructed. Savings are realized in both the construction costs and the final cap costs. A revised total landfill estimate is also given in the table.

Assumptions used to reduce the cost of constructing a landfill with five cells, rather than the six cell design, include:

- Cell 6 is 45% of the capacity of Cells 5 and 6 combined. Reductions in construction costs (site preparations, liner, cell) are likewise reduced by 45%.
- Cell 6 is 13% of the total capacity of Cells 1–6. Final capping materials and labor are reduced by 13%.
- Project management, oversight, and quality assurances costs for Phase III construction will not decrease commensurate with size reduction; a 25% reduction in cost is assumed.
- Project management, oversight, and quality assurances costs for Final Cap construction will not decrease commensurate with size reduction; a 5% reduction in cost is assumed.
- No reduction in engineering costs is assumed.
- No reduction in mobilization/demobilization costs is assumed.
- No reduction in project management for final capping is assumed.

Final On-site Disposal Alternative and Conceptual Design estimated costs are given in Table I-6.

**Table I-5. Summary of Cost Reductions for Landfill Construction of Five Cells versus Six Cells**

| WBS Element | Original Cost ($) | Revised Five Cell Estimated Cost ($) | Reduction Taken for Cell 6 ($) |
|---|---|---|---|
| **EMDF Construction Phase III** | **$49,751,900** | **$30,950,506** | **$18,801,394** |
| **Project Management** | **$5,327,856** | **$3,622,942** | **$1,704,914** |
| **Engineering (design, DOE/CERCLA doc.)** | **$2,102,443** | **$2,102,443** | **$0** |
| **Construct Cells 5 and 6** | **$42,321,602** | **$25,225,122** | **$17,096,480** |
| *Construction Management* | *$3,142,200* | *$2,356,650* | *$785,550* |
| *Oversight and Quality Assurance* | *$2,969,358* | *$2,227,018* | *$742,339* |
| *Mobilization/demobilization* | *$1,613,176* | *$1,613,176* | *$0* |
| *Cell 5 & 6 Preparations* | *$5,443,382* | *$2,993,860* | *$2,449,522* |
| *Cells 5 & 6 Buffer and Liner Systems* | *$18,938,029* | *$10,415,916* | *$8,522,113* |
| *Cells 5 & 6 Construction* | *$10,215,457* | *$5,618,501* | *$4,596,956* |
| **EMDF Construction Final Cap** | **$69,219,039** | **$63,352,358** | **$5,866,681** |
| **Project Management** | **$7,072,992** | **$7,072,992** | **$0** |
| **Construct Final Cap** | **$62,146,047** | **$56,279,366** | **$5,866,681** |
| *Construction Management and Oversight* | *$6,665,242* | *$6,331,980* | *$333,262* |
| *Oversight and Quality Assurance* | *$6,498,415* | *$6,173,495* | *$324,921* |
| *Mobilization/demobilization* | *$3,271,078* | *$3,205,657* | *$65,422* |
| *Final Cap Construction* | *$45,711,311* | *$40,568,234* | *$5,143,077* |
| | | | |
| **SUBTOTAL (FY 2012 $)** | | | **$24,668,075** |
| **Contingency (22%)** | | | **$5,426,977** |
| **TOTAL with Contingency (FY 2012 $)** | | | **$30,095,052** |

**Table I-6. On-site Disposal Alternative Landfill Estimated Costs, Conceptual Design and Five Cells**

| Estimated Costs (Includes all capital costs; operations for 22 years; final cap; perpetual care fee; and post-closure care) | Conceptual Design EMDF (Six Cells) | On-site Disposal Alternative (Use of Five Cells) |
|---|---|---|
| **FY 2012 dollars Subtotal** | **$ 704,079,148** | **$ 679,411,069** |
| Contingency (7% scope, 15% bid), 22% | $ 103,098,612 | $ 97,671,635 |
| **FY 2012 TOTAL with Contingency** | **$ 807,177,760** | **$ 777,082,705** |
| | | |
| **Escalated Subtotal** | $ 1,117,699,480 | $ 1,073,685,997 |
| **Escalated TOTAL with Contingency** | **$ 1,280,889,759** | **$ 1,227,193,309** |
| | | |
| **Present Worth Subtotal** | $ 790,975,767 | $ 762,779,903 |
| **Present Worth TOTAL with Contingency** | **$ 905,574,502** | **$ 871,175,548** |

# 4. OFF-SITE DISPOSAL ALTERNATIVE COST ESTIMATE

This section provides the key assumptions for the Off-site Disposal Alternative cost estimate, the basis for the estimate, and the summary results.

## 4.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS

A cost estimate was assembled for the Off-site Disposal Alternative based on the as-generated waste volume estimate discussed in Chapter 2 and Appendix A of the RI/FS. This section provides the conditions and assumptions for the estimate. Table I-7 summarizes those volumes as they are used in the off-site estimate. Note that an assumption is made that mixed waste soil is treated by generators to meet Land Disposal Restrictions prior to disposal, and therefore is considered only LLW or LLW/TSCA for purposes of disposal.

The cost estimate for the Off-site Disposal Alternative includes truck-to-rail transfer, long-distance transportation of the waste to the off-site disposal facilities, and disposal fees. Costs excluded from the estimate are those common to both disposal alternatives (see Section 2 of this Appendix).

Figures I-3 and I-4 show the off-site disposal activities and responsible entities for waste shipments to NNSS, Energy*Solutions* and/or WCS.

**Table I-7. As-generated Waste Volume Estimate (FY 2022 – FY 2043) for Off-site Disposal Alternative**

| Off-site Disposal Facility | Waste Type | Volume Including 25% Contingency ($yd^3$) |
|---|---|---|
| **Option 1: NNSS (Non-Classified)**<br><br>**Option 2: Energy*Solutions*** | LLW and LLW/TSCA Debris | 1,151,440 |
| | LLW and LLW/TSCA Soil | 607,468 |
| | **SUBTOTAL** | **1,758,908** |
| **NNSS (Classified)** | LLW Debris | 35,612 |
| | LLW/RCRA (mixed) Debris[1] | 4,621 |
| | **SUBTOTAL** | **40,233** |
| **Energy*Solutions* or WCS** | LLW/RCRA (mercury) Debris | 149,418 |
| | **SUBTOTAL** | **149,418** |
| | **TOTAL** | **1,948,559** |

[1]This waste volume assumed to be treated by generator prior to disposal, and thus meets land disposal restrictions.

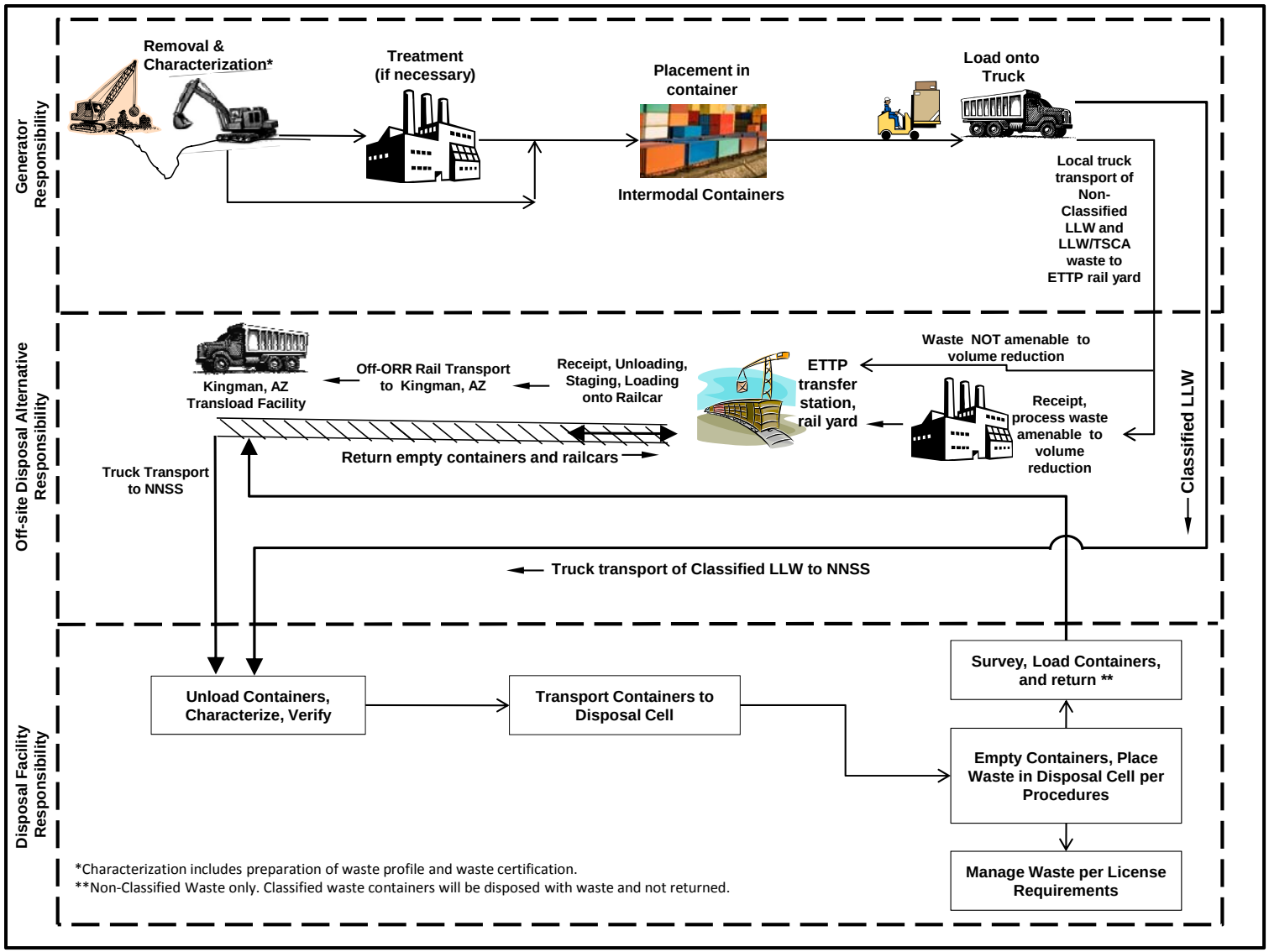



**Figure I-3. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative**

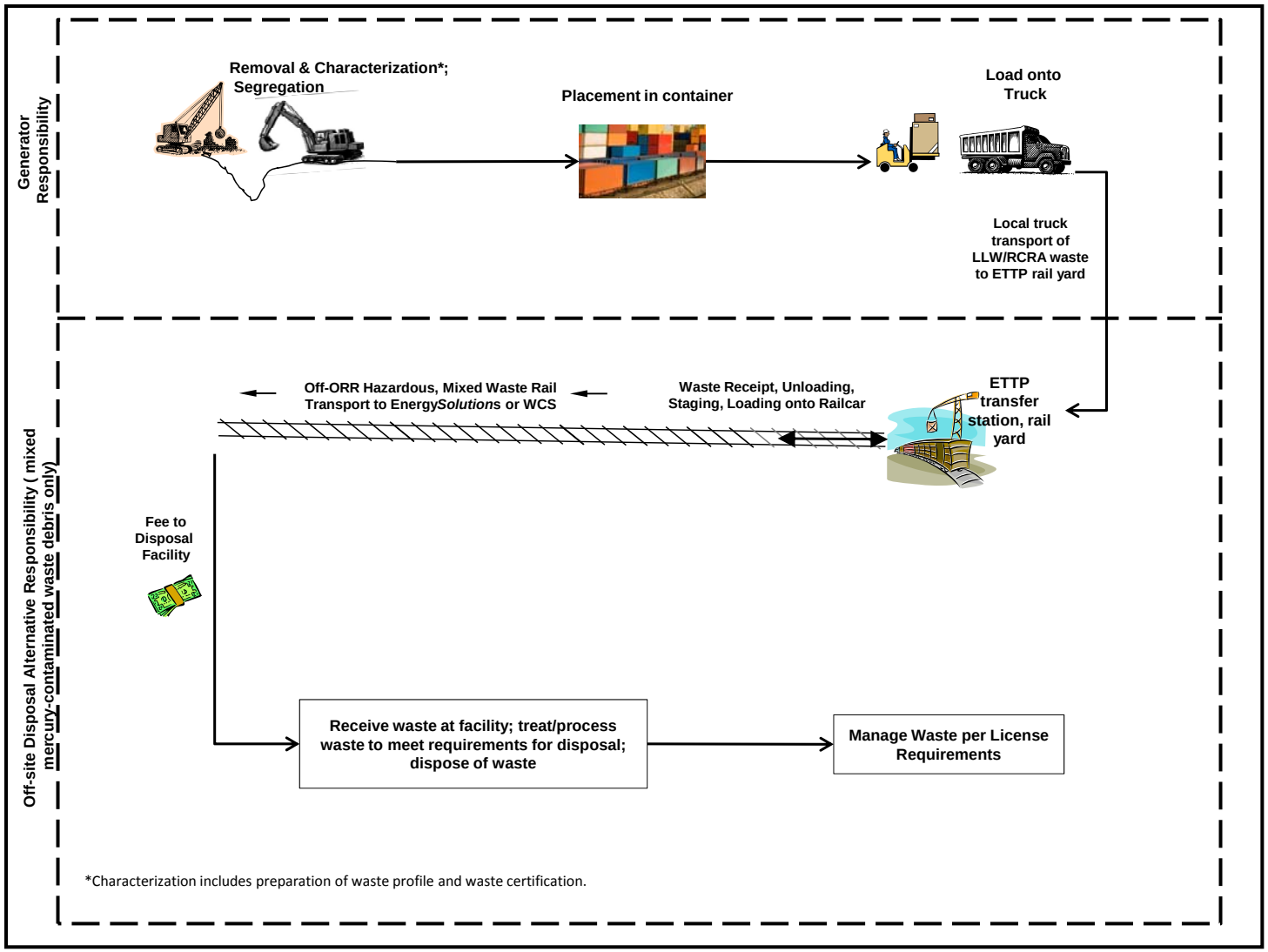



**Figure I-4. Schematic of Responsibilities for Waste Shipments of Mercury-contaminated Waste to Energy*Solutions* or WCS in Off-site Disposal Alternative**

This alternative provides for the transportation of future candidate waste streams off the ORR to approved disposal facilities and placement of the wastes in those facilities. For purposes of the cost estimate, two options are examined: non-classified LLW and LLW/TSCA waste would be shipped to either NNSS in Nye County, Nevada, or Energy*Solutions* in Clive, Utah. Any classified LLW or LLW/TSCA waste would be shipped for disposal at NNSS. Classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS. Any mixed (LLW/RCRA) waste requiring treatment (e.g., the mercury-contaminated debris) is assumed to go to either Energy*Solutions* or WCS in Andrews, Texas, where it would undergo treatment to meet land disposal restrictions and be disposed. Waste generator costs for treatment of waste to meet the facility WAC are not included in the Off-site Disposal Alternative estimate. All non-classified waste would be shipped by rail to Energy*Solutions* or NNSS. For transport to NNSS, rail to a transloading station in Kingman, Arizona, would be followed by truck transport to NNSS. All classified waste shipments to NNSS would be by truck transport. Thus, two options are considered:

**Option 1 (Major Destination NNSS):**

- All classified waste disposed by NNSS
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS
- All LLW and LLW/TSCA disposed by NNSS

**Option 2 (Major Destination Energy*Solutions*):**

- All classified waste disposed by NNSS
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS
- All LLW and LLW/TSCA disposed by Energy*Solutions*

The key assumptions for the Off-site Disposal Alternative cost estimates for both options are as follows:

- All classified LLW would be disposed at the NNSS facility in Nye County, Nevada.
- Classified mixed waste would be treated by generators to meet NNSS WAC, and transported after treatment by truck to NNSS for disposal.
- Classified waste would travel in intermodals to NNSS. Those intermodals would be disposed with the waste.
- The NNSS WAC allows for the use of returnable intermodal containers used for LLW and LLW/TSCA (non-classified).
- All LLW/RCRA (mixed) waste would be treated and disposed at the Energy*Solutions* facility in Clive, Utah, or WCS in Andrews, Texas.
- All non-classified waste shipped to NNSS would be transported in lined intermodal containers from the individual remedial sites to the ETTP rail siding, loaded onto railcars, and shipped by rail to Kingman, Arizona, transload facility followed by truck transport to NNSS (two intermodal containers per truckload for debris and one intermodal container per truckload for soil).
- Articulated bulk container (railcars would be used for transportation of soil and debris to NNSS.
- Each intermodal would contain approximately 21.2 $yd^3$ of debris waste or 14.5 $yd^3$ of soil waste and each railcar will carry eight intermodal containers.
- Intermodal containers would be purchased and reused for all non-classified, non-RCRA hazardous waste shipment.
- All waste shipped to Energy*Solutions* would be collected in sealands with liners, transferred to high-sided gondolas at the transloading station at ETTP, and shipped (rail) to Energy*Solutions* for disposal.
- All intermodal/sealand containers would include a plastic liner for each shipment.

- Intermodal/sealand container design life is 10 years. Containers are purchased then disposed when they reach 10 years.
- High-sided gondolas (super gondolas) have a weight limit of 100 tons.
- Three sealands fill one gondola.
- Intermodal containers would be purchased for all classified waste shipments (non-returnable containers).
- Macroencapsulation is the assumed waste treatment for LLW/RCRA (mixed) waste disposed at Energy*Solutions* or WCS.
- Waste treatment/disposal fees for Energy*Solutions* or WCS are based on the actual volume shipped in the container and not on the total container volume.
- Energy*Solutions* and WCS provided vendor estimates for the treatment and disposal of mercury-contaminated debris. Those quotes were for 100,000 $yd^3$ of waste. The quotes were adjusted to account for the higher volume in this RI/FS (that volume is 149,418 $yd^3$).
- The WCS quote did not include packaging. This was added into their quote. Both quotes included transportation.
- The two quotes were averaged for a final estimated cost to package, transport, treat, and dispose of 149,418 $yd^3$ of mercury-contaminated waste. The quotes were given in FY 2014 dollars. The quotes were de-escalated to obtain FY 2012 dollars. A value of $216,740,474 was calculated as an average of the two quotes.
- Per a National Nuclear Security Administration memorandum (NNSA 2008), a disposal access fee rate of $14.51 per $ft^3$ is applied for NNSS disposal.
- No capital improvements would be required at ETTP to handle loaded intermodal containers. (All labor and necessary equipment costs for handling at ETTP are included in the rail shipment cost estimate.)
- Energy*Solutions* IDIQ contract fees for LLW debris and soil disposal were used, for year one (FY 2012). Disposal fees were discounted by 15% when yearly shipments exceeded the 50,000 $yd^3$ per year cap, per the IDIQ.
- Volume reduction is applied to the Off-site Disposal Alternative, Option 1 (all LLW and LLW/TSCA disposed at NNSS). Per Appendix B, this includes construction and operation of a size reduction facility. Corresponding net avoided cost of Option 1 off-site disposal costs (total) in FY 2012 dollars is $80,501,000.
- For the Off-site estimate, the scope contingency was estimated at 12%, toward the higher value recommended by EPA (off-site disposal 5-15% contingency range) since the scope (e.g., disposal cost per volume of waste) used in the estimate is not adjusted for surcharges that are likely to be leveled (e.g., those for fuel, over-sized equipment disposal, water content of soils). A mid-value bid contingency of 15% is applied due to the significant risk inherent in an alternative that might be affected by external uncontrollable influences such as travel across state lines, potential for modified off-site availability, and the unusually long timeframe in which waste is expected to be generated. Therefore, a total 27% contingency is applied to the off-site alternative.
- Project Management by a Management and Operating Contractor, to oversee and coordinate the off-site packaging, shipment and disposal is assumed at 3% of the off-site transport and disposal costs.
- Present Worth calculations assume a 2% real discount rate.
- Escalation calculations assume a 2.3% escalation rate.

## 4.2 FINANCIAL BASIS OF ESTIMATE

The key components of the Off-site Disposal Alternative cost estimate are those costs associated with packaging, transportation, and treatment/disposal. Costs calculated for the Off-site Disposal Alternative estimates are situation-specific rates based on privatized cost estimates, and include an allowance for involvement of an integrating contractor. Table I-8 shows the costs used for transportation and disposal.

The transportation and treatment/disposal costs are based on assumed contractual parameters and may not represent individual shipments. The estimate includes purchase cost for intermodal containers for waste shipments to NNSS and sealand containers for waste shipments to Energy*Solutions*. Intermodal/sealand containers used for LLW would be reused as many times as possible during an assumed design life of 10 years. Intermodal containers for classified waste are considered single use. Disposal costs for Energy*Solutions* are based on Indefinite Delivery/Indefinite Quantity rates in the current contract with DOE (Energy*Solutions* 2012). All containers are assumed to require liners, which are purchased for each shipment.

Rail transportation, which is approximately 11% less expensive than truck transport, is assumed for all shipments (with the exception of classified waste shipments to NNSS). It is likely that a combination of rail and truck transport would be used.

**Table I-8. Transportation and Treatment/Disposal Costs for Off-site Disposal Alternative**

| **Transportation Costs*** | | |
|---|---|---|
| Rail from ETTP Railyard to Kingman, Arizona | $ 25,440 | Per ABC railcar<br>(8 intermodals per railcar) |
| Rail from ETTP Railyard to Clive, Utah | $ 18,500 | Per Gondola<br>(3 sealands per gondola) |
| Truck transport from Kingman, Arizona to NNSS | $1,000 | Per truckload for soil waste<br>(1 intermodal per truckload) |
| | $ 2,000 | Per truckload for debris waste<br>(2 intermodals per truckload) |
| Rail loading/unloading for truck transport and return of empty containers (Kingman, Arizona) | $ 370 | Per intermodal |
| Container purchase (classified waste shipments) | $ 6,300 | Per intermodal |
| Container purchase (sealands) | $ 8,804 | Per sealand |
| Container liner purchase | $ 545 | Per intermodal/sealand, per trip |
| Truck transport to NNSS for classified waste | $ 15,887 | Per truckload<br>(2 intermodals per truckload for classified debris waste) |
| **Treatment/Disposal Costs*** | | |
| Energy*Solutions* / WCS Vendor Quote (modified for new volume, to include packaging for WCS, de-escalated) | $ 216,740,474 | Packaging, transport, treatment, and disposal of mercury-contaminated debris<br>(149,418 $yd^3$) |
| Energy*Solutions* Disposal Fee for bulk LLW debris | $ 533.96 | Per lined gondola/railcar |
| Energy*Solutions* Disposal Fee for bulk LLW soil | $ 198.35 | Per lined gondola/railcar |
| Surcharge for sealands by railcar | $ 16.63 | Per Gondola/railcar |
| NNSS disposal access fee rate | $ 391.77 | Per $yd^3$ |

**All rates are in 2012 dollars*

## 4.3 CONTINGENCY AND RISK

For the Off-site estimate, the scope contingency was estimated at 12%, toward the higher value recommended by EPA (off-site disposal 5–15% contingency range) since the scope (e.g., disposal cost per volume of waste) used in the estimate is not adjusted for surcharges that are likely to be leveled (e.g., those for fuel, over-sized equipment disposal, water content of soils).

A mid-value bid contingency of 15% is applied due to the significant risk inherent in an alternative that might be affected by external uncontrollable influences such as travel across state lines, potential for modified off-site availability, and the unusually long timeframe in which waste is expected to be generated. Therefore, a total 27% contingency is applied to the off-site alternative.

Risks, implications to cost, and probability of occurrence associated with off-site disposal include:

| Risk | Cost Implications | Probability of Occurrence |
|---|---|---|
| • Public road travel from demolition site to rail transloading station located at ETTP | High cost | Very likely |
| • Fuel, debris size/weight, soil water content surcharges | Low to high cost | Very likely |
| • Mercury-contaminated debris that does not exhibit the hazardous characteristic must be disposed of as mixed waste, regardless | Moderate to high cost | Moderate |
| • Shutdown of off-site facilities due to violations | Very high cost | Unlikely |
| • Unavailability of facilities due to state equity issues | Very high cost | Unlikely |
| • Multi-state travel; equity issues | Moderate to very high cost | Moderate |
| • Long-term DOE liability at an off-site location | Moderate to very high cost | Unlikely |

Estimates for the two off-site disposal options are given in Tables I-9 and I-10.

## 4.4 PRESENT WORTH

The present worth calculation approach for the Off-site Disposal Alternative using a real discount rate of 2.0% is the same used for the On-site Disposal Alternative estimate as described in Section 4.2.7 of this Appendix. Present worth is given in FY 2015 dollars.

**Table I-9. Off-site Disposal Alternative Estimated Cost, Option 1 Disposal at NNSS**

| Element | Volume ($yd^3$) | Cost (FY 2012 dollars) | |
|---|---|---|---|
| | | **Destination: NNSS** | **Destination: Energy*Solutions* or WCS[1]** |
| Classified Waste – Debris | 28,489 | | NA |
| With 25% uncertainty | 35,612 | | |
| Packaging (intermodals and liners) | | $ 12,990,231 | |
| Transportation | | $ 30,149,861 | |
| Disposal Fee | | $ 15,761,969 | |
| **Subtotal** | | **$ 58,902,061** | |
| Mercury-contaminated Debris for macroencapsulation | 119,532 | NA | |
| With 25% uncertainty | 149,418 | | |
| Vendor quotes (adjusted to 149,418 $yd^3$) | | | **$ 216,740,474** |
| LLW or LLW/TSCA – Debris | 921,152 | | |
| With 25% uncertainty | 1,151,440 | | |
| Packaging (intermodals and liners) | | $ 41,023,424 | |
| Transportation (ABC rail cars/truck) | | $291,491,200 | |
| Disposal Fee | | $ 451,099,668 | |
| **Subtotal** | | **$ 783,614,291** | |
| LLW or LLW/TSCA – Soil | 485,974 | | |
| With 25% uncertainty | 607,468 | | |
| Packaging (intermodals and liners) | | $ 26,863,990 | |
| Transportation (ABC rail cars/truck) | | $ 190,881,600 | |
| Disposal Fee | | $ 237,987,742 | |
| **Subtotal** | | **$ 455,733,332** | |
| Project Management and Oversight | | $ 37,874,754 | |
| **SUBTOTAL (FY 2012 $)**<br>• LLW and LLW/TSCA debris and soil, classified debris to NNSS for disposal<br>• Mixed debris to Energy*Solutions*/WCS for treatment/disposal | | **$ 1,553,914,913** | |
| Subtract the net cost avoided by implementing volume reduction for Option 1 only (see Appendix B) | | **– $ 80,501,000** | |
| Revised SUBTOTAL (FY 2012 $) | | **$ 1,473,413,913** | |
| CONTINGENCY (12% Scope, 15% Bid) 27% | | **$ 397,821,756** | |
| TOTAL with CONTINGENCY | | **$ 1,871,235,669** | |
| ESCALATED COST with CONTINGENCY (FY 2022 – FY 2043) | | **$ 3,122,038,955** | |
| PRESENT WORTH with CONTINGENCY (FY 2015) | | **$ 2,119,688,651** | |

[1] WCS destination only for mixed, mercury-contaminated debris.

**Table I-10. Off-site Disposal Alternative Estimated Cost, Option 2 Disposal at Energy*Solutions***

| Element | Volume ($yd^3$) | Cost (FY 2012 dollars) | |
|---|---|---|---|
| | | **Destination: NNSS** | **Destination: Energy*Solutions* or WCS[1]** |
| Classified Waste – Debris | 28,489 | | NA |
| With 25% uncertainty | 35,612 | | |
| Packaging (intermodals and liners) | | $ 12,990,231 | |
| Transportation | | $ 30,149,861 | |
| Disposal Fee | | $ 15,761,969 | |
| **Subtotal** | | **$ 58,902,061** | |
| Mercury-contaminated Debris for macroencapsulation | 119,532 | NA | |
| With 25% uncertainty | 149,418 | | |
| Vendor quotes (adjusted to 149,418 $yd^3$) | | | **$ 216,740,474** |
| LLW or LLW/TSCA – Debris | 921,152 | | |
| With 25% uncertainty | 1,151,440 | | |
| Packaging (sealands and liners) | | | $ 20,557,328 |
| Transportation (Gondola) | | | $ 186,824,215 |
| Disposal Fee | | | $ 584,008,511 |
| **Subtotal** | | | **$ 791,390,054** |
| LLW or LLW/TSCA – Soil | 485,974 | | |
| With 25% uncertainty | 607,468 | | |
| Packaging (sealands and liners) | | | $ 15,484,253 |
| Transportation (Gondola) | | | $ 140,720,300 |
| Disposal Fee | | | $ 80,630,607 |
| **Subtotal** | | | **$ 236,835,160** |
| Project Management and Oversight | | $ 33,646,694 | |
| **SUBTOTAL (FY 2012)**<br>• Classified debris to NNSS for disposal<br>• Mixed debris to Energy*Solutions*/WCS for treatment/disposal<br>• LLW and LLW/TSCA debris and soil to Energy*Solutions* for disposal | | **$ 1,337,514,442** | |
| CONTINGENCY (12% Scope, 15% Bid) 27% | | **$ 267,502,888** | |
| TOTAL with CONTINGENCY | | **$ 1,605,017,331** | |
| ESCALATED COST with CONTINGENCY (FY 2022 – FY 2043) | | **$ 2,793,560,511** | |
| PRESENT WORTH with CONTINGENCY (FY 2015) | | **$ 1,920,534,551** | |

[1] WCS destination only for mixed, mercury-contaminated debris.

# 5. REFERENCES


Energy*Solutions* 2012. IDIQ contract no. DE-EM0002406.

EPA 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA-540-4-00-002, July 2000.

Means 2012, R. S. Means CostWorks 2012 Software, Version 15.16.1.

OMB 2012. Memorandum for the Heads of Departments and Agencies from Jacob J. Lew, OMB Director, 2012 Discount Rates for OMB Circular No. A-94, January 3, 2012.

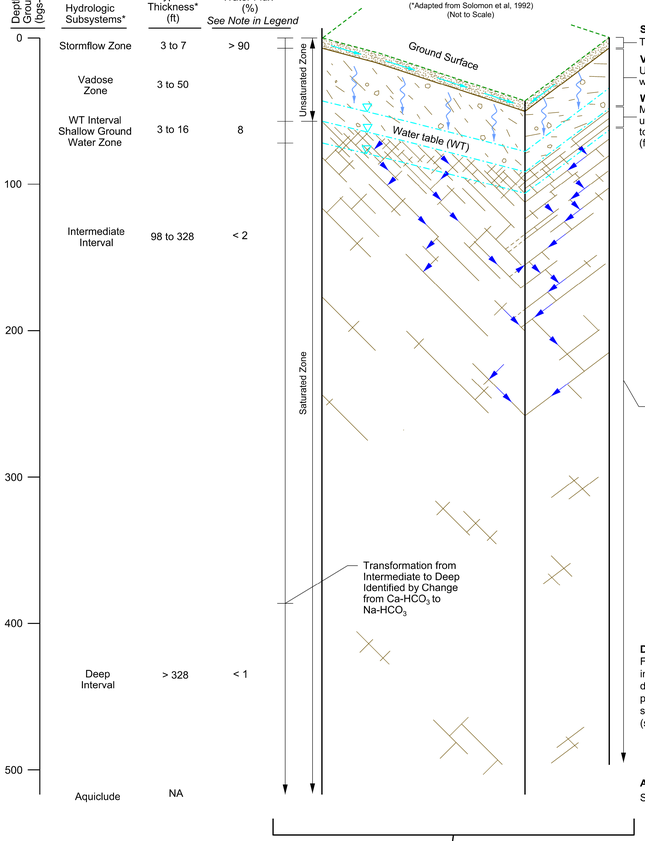
P2S 2015. *D3 RI/FS Basis of Estimate for CERCLA ORR Additional Waste Disposal, On-site Alternative, East Bear Creek Valley Option*, Professional Project Services, March 2015.

NNSA 2008. Memorandum from the National Nuclear Security Administration, *Request for Fiscal Year 2009 Preliminary Mixed and Low-Level Radioactive Waste Forecasts and Transmittal of the NNSA-Nevada Site Office Program Management Strategy for Disposal Operations*, July 15, 2008.

UCOR 2015. Focused Feasibility Study for Water Management from the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee, DOE/OR/01-2664&D0, February 2015.

| Depth Below Ground Surface (log-ft) | Hydrologic Subsystems* | Typical Thickness* (ft) | Estimated Water Flux* (%) See Note in Legend |
|---|---|---|---|
| 0 | Stormflow Zone | 3 to 7 | > 90 |
| | Vadose Zone | 3 to 50 | |
| | WT Interval Shallow Ground Water Zone | 3 to 16 | 8 |
| 100 | Intermediate Interval | 98 to 328 | < 2 |
| 200 | | | |
| 300 | | | |
| 400 | Deep Interval | > 328 | < 1 |
| 500 | Aquiclude | NA | |

Subsurface Profile
(*Adapted from Solomon et al, 1992)
(Not to Scale)



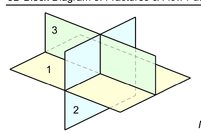

Descriptions of Subsurface Hydrologic Framework Zones/Intervals
(Adapted from Solomon et al, 1992)

**Stormflow Zone:**
Thin topsoil/root zone; typically <1 ft thick; high permeability; discharge to NT stream channels

**Vadose Zone:**
Upper mostly clayey residuum; typically 2-10 ft thick; transitions downward to highly weathered & fractured bedrock (saprolite) mostly weathered shale; water flow is mostly vertical along preferential pathways to water table; recharges ground water (GW) zone in pulses

**Water Table (WT) Interval:**
Most GW transmitted through closely spaced, connected fractures near the WT and near top of weathered bedrock (saprolite); flow from upland recharge areas downgradient to discharge areas along NT valleys; base of WT interval occurs near the transition zone from regolith to bedrock; overall GW flow paths mimic surface topography with dominant strike parallel flow toward NT tributaries
(fracture apertures widened)

3D Block Diagram of Fractures & Flow Paths



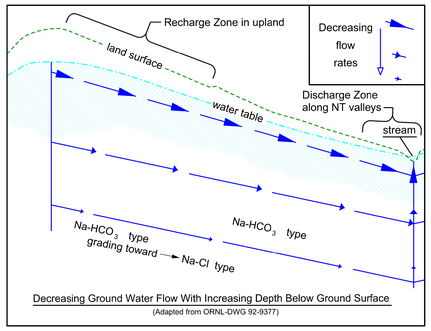

3 or more fracture sets are common[1]:
1) Parallel to bedding planes (dominant)
2) Parallel to strike
3) Perpendicular to strike
([1]Additional joints and shear fractures may be superimposed on this basic set of 3 fractures)

*Note: Fracture sets are associated with water table, intermediate, and deep intervals of saturated zone*

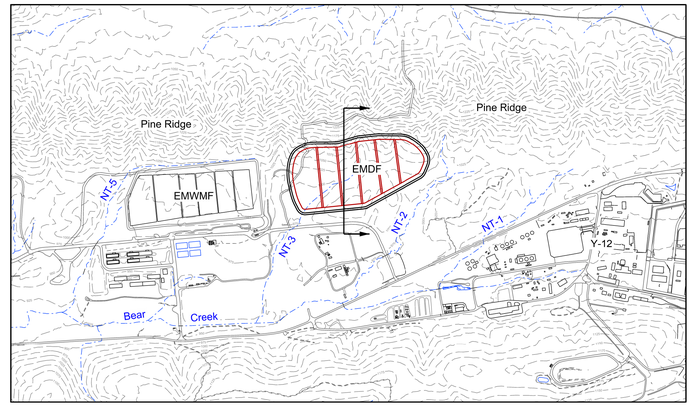
**Intermediate Interval:**
In less weathered to unweathered bedrock; fracture sets control GW flow paths and directions; GW movement primarily in permeable fractures poorly connected in 3D; permeability may be increased by weathering and generally diminishes with depth; slower migration rates from deeper upland areas to lower NT discharge areas (relative to WT interval); upward vertical gradients may occur within discharge zones along NT valleys; preferential GW movement along strike toward cross cutting NT-2/NT-3 tributaries
(narrowing fracture apertures)

**Deep Interval:**
Fewer connected fractures, shorter in length and with greater spacing; diminished flow rates and very low permeability; fracture orientations similar to Intermediate Interval (small aperture fractures)

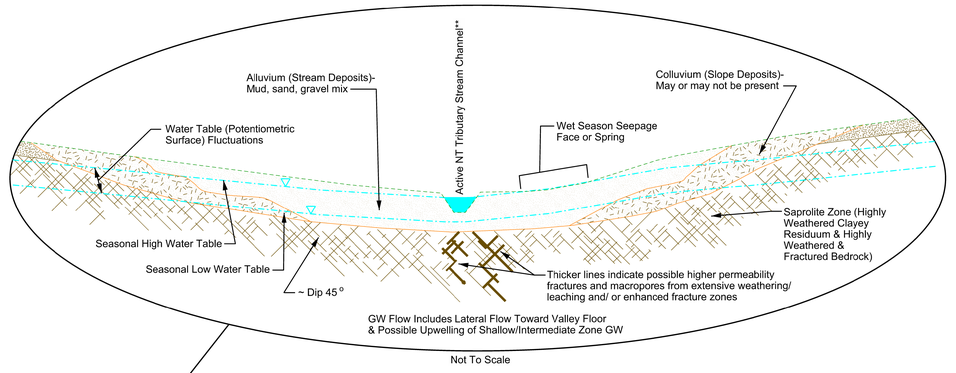
**Aquiclude:**
Saline water with very high TDS (2,000 - 275,000 mg/L)




Decreasing Ground Water Flow With Increasing Depth Below Ground Surface
(Adapted from ORNL-DWG 92-9377)




Section Cut Location Map
Not To Scale




Not To Scale

** Stream Channels Flow Continuously in Wet Season (Typically Winter/Early Spring Non-growing Season)
Channels Dry During Low/No Flow Season (Typically Summer/Early Fall Growing Season)

NO VERTICAL EXAGGERATION



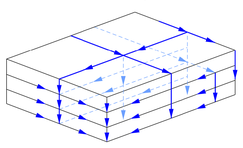

€rs

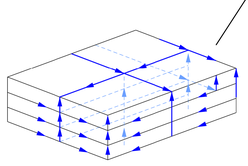
€pv

€rt

€rg

€m





3 or more fracture sets are common:
1) Predominant strike parallel flow along bedding planes (BP) toward discharge zones along NT valleys
2) Secondary flow paths along fractures perpendicular to BPs but parallel and perpendicular to strike
3) Tertiary fractures at other angles relative to BPs and orthogonal sets (not shown)

Legend:
- Final Grades
- Top of Waste
- Top of Liner
- Bottom of Liner
- Bottom of Geo Buffer
- Existing Grade
- Estimated High Water
- Geologic Formation Contact
- Blanket Drain in Underdrain
- Trench Drain in Underdrain
- French Drain (Upgradient)

Note:
Water balance modeling by R.B. Clapp (1997) indicates the following percentages of total annual runoff for the ORR aquitards:

Overland flow 6.2%
Subsurface stormflow 46.6.%
Groundwater discharge 47.2%

These results suggest that the % flux at the water table interval may be higher and the stormflow zone % flux may be lower than that presented by Solomon et al, 1992. The Clapp modeling also suggests that annual ground water recharge rates range from 2 to 10 inches with a most likely average near 8 inches.

Geologic Formations:
- €rs - Rome Formation Sandstone Member
- €pv - Pumpkin Valley Shale
- €rt - Rutledge Formation
- €rg - Rogersville Shale
- €m - Maryville Formation

Scale in Feet:
0' 20' 40' 80' 120'
1" = 40' on ANSI E Page (44"x34")

Pro2Serve

Plate 1
Site Conceptual Model With Details

| FILE: | Plate-1-EMDF-DQO-SECT-7-Features.dgn | |
|---|---|---|
| PROJ: | 7206-800 | DATE: 03/24/2015 |

## GW-968 (Intermediate Well)

TOC Elev = 1082.56
Stickup = 12.35 ft
Estimated Original G.S. = 1077.39'
Max = 1077.33'
Min = 1072.29'
GS = 1070.21'
Auger Refusal at 10 ft (Top of Bedrock)
(0.020)
(0.022) YSI
Packer Test Average k = 3.1x10$^{-4}$ cm/sec
(0.00)
(0.015)
(0.019) Troll
(0.00)
(0.00)
(0.018)
(0.00)
(0.016)
(0.00)
Sump
End Cap @ 92.6 ft
TD = 100 ft

## GW-969 (Shallow Well)

TOC Elev = 1082.98
Stickup = 12.53 ft
Estimated Original G.S. = 1075.25'
Max = 1074.48'
Min = 1070.15'
GS = 1070.45'
Shelby Tube Sample k = 3.89x10$^{-7}$ cm/sec
Slug Test Results k = 7.65x10$^{-7}$ cm/sec
YSI & Troll
Auger Refusal at 13.5 ft (Top of Bedrock)
BOH = 13.5

## GW-970 (Intermediate Well)

Max = 1035.70'
Min = 1028.72'
GS = 1040.93'
Auger Refusal at 25.6 ft (Top of Bedrock)
YSI
Flow = 89.7 gpd (0.062)
Flow = 56.2 gpd (0.039)
Troll
Flow = 44.9 gpd (0.031)
(0.017)
(0.00)
(0.00)
Packer Test Average k = 1.5x10$^{-4}$ cm/sec
Packer Test Average k = 3.1x10$^{-4}$ cm/sec
Packer Test Average k = 1.4x10$^{-3}$ cm/sec
8" Open Borehole
Total Well Depth = 97.4 ft
TD = 101 ft
Zones with Increase in 8" Borehole Diameter to ~8.8" - 10"

## GW-971 (Shallow Well)

Max = 1036.26'
Min = 1027.90'
GS = 1040.69'
Shelby Tube Sample k = 6.36x10$^{-7}$ cm/sec
Slug Test Results k = 1.22x10$^{-7}$ cm/sec
YSI & Troll
Auger Refusal at 23.8 ft (Top of Bedrock)

## GW-972 (Intermediate Well)

Max = 1021.85'
Min = 1016.19'
GS = 1023.55'
Auger Refusal at 24.2 ft (Top of Bedrock)
(0.00)
YSI
42
45 Troll
(0.00)
(0.00)
(0.00)
(0.00)
(0.026)
(0.00)
No / Limited Flow 'k' Indeterminate
No / Limited Flow 'k' Indeterminate
8" Open Borehole
Total Well = 99.6 ft
TD = 101.0 ft
Dip in Degrees
Zones with Increase in 8" Borehole Diameter to ~8.8" - 10"

## GW-973 (Shallow Well)

Max = 1021.89'
Min = 1016.11'
GS = 1024.46'
Shelby Tube Sample k = 3.53x10$^{-6}$ cm/sec
Slug Test Results k = 1.46x10$^{-6}$ cm/sec
YSI & Troll
Auger Refusal at 23.0 ft (Top of Bedrock)

## GW-974 (Intermediate Well)

Max = 1000.95'
Min = 996.93'
GS = 1002.80'
8" Casing Grouted Inside 10" Casing
Auger Refusal at 12.5 ft (Top of Bedrock)
YSI
Troll
(0.00)
(0.016)
No / Limited Flow 'k' Indeterminate
(0.00)
(0.00)
(0.00)
(0.00)
8" Open Borehole
Total Well Depth = 97.9 ft
TD = 101 ft

## GW-975 (Shallow Well)

Max = 999.72'
Min = 995.49'
GS = 1002.52'
Slug Test Results k = 3.43x10$^{-7}$ cm/sec
Shelby Tube Sample k = 6.54x10$^{-6}$ cm/sec
YSI & Troll
Auger Refusal at 10.0 ft (Top of Bedrock)

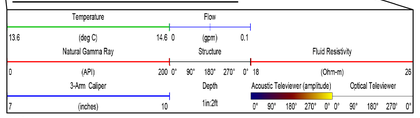
## GW-976 (Intermediate Well)

Max = 1027.56'
Min = 1022.17'
GS = 1065.84'
Auger Refusal at 24.4 ft (Top of Bedrock)
YSI
(0.00)
(0.00)
(0.00)
(0.00)
(0.00)
(0.00)
(0.00)
Troll
Flow = 48.6 gpd (0.034)
(0.022)
(0.00)
(0.00)
Packer Test Average k = 5.6x10$^{-5}$ cm/sec
Packer Test Average k = 1.2x10$^{-3}$ cm/sec
8" Open Borehole
Total Well Depth = 100.3 ft
TD = 101 ft
Dip in Degrees
Zones with Increase in 8" Borehole Diameter to ~8.8" - 10"

## GW-977 (Shallow Well)

GS = 1065.63'
Shelby Tube Sample k = 5.03x10$^{-5}$ cm/sec
No Water Measured (Dry)
Auger Refusal at 25.1 ft (Top of Bedrock)

## Geophysical Log Legend:




Notes:
1. Structure Log Interpretations- All structures in orange, red, and purple are possible fractures.
   - Major Open Fracture / Joint
   - Minor Open Fracture / Joint
   - Partially Open Fracture / Joint
   - Bedding / Band / Foliation
   - Filled Fracture / Joint
2. Heat pulse flowmeter results are in gallons per minute (gpm).
3. See full scale borehole geophysical logs for details.
4. Yellow highlighting in first column indicates zones where the 8" borehole diameter increases to ~ 8.8" to 10".

## Notes:

1. ***(0.018)*** Heat pulse flowmeter (HPF) results in bold parentheses are shown in gpm except where flow rates exceed the minimum quantifiable flow rate of 0.03 gpm (43 gpd) where flow rates are shown in gpd and gpm. Results with the ✱ symbol indicate locations with quantifiable flow. All HPF results indicated upward flow directions.
2. The maximum and minimum water level data on logs were collected between November 21, 2014 and February 26, 2015.

## Abbreviations:

| | |
|---|---|
| BOH | Bottom of Hole |
| TD | Total Depth |
| TOC | Top of Casing |
| gpd | Gallons Per Day |
| gpm | Gallons Per Minute |
| HPF | Heat Pulse Flowmeter |

## Well Legend:

- Isolation Casing
- Protective Casing
- Bentonite Seal
- Cement / Bentonite Grout
- Sandpack
- Screen
- Open Borehole
- Open Hole Collapse
- YSI Sonde
- Troll Sonde
- (0.034) ✱ HPF Indicates Flow
- (0.00) — HPF Indicates No Flow Or Flow Less Than 0.030

## Lithology Legend:

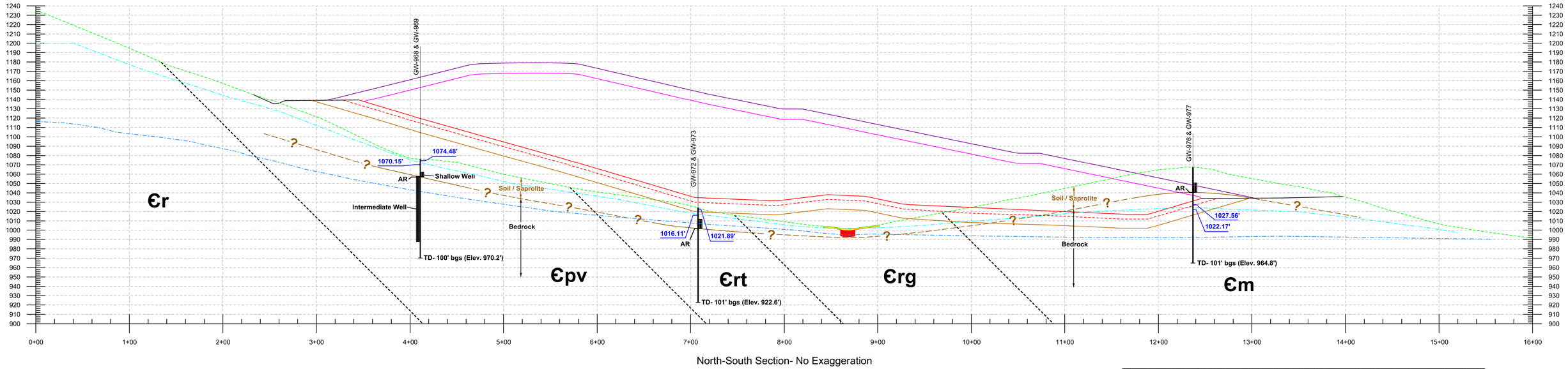
- Gravel
- Gravelly Sand
- Silty Sand / Sandy Silt
- Silt / Clayey Silt
- Siltstone
- Shale
- Saprolite
- Interbedded, Laminated-Thin Bedded Shale and Siltstone
- Interbedded, Mostly Laminated Shale and Calcareous Siltstone / Limestone
- Interbedded, Mostly Laminated Limestone and Shale
- Limestone
- No Data or Lost Core (Shallow)
- No Data or Lost Core (Bedrock)
- Possible Flow Zone? (Based on Cores)

0' 2' 4' 8' 12'
SCALE: 1 INCH= 4 FEET
(On 44"x34" Page)

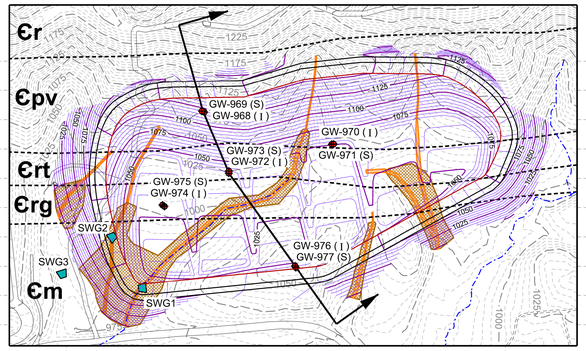
Pro2Serve

# Plate 2:
# Phase 1 Composite Boring, Borehole Geophysical, and Well Construction Logs

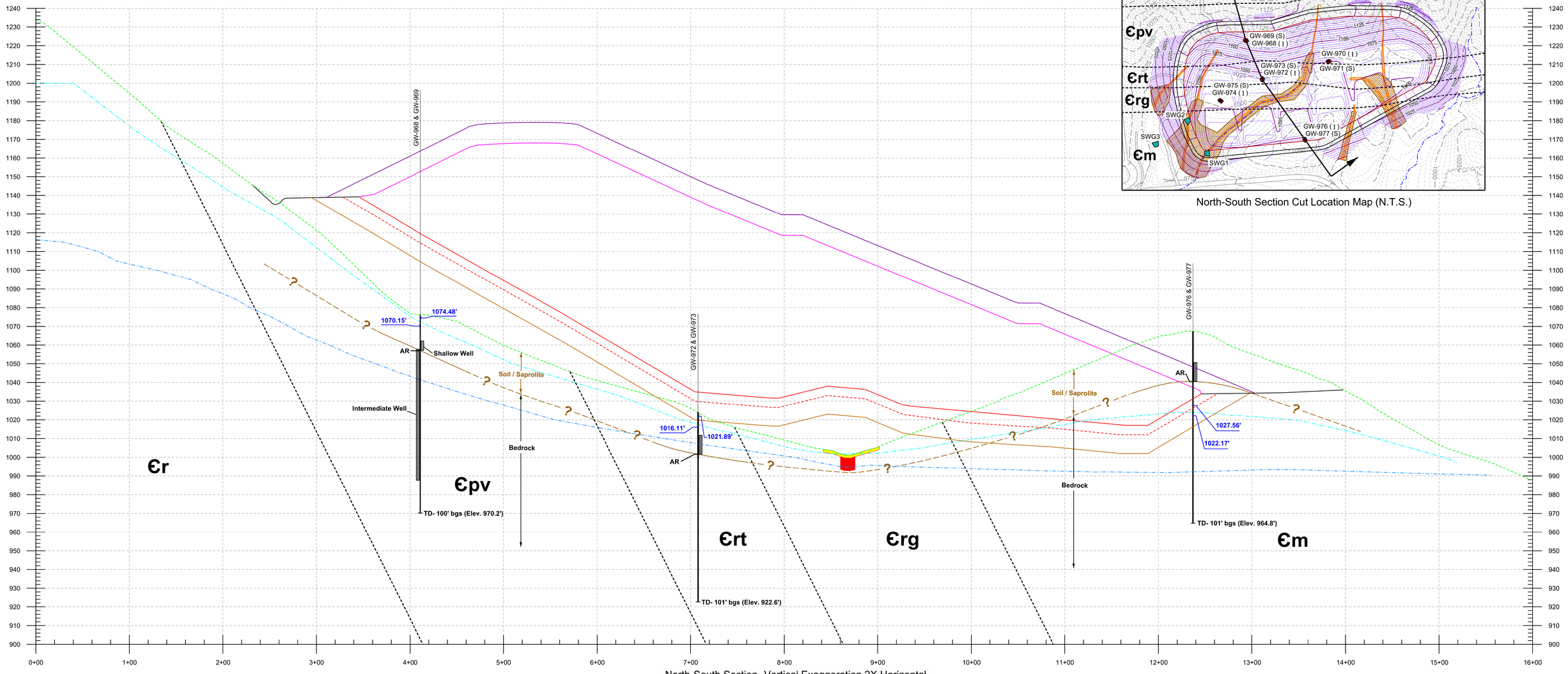
FILE: PLATE-EMDF-P1-Well-Log-Information.dgn
PROJ: 7206-800
DATE: 03/24/2015




North-South Section- No Exaggeration




North-South Section Cut Location Map (N.T.S.)




North-South Section- Vertical Exaggeration 2X Horizontal

Legend:

- Existing Grade
- Water Table [Potentiometric Surface for Water Table Interval on 12/25/2014]
- Model Predicted Water Table [Post Construction, Steady-State Ground Water Flow Conditions]
- Top of Cap
- Top of Waste
- Top of Liner
- Bottom of Liner
- Geologic Buffer Bottom
- Proposed Grade
- Geologic Formation Contact
- Blanket Drain
- Trench Drain
- Landfill Underdrain System
- Screened Interval of Shallow Well (Except GW-968/969)
- Auger Refusal (AR) In Shallow Well (Solid Where Known, Dashed with ? Where Inferred)

Geologic Formations:

- Crs - Rome Formation Sandstone Member
- Cpv - Pumpkin Valley Shale
- Crt - Rutledge Formation
- Crg - Rogersville Shale
- Cm - Maryville Formation

Notes:

1. A combination of both the shallow and intermediate well logs are shown on the section cuts. Except for GW-968, water levels and screens are for the shallow wells. Depth of well is for the intermediate wells.
2. Geologic formation contact is shown at 45 degrees to southeast, but varies depending on where section cut aligns with contact in plan view.
3. Total depth (TD) shown on sections is for the deeper cluster well in the intermediate ground water interval.
4. Ground surface at well clusters on the sections is for the surveyed ground surface elevation at the deeper cluster well. Existing topography is from OREIS.
5. Except for GW-976, maximum and minimum water level elevations based on continuous hourly monitoring from 11/21/2014 through 2/26/2015 in shallow wells.
6. See Plate 2 for detailed well profiles.

0' 20' 40' 80' 120'
Horizontal Scale: 1 Inch = 40 Feet

0' 10' 20' 40' 60'
Exaggerated Vertical Scale: 1 Inch = 20 Feet
(On 44"x34" Page)

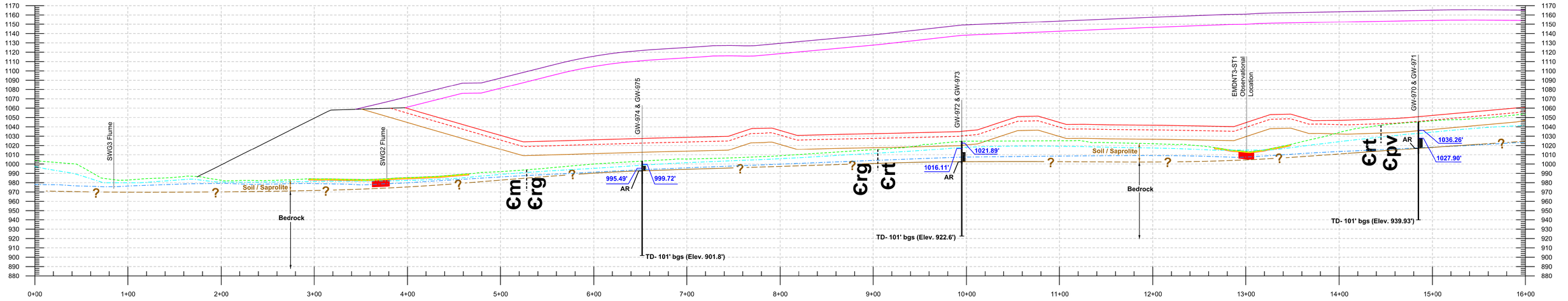
Pro2Serve

# Plate 3:
# North-South Cross Section Through Phase 1 Well Clusters

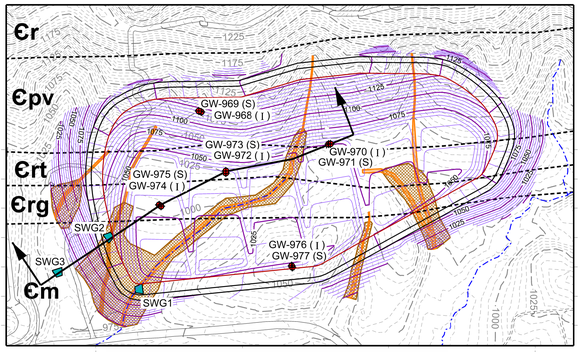
FILE: Plate-EMDF-P1-SC-Sections-NS.dgn

PROJ: 7206-800

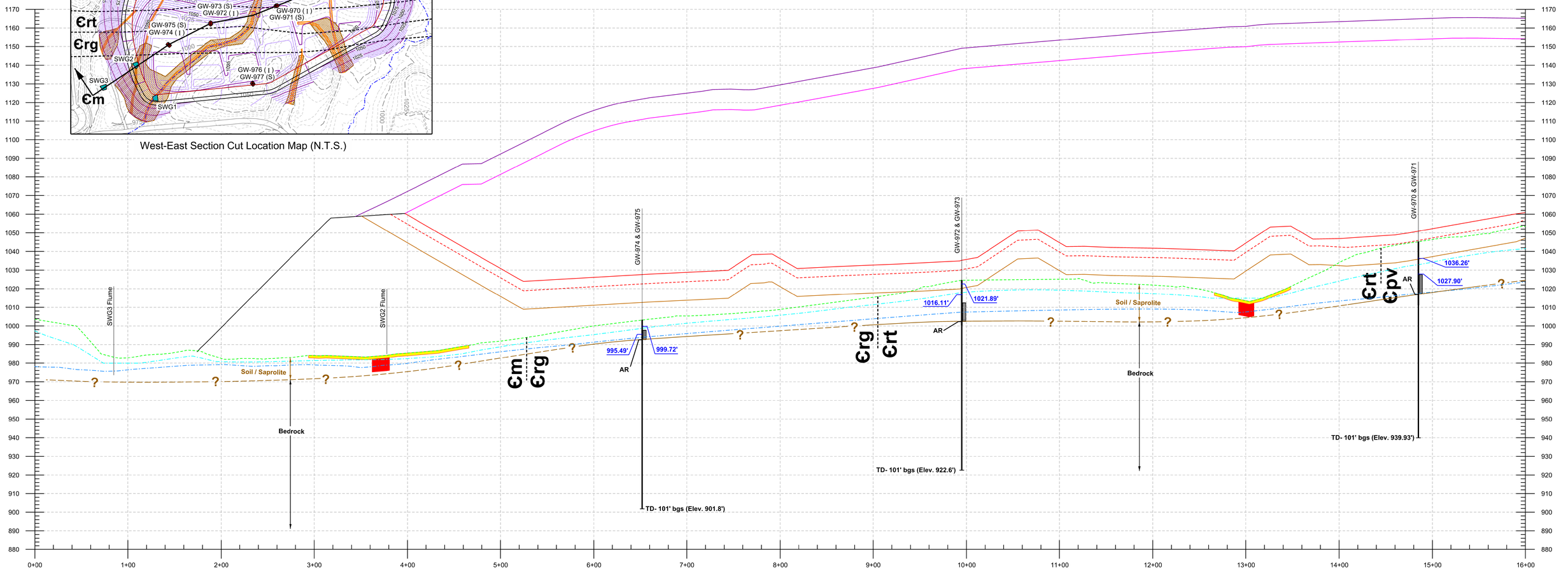
DATE: 03/24/2015




West-East Section Cut- No Exaggeration




West-East Section Cut Location Map (N.T.S.)




East-West Section Cut- Vertical Exaggerated Two Times Horizontal

## Legend:

- Existing Grade
- Water Table [Potentiometric Surface for Water Table Interval on 12/25/2014]
- Model Predicted Water Table [Post Construction, Steady-State Ground Water Flow Conditions]
- Top of Cap
- Top of Waste
- Top of Liner
- Bottom of Liner
- Geologic Buffer Bottom
- Proposed Grade
- Geologic Formation Contact
- Blanket Drain (Landfill Underdrain System)
- Trench Drain (Landfill Underdrain System)
- Screened Interval of Shallow Well (Except GW-968/969)
- Auger Refusal (AR) In Shallow Well (Solid Where Known, Dashed with ? Where Inferred)

## Geologic Formations:

- €rs - Rome Formation Sandstone Member
- €pv - Pumpkin Valley Shale
- €rt - Rutledge Formation
- €rg - Rogersville Shale
- €m - Maryville Formation

## Notes:

1. A combination of both the shallow and intermediate well logs are shown on the section cuts. Except for GW-968, water levels and screens are for the shallow wells. Depth of well is for the intermediate wells.
2. Geologic formation contact is shown at 45 degrees to southeast, but varies depending on where section cut aligns with contact in plan view.
3. Total depth (TD) shown on sections is for the deeper cluster well in the intermediate ground water interval.
4. Ground surface at well clusters on the sections is for the surveyed ground surface elevation at the deeper cluster well. Existing topography is from OREIS.
5. Except for GW-976, maximum and minimum water level elevations based on continuous hourly monitoring from 11/21/2014 through 2/26/2015 in shallow wells.
6. See Plate 2 for detailed well profiles.

0' 20' 40' 80' 120'
Horizontal Scale: 1 Inch = 40 Feet

0' 10' 20' 40' 60'
Exaggerated Vertical Scale: 1 Inch = 20 Feet
(On 44"x34" Page)

Pro2Serve

# Plate 4:
# East-West Cross Section Through Phase 1 Well Clusters

FILE: Plate-EMDF-P1-SC-Sections-EW.dgn

PROJ: 7206-800

DATE: 03/24/2015