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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:

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CONTENTS

FIGURES

TABLES

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
BHHRA	Baseline Human Health Risk Assessment
BMP	best management practice
BNSF	Burlington Northern Santa Fe
BV	Bethel Valley
BY/BY	Boneyard/Burnyard
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
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
LDR	land disposal restrictions
LCRS	leachate collection and removal system
LDRS	leak detection and removal system
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	low-level waste
LMD	legacy material disposition
M	Million
MCC	Modular Concrete Canister
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
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
PWAC	preliminary waste acceptance criteria
PWTC	Process Waste Treatment Complex
RA	Reference Area
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act of 1976
RDR	Remedial Design Report
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
S&M	surveillance and maintenance
SPCC	safety and spill prevention, control, and countermeasures

TBC	to be considered
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 Specialist
WGF	waste generation forecast
WL	waste lot
WMI	Waste Management, Inc.
WWSY	White Wing Scrap Yard
Y-12	Y-12 National Security Complex

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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 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 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 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 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:

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 remain the same as those used for the evaluation that led to construction and operation of the EMWMF (DOE 1998):

- Prevent exposure to future-generated CERCLA waste that exceeds a human health risk of 1×10^{-5} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.
- Prevent ecological exposure to future-generated CERCLA waste.
- Prevent releases of future-generated CERCLA waste or waste constituents that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or that do not meet applicable and relevant and appropriate requirements (ARARs) for environmental media.
- 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 (2.18M yd^3) is estimated to be reached in FY 2023. Based on these estimates, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2023[1]. 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. A higher funding scenario could result in EMWMF reaching capacity sooner.

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 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, and volume reduction efforts. The conceptual

[1] For purposes of the RI/FS evaluation, operational start-up of a new facility is assumed to begin when EMWMF capacity is reached. However, in order to continue compliant disposal of CERCLA waste materials on the ORR, the operational start-up of a new disposal facility would actually be planned prior to the EMWMF reaching maximum capacity if the On-site Disposal Alternative is selected.

design capacity of the proposed EMDF site for the On-site Disposal Alternative is 2.5M yd^3, which includes a 25% uncertainty allowance.

The as-generated waste volume estimate used in the RI/FS for FY 2023 through FY 2043 (post-EMWMF) is approximately 2.04M yd^3, including a 25% uncertainty allowance. Approximately 75% of the 2.04M yd^3 is debris. This estimate is used as the basis for analyzing waste shipments in the Off-site Disposal Alternative.

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 the EMWMF. This methodology relies on the assumption that available data for waste disposed at the EMWMF approximately represent the waste characteristics of future waste streams. 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. Chemical contaminants contribute relatively minimal transportation and natural phenomenon risk; consequently, waste characterization information in the RI/FS for chemical contaminants is limited to a discussion of the anticipated chemical constituents.

REMEDIAL ALTERNATIVES

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

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 in design to the 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 the EMDF near the existing EMWMF was identified utilizing a screening evaluation that included some of the sites identified in a previous 1996 siting study (DOE 1996) as well as other possible favorable locations.

By design, the WAC of a new facility would ensure risk to future receptors would not exceed risk criteria (1×10^{-5} ELCR or an HI of 1 in the first 1,000 years). This RI/FS provides results of fate and transport analysis which demonstrate that preliminary waste acceptance criteria (PWAC) 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 PWAC 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.

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 of sharing existing EMWMF infrastructure and being in close proximity to existing utilities.

The estimated total project cost for implementing the On-site Disposal Alternative at the proposed EMDF site is $817M (2012 dollars) or $547M (present worth) with contingency.

Under the Off-site Disposal Alternative, future CERCLA waste would be transported off-site for disposal in approved disposal facilities, primarily by rail transport. All waste would be shipped in intermodal containers. Representative routes were assumed for the cost estimate and risk evaluation. Approximately 96% of the waste (non-classified LLW and LLW/TSCA waste) would be shipped to the Nevada National Security Site (NNSS) in Nye County, NV by rail transport from the East Tennessee Technology Park (ETTP) to a transfer facility in Kingman, AZ. 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 the disposal facility at Energy*Solutions*, Clive, UT. Classified LLW waste would be shipped by truck to NNSS.

The estimated total project cost for implementing the Off-site Disposal Alternative is $2.356 Billion (B) (2012 dollars) or $1.556B (present worth) with contingency.

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 these generator responsibility elements are not included in the cost estimates because they are not a differentiator between the On-site and Off-site Disposal Alternatives.

VOLUME REDUCTION

Volume reduction (VR) approaches and potential benefits for the On-site and Off-site Disposal Alternatives are evaluated in this RI/FS. For the On-site Disposal Alternative, VR processing could reduce capacity needs by up to two disposal cells (over 800,000 yd^3 of disposal capacity) and result in estimated cost savings of up to $65M in 2012 dollars. For the Off-site Disposal Alternative, VR processing could result in an avoided shipping volume of over 300,000 yd^3 and estimated cost savings of up to $251M in 2012 dollars. The RI/FS provides a comparison between unit costs ($/$yd^3$ as-generated material) for on-site and off-site disposal with and without VR processing. In almost all cases, off-site disposal costs are significantly higher than on-site disposal.

Incorporating VR efforts in project planning and practical field implementation could result in significant cost savings and reduced need for disposal capacity. The largest cost savings and capacity gain could be achieved with deployment of size reduction equipment on a multiple project or programmatic basis; however, uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement this approach. The EMDF conceptual design allows the ability to construct the landfill in phases such that cells could be built as needed.

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, a waiver of two hydrologic condition ARARs would be requested on the basis of equivalent protectiveness provided by the landfill design, and a waiver for a water discharge criteria ARAR 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. 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 approximately the same for both alternatives. Off-site transportation carries a much higher risk due to the public roads and railroads travelled and the long distances involved. 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 (the majority of shipments evaluated in the Off-site Disposal Alternative are by rail).

For the Off-site Disposal Alternative, modeling of radiation exposure during routine and accident scenarios resulted in an estimated total cancer risk (fatal and non-fatal) for maximum exposed individuals that ranged from 9.90×10^{-4} to 6.52×10^{-2}. The collective population risk, which analyzed drivers, persons along or near the route, and handlers, resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 1.44×10^{-4} to 2.80×10^{-1}. In comparison, risk to the same population groups for the On-site Disposal Alternative ranged from 2 to thousands of times lower. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 22.7 total incidents of illness, trauma, or death for the Off-site Disposal Alternative, and less than one for the On-site Disposal

Alternative. 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 the estimated vehicular risk range in order of magnitude from 10^{-13} to 10^{-5}.

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 likely to continue for 30 more years, 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 projected cost for the Off-site Disposal Alternative ($2.356B [2012 dollars] or $1.556B [present worth]) is approximately 2.9 times the estimated cost of the On-site Disposal Alternative ($817M [2012 dollars] or $547M [present worth]).

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, TN 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; the Oak Ridge National Laboratory (ORNL); and the 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 the ETTP was uranium enrichment, which has been completed, and the facilities and site are undergoing deactivation and decommissioning (D&D)[2] 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.

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

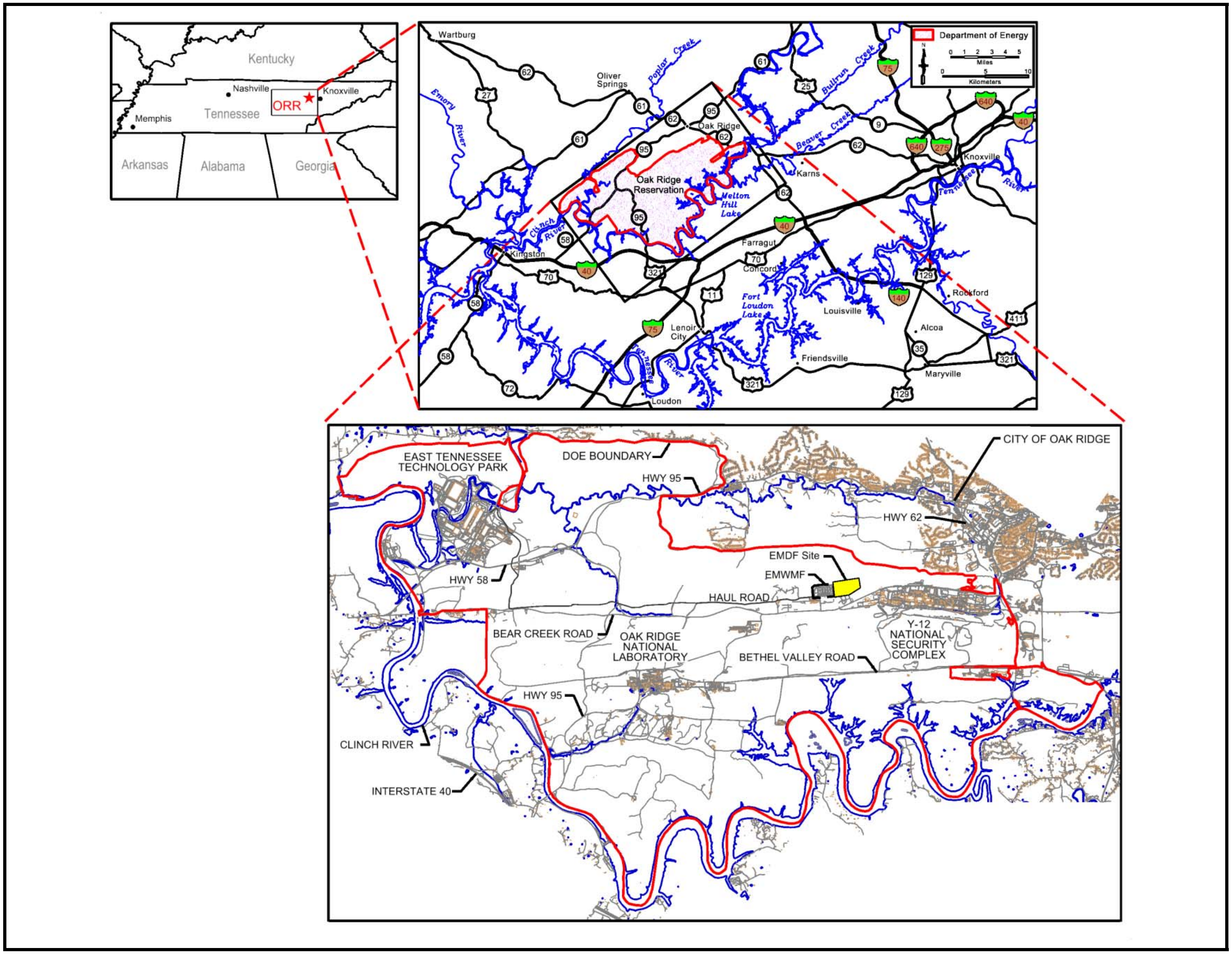

Figure 1-1. Oak Ridge Reservation, EMWMF, and Proposed EMDF Site Locations

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, the EMWMF, has been constructed and is accepting CERCLA cleanup wastes. The capacity of the 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 the 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 significantly increase the volume of CERCLA waste projected to be generated. Current waste volume estimates detailed within this RI/FS are approximately three times higher than the largest estimates made during the EMWMF RI/FS development.

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 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
- 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 screening evaluation of other considered sites. The WBCV and WWSY sites were considered along with other candidate sites, but were eliminated from further evaluation as discussed in Appendix C.

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	*Evaluation of Baseline Risk*
4	*Remedial Action Objectives*
5	*Technology Screening and Alternatives Assembly*
6	*Alternatives Description*
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 Disposal Alternative Site Description*
D	*Alternatives Risk Assessment and Fugitive Emissions Modeling*
E	*Applicable or Relevant and Appropriate Requirements (ARARs)*
F	*On-site Disposal Facility Preliminary Waste Acceptance Criteria*
G	*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 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, *Evaluation of Baseline Risk* 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.

The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are specified in Chapter 4 and remain the same as those established in the EMWMF RI/FS.

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 G 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 provides applicable information about the region, updated as appropriate, and the proposed EMDF site. The EMWMF RI/FS is a reference for additional information about the regional environmental setting.

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

Appendix E 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 WAC was later updated and approved in the WAC Attainment Plan (DOE 2001b). Appendix F of this RI/FS, *On-site Disposal Facility Preliminary Waste Acceptance Criteria*, provides preliminary waste acceptance criteria (PWAC) 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 G provides summary cost estimate information and supporting assumptions for the On-site and Off-site Disposal Alternatives.

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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[3] (WGFs)
- 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 the same approach taken in the Fiscal Year (FY) 2013 PCCR. Uncertainty is added as a percentage (increase only, to be conservative) to the annual predicted volumes. Uncertainty/ sensitivity is not applied to characterization since characterization used in this RI/FS serves mainly to identify risk for on-site versus off-site alternatives (refer to Table 2-1), and that comparison may be made using a single data set; looking at variability in that data set would not alter the comparison conclusions. The volume and characterization estimate processes are outlined below.

<u>Waste Volume Estimates</u>

The RI/FS waste volume estimates of future CERCLA waste were developed based on an individual project basis, as reported in WGF 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 (May 2013). This sequencing has resulted in a slightly different annual waste volume profile from that reported in the FY 2013 PCCR. Additionally, some project volumes were adjusted based on known uncertainties (e.g., Zone 2 soils at ETTP were adjusted from those in the WGF) which resulted in a slightly higher total forecasted waste volume than is reported in the FY 2013 PCCR (~8% higher).

[3] WGF download May 2013.

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 the EMWMF. This source term is used in the transportation and natural disaster risk analysis. As mentioned, no uncertainty is applied to these data.

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

Wastes generated on the ORR that are excluded from consideration in the RI/FS because they are not acceptable from a WAC standpoint or because disposition will be addressed by other established programs or by projects generating the waste 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 that is not land disposal restriction (LDR)-compliant or that contains a listed waste 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.
- Transuranic (TRU) waste is excluded because it will be treated on-site at the TRU Waste Processing Center for disposal at the Waste Isolation Pilot Plant.
- 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 Cost Estimate**	**Chapter 6 Appendix G**	Disposal capacity for new disposal facility (Based on "as-disposed" waste volume estimate)	
	Schedule	**Chapter 2 Appendix G**	When maximum EMWMF capacity is reached and operation of new disposal facility begins (Based on "as-disposed" waste volume estimate) When capacity of cells in new disposal facility are reached (Based on "as-disposed" waste volume estimate)	
	Risk (Natural Phenomenon)	**Appendix D**		Waste contamination released by a tornado strike
	Risk (Transportation)	**Appendix D**	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 F**		Preliminary WAC allows most future CERCLA waste to be disposed Proposed conceptual design provides adequate assurance that disposed contaminants would pose acceptable risks
Off-site Disposal	**Conceptual Design Cost Estimate**	**Chapter 6 Appendix G**	Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate)	
	Risk (Transportation)	**Appendix D**	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 types (regulatory classifications) and material types (waste forms). 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 and 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[4] was packaged, shipped, and disposed at an approved off-site facility. 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 F, respectively:

- The characteristics of future CERCLA waste generated are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002.
- PWAC 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 similarity in current and future CERCLA waste generation, less than 3% 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

[4] Total excludes CERCLA waste disposed at ORR Landfills

estimate information (for both alternative) 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 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 are not anticipated to change with the change of report title. Similar to the definitions in both the CARAR (DOE 2012a) and PCCR (DOE 2013a), 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.
  - 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 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 for On-site Disposal Alternative).
  - 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 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 by using existing contractor WGF data[5] 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.
- Forecasted volumes were modified for specific projects such as ARRA projects and other projects (e.g., ETTP Zone 2 soil estimate was increased) for which updated waste volume estimates were available.
- The schedule for ORR cleanup projects and associated waste generation was revised based on an assumed $420M funding scenario[6] for ORR cleanup projects from FY 2013 through FY 2046, with ORR CERCLA waste generation through FY 2043.

The base as-generated waste volume estimate covers the FY 2013 through FY 2043 timeframe and does not include applied uncertainty. The annual estimate for base as-generated waste volumes ranges from about 20,000 yd^3 per year to 153,000 yd^3 per year as shown in Figure 2-1. These projected volumes are quite variable, especially in out-years, 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.

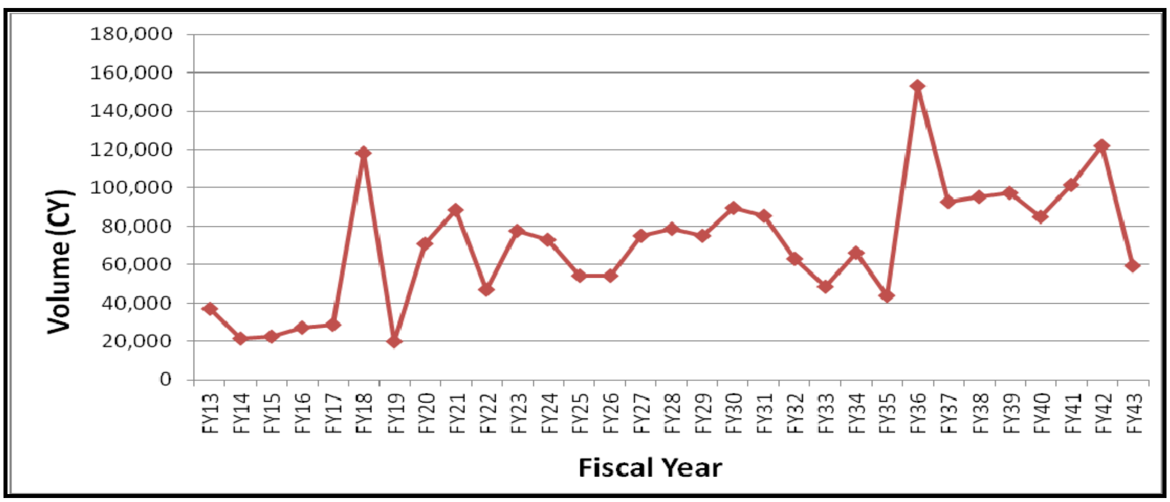

Figure 2-1. As-generated Waste Volume Estimate without Uncertainty

[5] WGF download May 2013.

[6] The RI/FS waste volume estimate is based on an approximation of project sequencing for a scenario that assumes funding of $420M in FY 2013, annual funding of $420M for FY 2014 through FY 2018, and annual funding of $420M escalated each year through the end of the program (FY 2046).

A calculated average of 70,034 yd^3 of waste per year is well within the EMWMF annual operational range of waste processed thus far (approximately 40,000 up to 133,000 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 the EMWMF will be filled to capacity in FY 2023. Any accelerated waste generation during the FY 2013 to FY 2023 time frame would require a significantly large increase in funding, and while this is highly unlikely given 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 post-EMWMF (FY 2023 - FY 2043) portion of the as-generated waste volume estimate 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*. 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 2023 - 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	1,183,602	45,685	1,229,288	75%
Debris/Classified	0	1,175	1,175	<0.1%
Soil	389,768	11,975	401,743	25%
Total	1,573,370	58,835	**1,632,206**	
% by Waste Type	96%	4%		

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 2013 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 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.

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 that is based on a field-determined ratio of total fill density to as-disposed debris density.
- Calculate the volume of clean fill soil needed by subtracting the as-disposed soil waste volume from the total fill volume. (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 an uncertainty allowance comparable to the FY 2013 PCCR value for 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.

Using the as-disposed volume (1,993,349 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 ~2.5M yd^3 of additional capacity, which is the conceptual design capacity of the proposed EMDF site for the On-site Disposal Alternative (Table 2-4). The additional 25% uncertainty adds approximately the volume of one cell to the projected disposal capacity without uncertainty.

Table 2-3. As-Disposed Waste Volume Determination

Waste Type	Volume (yd^3)	Basis
AD Debris (compacted)	611,457 (A)	AG debris volume divided by 2.01 (as defined in Appendix A)
AD Waste Soil (compacted)	309,417 (B)	AG waste soil volume divided by 1.30 (as defined in Appendix A)
Total Fill	1,381,893	AD debris volume multiplied by 2.26 (as defined in Appendix A for filling void space and for operational needs)
Clean Fill	1,072,475 (C)	AD Waste Soil subtracted from Total Fill
Total AD Volume	1,993,349	Add values A, B, and C
AD=As-disposed; AG=As-generated.		

The *Fiscal Year 2013 Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Facility* (DOE 2013a) predicts that a total CERCLA waste volume of 4.4M yd^3 is required at the 95% UCL. Subtracting 2.18M yd^3 (capacity of the EMWMF) leaves an additional 2.22M yd^3 additional disposal capacity needed. The difference between the two estimates, 2.5M yd^3 needed per this RI/FS and 2.22M yd^3 needed per the FY 2013 PCCR, is a result of the following:

- A greater uncertainty is assumed in this RI/FS (25% versus the 95% UCL in the PCCR, which equates to about 19% uncertainty in future waste generation) due to the extensive time frame considered (30 years into the future) and the possibility that some new scope may be introduced into the program in the future.
- An 8% difference in waste generation estimates in the RI/FS versus the PCCR (mainly attributed to a higher ETTP Zone 2 soils volume estimate, see Appendix A).

In addition to the differences in needed disposal capacity, the FY 2013 PCCR predicts the EMWMF reaches capacity in 2020-2021, whereas this analysis predicts that date is 2023. As mentioned previously, the waste volume sequencing completed for this RI/FS analysis is based on the most recent OREM baseline planning (May 2013), which predicts a slower annual waste generation than the FY 2013 PCCR, for many years of the program, and extends that waste generation by one year, to complete in FY 2043 as opposed to the PCCR prediction of FY 2042.

Table 2-4. Percent Uncertainty and Corresponding Projected Disposal Capacity Need

Assumed % Uncertainty in Future Volumes	Projected Disposal Capacity Need (yd^3)	EMDF Cells Needed
0	1,993,349	Cells 1-5
25	**2,491,686**	Cells 1-6

If the On-site Disposal Alternative is selected as the remedy, the capacity may 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 2-2 shows the cumulative CERCLA waste capacity demand estimate through FY 2043 including the 25% uncertainty allowance for future volumes. Figure 2-2 also shows the maximum capacity of EMWMF (2.18M yd^3) is estimated to be reached in FY 2023 based on 25% uncertainty in future volumes. Based on this estimate, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2023[7]. 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.

Table 2-5. Post-EMWMF As-generated Waste Volume Estimate (FY 2023 - 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	1,479,503	57,107	1,536,610
Debris/Classified	0	1,469	1,469
Soil	487,210	14,969	502,179
Total	**1,966,713**	**73,544**	**2,040,257**

[7] For purposes of the RI/FS evaluation, operational start-up of a new facility is assumed to begin when EMWMF capacity is reached. However, in order to continue compliant disposal of CERCLA waste materials on the ORR, the operational start-up of a new disposal facility would actually be planned prior to the EMWMF reaching maximum capacity if the On-site Disposal Alternative is selected.

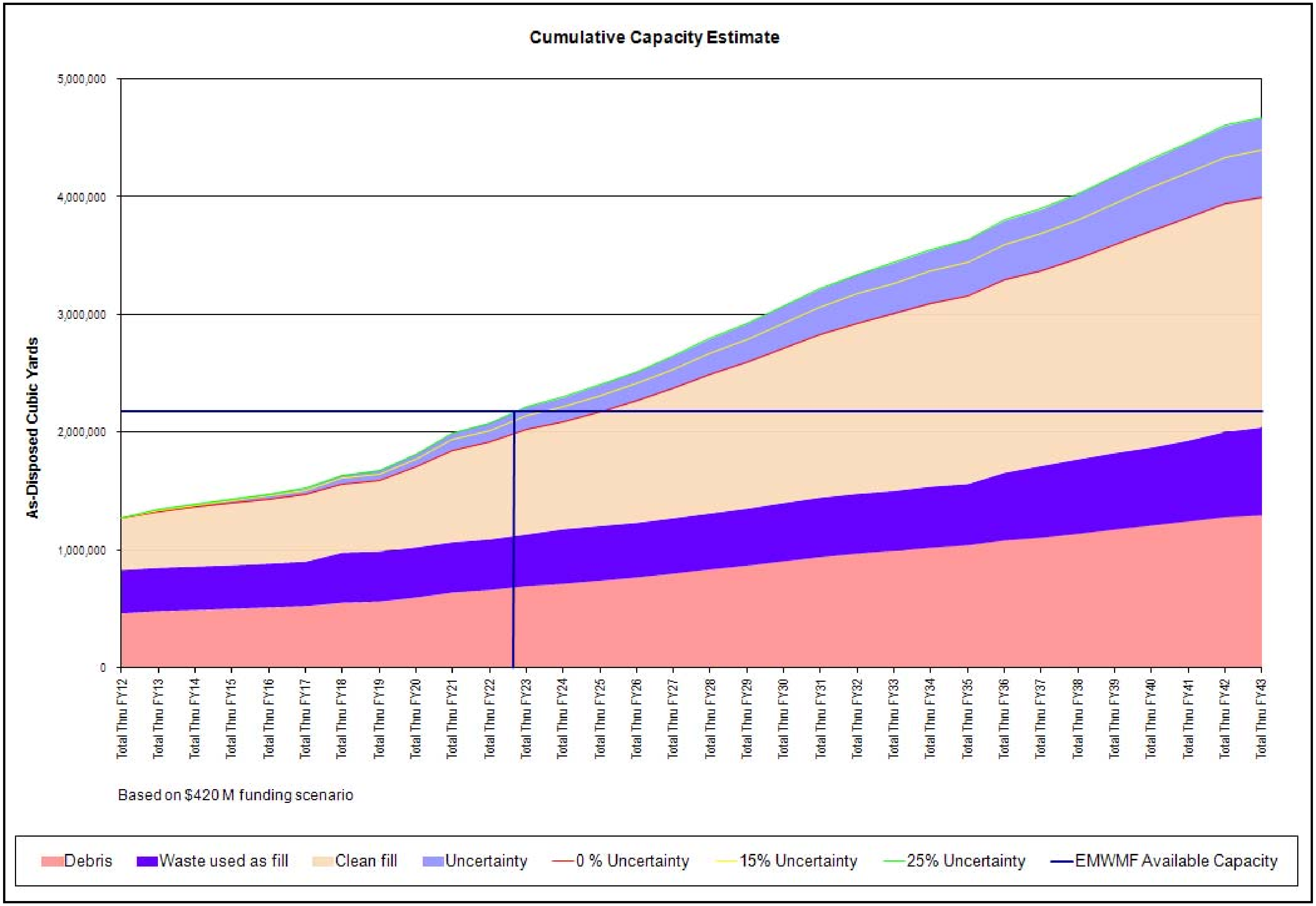

Figure 2-2. Cumulative CERCLA Waste Capacity Demand Estimate

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 the 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 the EMWMF approximately represent the waste characteristics of future waste streams. Use of characterization data for waste disposed at the 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 the assessment.

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 D. 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.

PWAC 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 PWAC evaluation is used to determine the following:

- Does the PWAC 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. 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:

1. Waste lots (WLs) for waste disposed at the EMWMF were identified using a Waste Transportation Management System[8] EMWMF Disposition Summary Report.
2. Radionuclide COPC concentration data for identified WLs were obtained from a Waste Acceptance Criteria Forecast Analysis Capability System[9] output report or waste profile data. The expected value concentrations of radionuclide COPCs reported in the individual waste WL data sets were identified.
3. 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:

1. 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.
2. 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 in the 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 limited to information about contaminants anticipated to be present in future generated CERCLA waste.

For on-site disposal of waste, the administrative WAC for a potential disposal facility would require the RCRA hazardous waste that is disposed meet applicable LDRs.[10] The analytic WAC identifies additional risk- and dose-based chemical limits for constituents which may be present in the waste disposed at the EMWMF (see Section 1.1 in Appendix F). Off-site waste shipments are required to meet the U.S. Department of Transportation (DOT) requirements.

[8] 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.

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

[10] 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. Specific constituent levels (i.e., treatment standards) must be achieved before the hazardous waste can be land disposed.

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

Isotope	Mass Weighted Average (pCi/g)
Ag-110m	4.76E-01
Am-241	9.18E+00
Am-243	5.77E-01
Bi-214	3.89E-01
C-14	2.91E+01
Cm-242	1.63E-01
Cm-243	6.69E+00
Cm-244	1.14E+04
Cm-245	1.39E-01
Cm-246	5.41E+00
Cm-247	9.55E-03
Co-57	1.48E-01
Co-60	5.05E+02
Cs-134	2.48E+04
Cs-137	5.83E+03
Eu-152	6.43E+03
Eu-154	4.85E+03
Eu-155	1.41E+03
F-59	1.49E+00
H-3	1.91E+02
I-129	1.79E+00
K-40	4.21E+00
Kr-85	1.04E+02
Mn-54	8.47E-01
Nb-94	7.93E-02
Ni-59	4.04E+01
Ni-63	1.05E+02

Isotope	Mass Weighted Average (pCi/g)
Np-237	2.91E-01
Pb-210	2.50E+00
Pb-214	4.02E-01
Pm-147	1.00E+01
Pu-238	5.69E+01
Pu-239	1.17E+01
Pu-240	1.74E+02
Pu-241	2.01E+02
Pu-242	3.79E-01
Pu-244	3.22E-02
Ra-226	9.10E-01
Ra-228	7.95E-01
Ru-106	6.27E+04
Sr-90	9.73E+03
Tc-99	3.67E+01
Th-228	4.27E-01
Th-229	4.00E-03
Th-230	1.55E+00
Th-232	1.69E+00
U-232	1.65E+00
U-233	8.13E+01
U-234	2.69E+02
U-235	1.63E+01
U-236	1.14E+01
U-238	1.60E+02
Zn-65	1.46E+00

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.

Table 2-7. Chemical Constituents

Chemical	CASN	Chemical	CASN
(1,1-Dimethylethyl)benzene	98-06-6	4-Chloro-3-Methylphenol	59-50-7
(1-Methylpropyl)benzene	135-98-8	4-Methyl-2-Pentanone (MIBK)	108-10-1
1,1,1-Trichloroethane	71-55-6	4-methylphenol (p-cresol)	106-44-5
1,1-Dichloroethane	75-34-3	Acenaphthene	83-32-9
1,1-Dichloroethene (Dichloroethylene)	75-35-4	Acenaphthylene	208-96-8
1,1,2-Trichloroethane	79-00-5	Acetone	67-64-1
1,1,2-Trichloro-1,2,2-Trifloroethane	76-13-1	Acetophenone	98-86-2
1,2,4-Trichlorobenzene	120-82-1	Aldrin	309-00-2
1,2,4-Trimethylbenzene	95-63-6	Alpha-BHC	319-84-6
1,2-Dichlorobenzene	95-50-1	alpha-Chlordane	5103-71-9
1,2-Dimethylbenzene	95-47-6	Aluminum	7429-90-5
1,2-Dichloroethane	107-06-2	Anthracene	120-12-7
1,2-Dichloroethene	156-59-2	Antimony	7440-36-0
1,3,5-Trimethylbenzene	108-67-8	Arsenic	7440-38-2
1,3-Dichlorobenzene	541-73-1	Asbestos	1332-21-4
1,4-Dichlorobenzene	106-46-7	Barium	7440-39-3
1-Methyl-4-(1-methylethyl)benzene	99-87-6	Benzo(a)anthracene	56-55-3
2,3,4,6-Tetrachlorophenol	58-90-2	Benzene	71-43-2
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	Benzenemethanol	100-51-6
2,4-Dimethylphenol	105-67-9	Benzo(a)pyrene	50-32-8
2,4-Dinitrophenol	51-28-5	Benzo(b)fluranthene	205-99-2
2,4,5-Trichlorophenol	95-95-4	Benzo(g,h,i)perylene	191-24-2
2-Butanone (also known as Methyl Ethyl Ketone)	78-93-3	Benzo(k)fluoranthene	207-08-9
2-Chlorophenol	95-57-8	Benzoic Acid	65-85-0
2-Chloronaphthalene	91-58-7	Beryllium	7440-41-7
2-Hexanone	591-78-6	Beta-BHC	319-85-7
2-Methylnaphthalene	91-57-6	Bis(2-ethylhexyl)phthalate	117-81-7
2-methylphenol (o-cresol)	95-48-7	Boron	7440-42-8
3-3'-Dichlorobenzidine	91-94-1	Butylbenzylphthalate	85-68-7
3-methylphenol (m-cresol)	108-39-4	Cadmium	7440-43-9
2-Nitroaniline (O-Nitroaniline) IP-Nitroaniline)	88-74-4	Calcium	7440-70-2
4,4'-DDD	53-19-0	Carbazole	86-74-8
4,4'-DDE	72-55-9	Carbon disulfide	75-15-0
4,4'-DDT	50-29-3	Carbon tetrachloride	56-23-5
4,6-Dinitro-2-methylphenol	534-52-1	Chlordane	57-74-9

Table 2-7. Chemical Constituents (Continued)

Chemical	CASN
Chlorobenzene	108-90-7
Chloroethane	75-00-3
Chloroform	67-66-3
Chromium	7440-47-3
Chrysene	218-01-9
cis-1,2-Dichloroethene	156-59-2
Cobalt	7440-48-4
Copper	7440-50-8
Cumene	98-82-8
Cyanide	57-12-5
Delta-BHC	319-86-8
Dibenz(a,h)anthracene	53-70-3
Dibenzofuran	132-64-9
Dieldrin	60-57-1
Diethylphthalate	84-66-2
Dimethylphthalate	131-11-3
Di-n-butyl phthalate	84-74-2
Di-n-octylphthalate	117-84-0
Endosulfan I	959-98-8
Endosulfan II	33213-65-9
Endosulfan Sulfate	1031-07-8
Endrin	72-20-8
Endrin Aldehyde	7421-93-4
Ethylbenzene	100-41-4
Fluoranthene	206-44-0
Fluorene	86-73-7
gamma-Chlordane	5103-74-2
Heptachlor Epoxide	1024-57-3
Hexachlorobutadiene	87-68-3
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
Lead	7439-92-1
Lithium	7439-93-2

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

3. EVALUATION OF BASELINE RISK

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.[11]

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.

Although this RI/FS does not present a typical evaluation of baseline risk of a contaminated site for the No Action Alternative, evaluations of transportation risk and natural phenomenon risk for the On-site Disposal Alternative and transportation risk for the Off-site Disposal Alternative are provided in Appendix D. Appendix F provides PWAC for the proposed on-site disposal facility based on contaminant pathway analysis modeling to meet risk and dose criteria. 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 D and Appendix F.

[11] 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 ROD	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	**To Be Determined**	**Bear Creek Valley White Wing Scrap Yard Record of Decision**	**BCV White Wing Scrap Yard Remedial Action**
		To Be Determined	Bear Creek Valley Burial Grounds Record of Decision	BCV Burial Grounds Record of Decision
		Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volume 1 (DOE/OR/01-1455/V1&D2)	*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

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

Acronyms

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

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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 and 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 from ORR and associated sites after EMWMF capacity is reached. Because the actions being evaluated are designed to provide for the disposition of various waste types derived from a wide range of sources and activities, establishing specific cleanup goals is not appropriate. Instead, remediation goals for site cleanup at the project-specific level have already been identified in existing CERCLA decision documents or will be made in future CERCLA decision documents.

The four RAOs for alternatives evaluated in this RI/FS remain the same as those established for the alternatives evaluated in the EMWMF RI/FS. The first three RAOs are most directly applicable to evaluation of the protectiveness of a permanent waste disposal facility under the On-site Disposal Alternative:

1. Prevent exposure to future-generated CERCLA waste that exceeds a human health risk of 1×10^{-5} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.
2. Prevent ecological exposure to future-generated CERCLA waste.
3. Prevent releases of future-generated CERCLA waste, or waste constituents, that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or that do not meet ARARs for environmental media.

Appendix C provides a description of the siting option in EBCV evaluated in this RI/FS and siting options that were screened out from further evaluation. As shown in Figure C-1 in Appendix C, the proposed EMDF site is located in the eastern portion of the Bear Creek Valley (BCV) Watershed on the ORR in BCV Zone 3 area designated for future DOE controlled industrial use in the BCV Phase I ROD (DOE 2000). This site will remain under DOE control within DOE ORR boundaries for the foreseeable future.

As described in Chapter 3, under the No Action Alternative, no coordinated ORR effort would be implemented to manage waste generated by future CERCLA actions after EMWMF capacity is reached. 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.

Under the Off-site Disposal Alternative, waste is shipped for permanent disposal at existing permitted off-site facilities. As a result, the first three RAOs are not directly applicable to the Off-site Disposal Alternative because the permits for each individual off-site facility specify requirements to protect human health and the environment and minimize exposure risk.

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

4. Facilitate timely cleanup of ORR and associated facilities.

Evaluation of disposal alternatives for waste under the CERCLA process in this RI/FS will support DOE implementation of a recent Oak Ridge Site Specific Advisory Board (ORSSAB) recommendation (ORSSAB 2011), 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 lifecycle 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.

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

5. TECHNOLOGY SCREENING AND ALTERNATIVES ASSEMBLY

Section 5.1 of this chapter identifies and screens technologies and process options, and selects representative process options to support disposal of the candidate waste streams identified in Chapter 2. Section 5.2 assembles the representative process options into disposal alternatives and evaluates their ability to meet RAOs. Chapters 6 and 7, respectively, describe and evaluate the selected disposal alternatives.

5.1 IDENTIFICATION, SCREENING, AND SELECTION 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 is based on the general response actions, technology types, and process options that were presented in the EMWMF RI/FS. Applicable new information and lessons learned from construction and operation of the EMWMF are presented and applied throughout the screening process as well.

As specified in EPA RI/FS guidance (EPA 1988), steps are taken to logically reduce the number of technology types and process options to be considered for alternatives analysis. In the initial screening step, each process option is evaluated to determine its technical applicability to the remediation site(s). In the following step, 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. 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:

- No action
- On-site disposal
- Off-site disposal
- Waste packaging and transport
- Institutional controls

The process for developing and screening alternatives is presented in the EPA RI/FS guidance document (EPA 1988). Table 5-1 summarizes this process as it was applied and presented in the EMWMF RI/FS, where each process option was described and evaluated in detail. Applicable process options were then evaluated for effectiveness, implementability, and cost to select representative process options for each technology type within a general response action; results of the evaluation are summarized in the table. In most cases, the analysis for this RI/FS is consistent with the EMWMF RI/FS. Following the table, Sections 5.1.1 through 5.1.6 provide a discussion of the representative process options that were selected in the EMWMF RI/FS and retained for alternative development in this RI/FS as well.

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 additional CERCLA disposal facility/capacity is built on the ORR. D&D and RA projects individually arrange disposal	Ineffective as an ORR-wide disposal option	Disposal is independently implemented project by project	Little direct cost; indirect costs due to independent disposals may 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 engineered disposal facility but with fewer isolation features incorporated into design.	Ineffective due to insufficient waste isolation systems	Prohibited from receiving LLW or mixed waste	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 waste	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 (LLW landfill)	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 mixed waste	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 mixed waste	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 mixed-waste disposal.	Effective isolation of wastes; includes treatment as required for land disposal	Projected to be at capacity and unavailable	Moderate	Retained. Anticipated to be in use until 2023 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 mixed wastes.	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 mixed waste. Incurs potential risk of transportation accident or shut-down	Very High due to transportation costs and disposal fees	Retained as representative off-site disposal option for non-classified LLW and mixed waste
		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 LLW and mixed waste. Incurs potential risk of transportation accident or shut-down	Very High due to transportation costs and disposal fees	Retained as representative off-site disposal option for non-classified LLW and mixed waste
		DOE Hanford Reservation	DOE storage/disposal facility near Richland Washington.	Effective for LLW disposal, but lacks mixed waste disposal capability	Hanford's CERCLA ROD does not allow receipt of mixed waste 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	Commercial LLW/mixed waste facility in Andrews, Texas	Effective for LLW and mixed waste	DOE recently entered into a contract with WCS; rate schedule is not yet available	Very High	Retained as potential future process option, but costs not estimated. Energy Solutions is representative of commercial off-site disposal facility
	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 mixed waste	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
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 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
		Truck	Transportation of bulk waste on-site in dump trucks, or packaged waste to on- 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 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 Energy*Solutions* in Clive, UT. NNSS can be accessed by using rail to truck transfer facility in Kingman, AZ, then truck transfer to the 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 Energy*Solutions*

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
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

5.1.1 No Action

The “no action” general response action is required by the NCP to serve as a baseline for comparison to action-based alternatives. The No Action Alternative is described further in Section 6.1.

5.1.2 On-site Disposal

On-site disposal technology types considered include new and existing land disposal facilities. To be selected as a relevant process option through the initial screening step, the process must be able to accept candidate waste streams – unclassified or classified LLW and mixed solid waste types with RCRA and/or TSCA components. Additional screening considers effectiveness, implementability, and relative cost of the retained process options to narrow the selection(s) down to representative process option(s). Details of the analysis are available in the EMWMF RI/FS and summarized and updated in Table 5-1.

5.1.2.1 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 for on-site disposal, as concluded by the EMWMF RI/FS analysis and confirmed in this RI/FS, is the partially below-grade engineered disposal facility. It was originally selected based on equivalent or superior effectiveness, relative ease of implementation, and reduced cost compared to other process options. The conclusion for this RI/FS remains the same.

5.1.2.2 Existing Facilities

With the exception of the EMWMF, no existing facilities on the ORR have WAC that allow for disposal of projected candidate waste streams. Most of these options were eliminated in the EMWMF RI/FS analysis. This RI/FS eliminates all existing facility options and assumes that the EMWMF will be filled to capacity and therefore unavailable.

As it was in the EMWMF RI/FS, long-term storage is retained in this RI/FS as an interim option for waste that may not meet disposal facility WAC, pending identification of appropriate treatment and 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.

5.1.3.1 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. There is no such known plan for a new off-ORR engineered facility; therefore the option is eliminated in the initial screening as was the case in the EMWMF RI/FS.

5.1.3.2 Existing LLW and mixed waste facilities

LLW and mixed waste disposal sites evaluated in the EMWMF RI/FS included Chem Nuclear in Barnwell, SC; Energy*Solutions* (formerly Envirocare) in Clive, UT; the DOE Nevada National Security Site (NNSS) facility near Las Vegas, NV (formerly the Nevada Test Site); the DOE Hanford Reservation near Richland, WA; and U.S. Ecology-Hanford. All these sites would be effective at isolating wastes that meet their respective WAC. ORR wastes are currently being shipped to the Energy*Solutions* and NNSS facilities, and shipment and disposal at these sites is readily implementable. All sites would incur high transportation/disposal costs as well as risk liabilities until waste reaches its destination. Energy*Solutions* accepts mixed waste for disposal, with mixed-waste disposal fees higher than LLW fees. Chem Nuclear, DOE Hanford, and U.S. Ecology-Hanford were eliminated from consideration as described in Table 5-1. The Waste Control Specialists (WCS) facility in Andrews, TX is a potential process modification to the Off-site Disposal Alternative (see Section 6.3.3.8.1).

Energy*Solutions* of Clive, UT was retained for disposal of LLW and mixed waste in the EMWMF RI/FS and remains a representative process option for this RI/FS for non-classified LLW and mixed waste. Treatment of LLW/RCRA waste to meet LDRs prior to disposal is available at the Energy*Solutions* facility. The DOE NNSS facility near Las Vegas, NV was retained in the EMWMF RI/FS for LLW disposal only as a process modification and not as a representative process option because of administrative concerns and lack of mixed waste disposal capacity. The NNSS facility is retained in this RI/FS for unclassified and classified LLW and mixed waste disposal because of its expanded capabilities to accept mixed waste (LLW/TSCA waste as well as LLW/RCRA waste that meets LDR treatment standards). However, treatment of LLW/RCRA waste prior to disposal is not available at NNSS.

5.1.3.3 Existing RCRA/TSCA facilities

The Waste Management, Inc. (WMI)-Emelle (Emelle, AL), US Ecology-Beatty (Beatty, NV), Clean Harbors (Deer Park, TX), and Clean Harbors (Clive, UT) facilities were identified as existing RCRA/TSCA facilities in the EMWMF RI/FS and the WMI facility was retained for the EMWMF evaluation. All of the facilities are eliminated in this RI/FS 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 portion of the small percentage of CERCLA waste generated each year that does not meet the EMWMF WAC and is not a differentiator in the On-site and Off-site Disposal Alternatives because it would be shipped off-site in either alternative. Non-radioactive RCRA/TSCA waste and other waste that would not meet an on-site disposal facility WAC are not included in candidate waste streams for quantitative analysis (see Section 2.1.3).

There are other existing RCRA/TSCA facilities on the approved active TSDRF list for ORR cleanup, may be appropriate and acceptable for disposal of non-radioactive RCRA and TSCA waste. However, as stated above, non-radioactive RCRA and TSCA waste is a portion of the small percentage of CERCLA waste generated each year that does not meet the EMWMF WAC. The waste is not a differentiator in the On-site and Off-site Disposal Alternatives and is not included in candidate waste streams for quantitative analysis.

5.1.4 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.

5.1.4.1 Packaging

Small containers (e.g., B-12 and B-25 boxes, drums, and over-packs) are effective and implementable for specific candidate waste streams. They are typically disposed of with the waste rather than emptied and reused. They can be placed in large containers for ease of shipment. Small containers are costly due to the need to replace, rather than reuse the containers. In the EMWMF RI/FS the small containers process option was retained, and is retained as a process option for this RI/FS. Large containers are retained in this RI/FS for all waste streams as representative for the purpose of comparative analysis of On-site and Off-site Disposal Alternatives.

Use of large containers (e.g., roll-off bins, intermodal containers) for bulk waste and over-packs containing small containers are effective and implementable. They are in common use on the ORR, and the variety of sizes and configurations provides for diverse loading and unloading scenarios. Large containers are retained in this RI/FS.

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.

For this RI/FS, the large container packaging process option is retained as representative for the purpose of comparative analysis of alternatives.

5.1.4.2 Transport

Truck transport is applicable, effective, and implementable for both local and long-distance waste transport. Cost for long-distance transport is high. This process option is retained as representative, as it was in the EMWMF RI/FS.

Rail transport is viable for long-distance waste transport and is retained as it was previously. An existing transfer 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 mixed wastes. Transport by rail to NNSS in Nevada requires transfer of the waste from railcars to trucks at a transfer facility (Kingman, AZ assumed) for the last leg of the trip unless additional rail spurs are constructed to the disposal facility (outside of the scope of this RI/FS). The cost for rail transport, including the cost for transferring containers between vehicles (e.g., trucks, trains), would be lower than truck transport for very large waste volumes.

5.1.5 Institutional Controls

As shown in Table 5-1, all institutional controls process options were retained in the EMWMF RI/FS and are also representative in this RI/FS to be used in conjunction with other actions to ensure adequate protectiveness.

5.2 ASSEMBLY OF ALTERNATIVES AND ABILITY TO MEET RAOS

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. This section describes the ability of the alternatives to meet RAOs. The alternatives presented in Table 5-2 are described in detail in Chapter 6 and fully evaluated in Chapter 7.

Table 5-2. Alternatives Assembly, RI/FS for CERCLA Waste Disposal, Oak Ridge, TN

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			Required by NCP. No Action Alternative.
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			X	Energy*Solutions* and NNSS are used for off-site LLW and mixed waste disposal. Both are applicable for the Off-site Disposal Alternative.
		DOE NNSS			X	
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	

As described in Chapter 4, the first three RAOs are most directly applicable to the On-site Disposal Alternative. The On-site Disposal Alternative is designed to meet the RAOs as follows:

1. Prevent exposure to future-generated CERCLA waste that exceeds a human health risk ELCR of 1×10^{-5} or HI of 1.

   On-site Disposal Alternative. Construction and operation of a new on-site disposal facility for CERCLA waste would meet this RAO, for waste meeting the facility's WAC, by providing adequate capacity at an engineered facility that isolates waste with appropriate containment features to preclude human contact. 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. Appropriate controls, 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 of the facility for an indefinite period. Such isolation would be 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.

2. Prevent ecological exposure to future-generated CERCLA waste.

   On-site Disposal Alternative. The isolation features of an on-site disposal facility would be designed to protect ecological receptors from contact with or exposure to the waste. Candidate wastes would be contained during transport, operations, and disposal to prevent exposure to ecological receptors. The On-site Disposal Alternative would meet this RAO.

3. Prevent releases of future-generated CERCLA waste, or waste constituents, that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or ARARs for environmental media.

   On-site Disposal Alternative. This alternative would place most candidate wastes into an on-site engineered disposal cell, effectively isolating the wastes from the environment, minimizing release of contaminants, and reducing overall risk. By design, meeting the facility WAC would ensure that the ELCR from wastes disposed of at the facility would be $<1\times10^{-5}$, and the total non-carcinogenic risk would have an HI of <1 for future hypothetical residents living adjacent to the disposal facility. The On-site Disposal Alternative would meet this RAO.

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

4. 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. This alternative would meet this RAO by consolidating most candidate wastes from dispersed areas into a single on-site disposal facility. The availability of this disposal option could encourage waste removal at individual sites and facilitate timely cleanup of ORR. If a waste disposal option were not available, the need to procure disposal services on a project-by-project basis could increase the time and cost required to complete remedial actions at individual sites. Timely cleanup of the ORR is in keeping with the DOE and public goal of releasing portions of the ORR for beneficial uses by allowing unrestricted or less-restricted release of some currently contaminated areas.

Off-site Disposal Alternative. This alternative would meet this RAO by providing coordinated off-site disposal of candidate wastes. Similar to the On-site Disposal Alternative, the availability of disposal at off-site disposal facilities could encourage timely remediation and release of portions of ORR for beneficial use.

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 this RI/FS 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 ORR and associated waste generator sites after EMWMF capacity is reached would not be implemented.
- A centralized disposal facility would not be constructed on 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 for this RI/FS 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. Otherwise, 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 sitewide disposal strategy or infrastructure. While protective remedies would be implemented, the lack of a coordinated disposal program has potential cost and protectiveness impacts relative to the On-site Disposal Alternative and Off-site Disposal Alternative 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, TRU wastes, spent nuclear fuel, and sanitary wastes are not considered to be candidate waste streams for the EMDF. Uncontaminated or lightly contaminated waste generated during CERCLA remedial actions that can meet the WAC of existing Y-12 industrial or construction/demolition landfills are also not considered to be candidate waste streams for the EMDF. These wastes can be disposed of at the Y-12 Landfills regardless of the decision about on- or off-site disposal of CERCLA waste. Wastes not meeting the EMDF's WAC would be transported to off-site disposal facilities or placed in interim storage until treatment or disposal capacity becomes available.

This alternative only addresses disposition of CERCLA waste. It includes designing and constructing the landfill, support facilities, and roadways; receiving waste that meets the facility's WAC; unloading and placing the 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 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 monitoring (Section 6.2.4 through 6.2.6), management of waste exceeding WAC (Section 6.2.7), and facility closure and post-closure care, including institutional controls (see Section 6.2.8 and 6.2.9). Lessons learned, from design through operation of the EMWMF, are discussed throughout and summarized in Section 6.2.10.

6.2.1 EMDF Site

A proposed site in EBCV near EMWMF is evaluated in this RI/FS as part of the On-site Disposal Alternative for development of the EMDF. 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 EBCV Watershed. The proximity of the site to EMWMF offers advantages of sharing existing infrastructure (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 Bear Creek Valley (BCV) Phase I ROD (DOE 2000) as shown in Figure C-1 in Appendix C. Appendix C 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 mi. north, and is separated from the site by Pine Ridge.

Construction of a disposal facility at the EMDF site would 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 or upon Y-12. In order to revise this boundary, DOE would publish a notice of revision in the Federal Register.

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 the Haul Road to the south, a rerouted location for Northern Tributary (NT)-3 to the west (the proposed landfill would be constructed over a portion of NT-3), the steep upper slope of Pine Ridge to the north, and NT-2 to the east. The site is heavily wooded; most of the trees are deciduous. The topography varies from moderate in the southern part to very steep 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 further described and illustrated in Appendix C.

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 5ft 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.

Groundwater 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 groundwater table; however, strike-parallel flow is also an important component of the groundwater flow net. Based on the results of groundwater measurements made immediately east and west of the site in a similar topographic and geologic setting, the depth to groundwater 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 groundwater 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) groundwater and groundwater upwelling from bedrock. Shallow perched groundwater 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.

Several wetland areas occur along NT-2 and NT-3 within and bordering the EMDF site (see Figure C-17 in Appendix C). A biologically sensitive 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. No known federal- or state-listed threatened or endangered species have been identified in this area during previous studies; however, a field survey for endangered species would be performed during pre-design site characterization efforts to confirm previous findings. The Tennessee Dace is a fish that is listed by Tennessee as being in-need-of-management. 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 groundwater contamination is present in several areas south of the site, including along NT-3 south of the Haul Road. Contaminants originated from contaminated waste 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 groundwater has not been remediated.

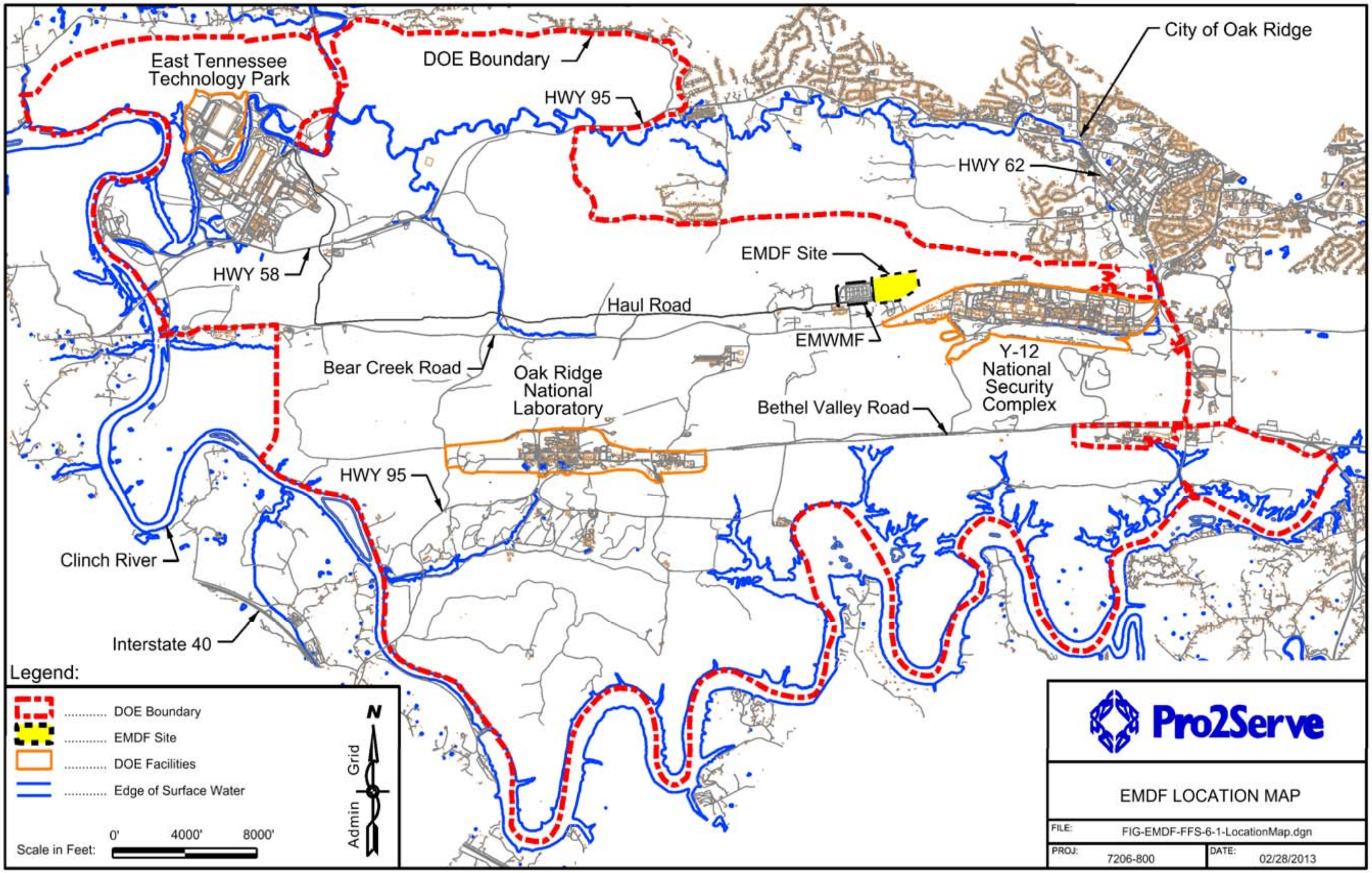

Figure 6-1. EMDF Location Map

There is no indication that the EMDF site has been contaminated on the surface or by subsurface migration from other areas. As further discussed in this chapter of the RI/FS, site–specific characterization data are not available for the selected site. Site characterization studies will be performed as part of the early actions described in Section 6.2.2.2. 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 have been factored into the conceptual design by making conservative estimates of site characteristics such as seasonal high groundwater 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 Bear Creek Valley. Process knowledge and previous groundwater 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 groundwater plumes.

6.2.2 EMDF Conceptual Design

This section describes the conceptual design for an on-site EMDF. Note that this feasibility-level, conceptual design is used to provide a comparative analysis of the On-site Disposal Alternative siting option. If the On-site Disposal 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. This conceptual design is based 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. With the exception of two hydrologic condition ARARs for which a waiver would be requested (see Section 3 in Appendix E), the design complies with ARARs and to-be-considered guidance identified for disposal of RCRA, TSCA, LLW, and mixed waste. 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 subsections that follow, and are summarized at the end, in Section 6.2.2.9.

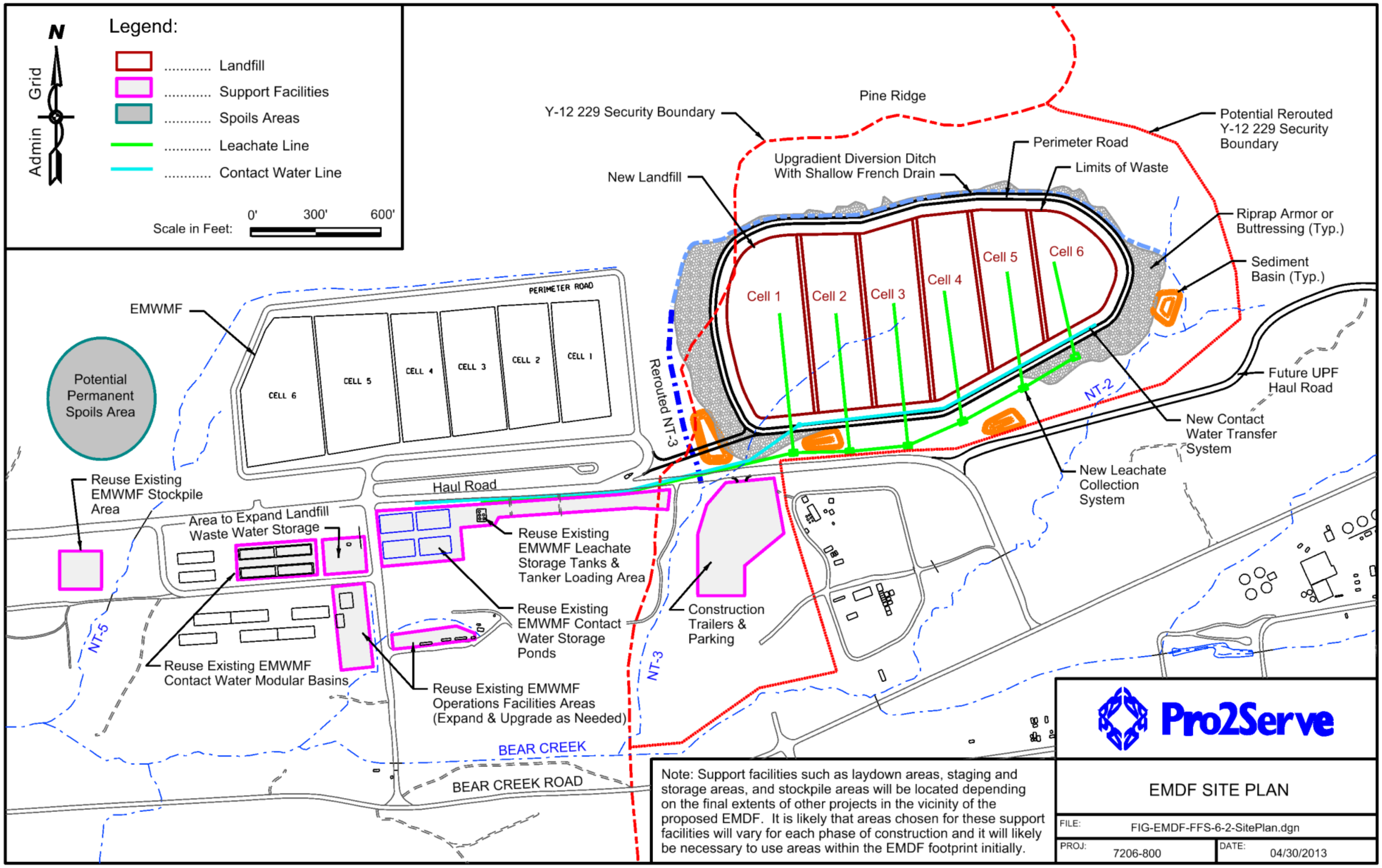

Figure 6-2. EMDF Site Plan

6.2.2.1 Remedial design

Remedial design would include preparation of RDRs, remedial design work plans, 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 the 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. 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 in turn caused the leak detection and removal system (LDRS) collection manholes to be undersized and 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 to be conservative when estimating the availability of contaminated soil for filling void spaces and general waste placement. The EMWMF design assumed that contaminated soil removal projects would be sequenced to better accommodate the demolition projects that would produce debris materials. This has not been the case to date, and operations personnel have had to purchase more clean fill than was anticipated, which added cost to landfill operations. Planning future project sequencing to minimize the need for clean fill will help to both maximize the amount of waste that can be placed in the landfill and minimize the costs associated with purchasing the clean fill.

6.2.2.2 Early actions

Certain remedial design activities would be performed 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 groundwater monitoring wells, and baseline groundwater monitoring.

Baseline Site Topographic Survey: The EMDF site topography and surface features would be mapped using civil land surveying techniques. This information would be used to perform hydrogeological/geotechnical investigations; establish locations, elevations, and depths for new groundwater monitoring wells; map wetlands (in concert with a qualified wetlands delineator); and conduct landfill site design.

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

Field Surveys for Threatened and Endangered Species: Field surveys would be performed by qualified biologists to identify whether any threatened and endangered species exist within areas of potential site disturbance prior to performing intrusive site activities such as clearing access for drilling equipment to perform hydrogeological and geotechnical investigations and construction clearing.

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

Construct New Groundwater Monitoring Wells and Surface Water Weirs: As part of the hydrogeological investigation, new groundwater monitoring wells and surface water weirs would be constructed around and within the landfill footprint to determine baseline groundwater and surface water conditions, support WAC modeling efforts, and monitor groundwater levels and surface water flow during construction, operations, monitor post-closure of the landfill, and if necessary, be used in remedial treatment programs. Existing groundwater monitoring wells down gradient of the EMDF site would be used, where possible, and additional groundwater 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 groundwater monitoring wells and six surface water monitoring weirs would be required. However, these numbers of groundwater 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 Groundwater and Surface Water Monitoring: Groundwater levels would be monitored for one year, and surface water and groundwater quality parameters (specific conductivity, pH, dissolved oxygen) and contaminants (radionuclides, metals, volatile organic compounds, and polychlorinated biphenyls (PCBs) would be monitored quarterly for one year. Groundwater flow would be determined by down-hole measurements. Surface water flow volume/rate would be monitored 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 the performance assessment and WAC finalization.

Three 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). One problem was the overestimation of the availability of suitable low permeability clay from the ORR borrow site. Another problem was the underestimation of the amount of unusable spoils that would require hauling off-site, and the last was the underestimation of the seasonal high groundwater table. The complications that arose from these three factors significantly slowed construction while increasing anticipated construction costs of the landfill. Fernald had similar landfill construction issues due to unsuitability of the low-permeability clay from the borrow area that had been selected for that project.

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 measures installed. Standard erosion and sediment controls would be installed per best management practices (BMPs) as construction proceeds.

- Clearing and grubbing for site development activities.
- Constructing 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.
- Preparing on-site spoil/borrow areas for future construction activities.
  - A temporary spoils area would be prepared near the landfill for temporary 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 restoring 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, 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-12 229 Security Boundary and installing new guard stations and fencing.
- Upgrading and installing a new 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 groundwater, geologic buffer, and multilayer cover to reduce infiltration and isolate the waste from human and environmental receptors, and landfill gas collection and venting 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 for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years (DOE O 458.1).
- Protection against animal and plant intrusion, and minimization of the potential for human intrusion.
- 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.

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 or animals. 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 typical side slopes of three horizontal to one vertical (3:1) or flatter, as determined by slope stability and erosion analyses. 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.

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 groundwater away from the landfill (Figure 6-5). The geomembrane liner would prevent surface water infiltration and recharge of groundwater 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 gravel wrapped with a geotextile filter fabric. The French drain would collect uncontaminated groundwater which could be discharged to the ground surface along the down gradient side of the landfill.

This would help lower the water table and minimize underflow towards the liner system. A design requirement will be to evaluate the possibility the upgradient ditches and drains could fail. This evaluation would be conducted in order to demonstrate the landfill will remain protective of the environment without the functioning of these features. This evaluation will be conducted with site characterization data collected prior to the commencement of the final design process.

Liner System: A multi-layer liner system will be installed to prevent leachate from migrating out of the disposal unit and impacting groundwater. 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.

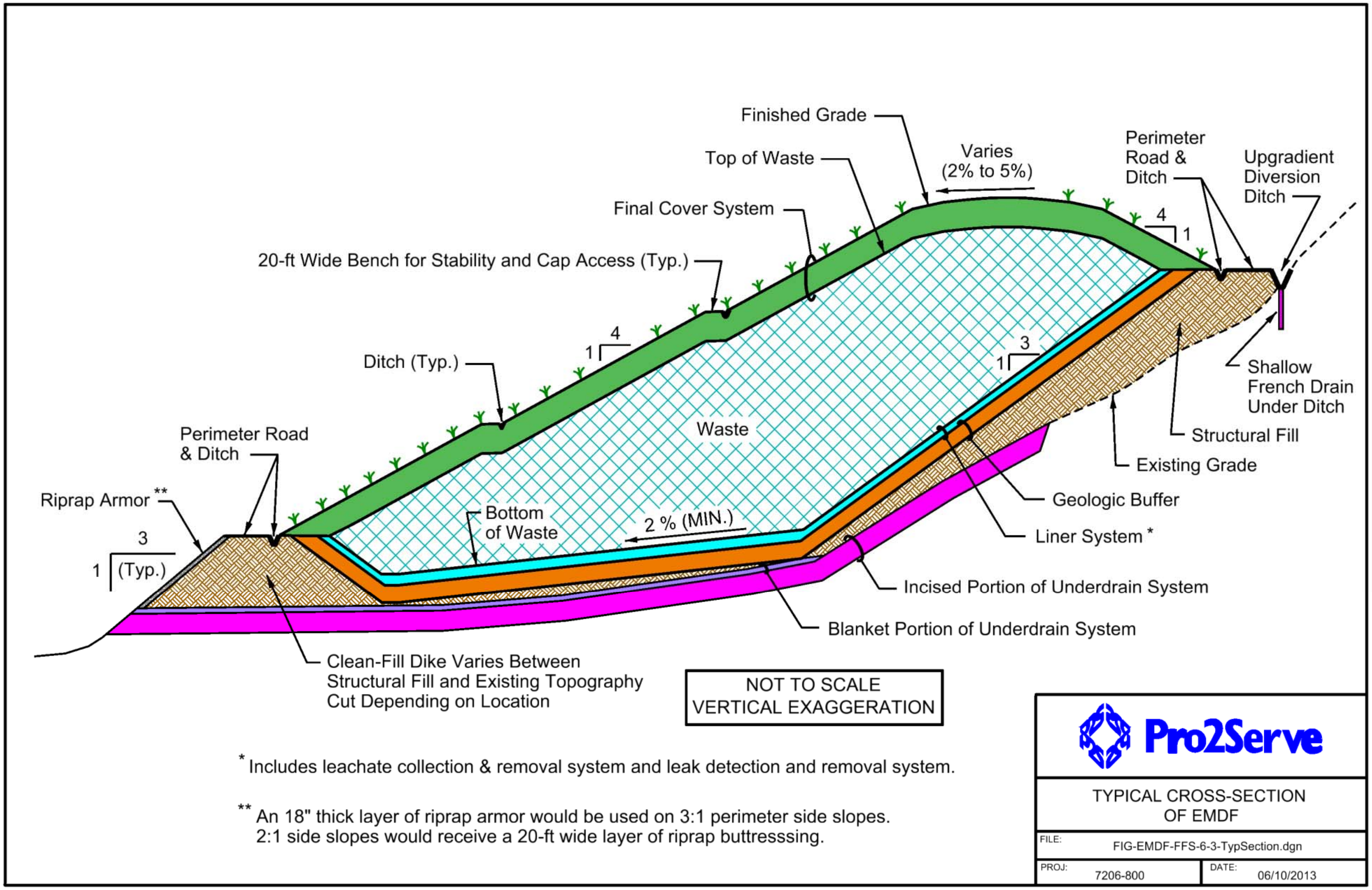

Figure 6-3. Typical Cross-section of EMDF

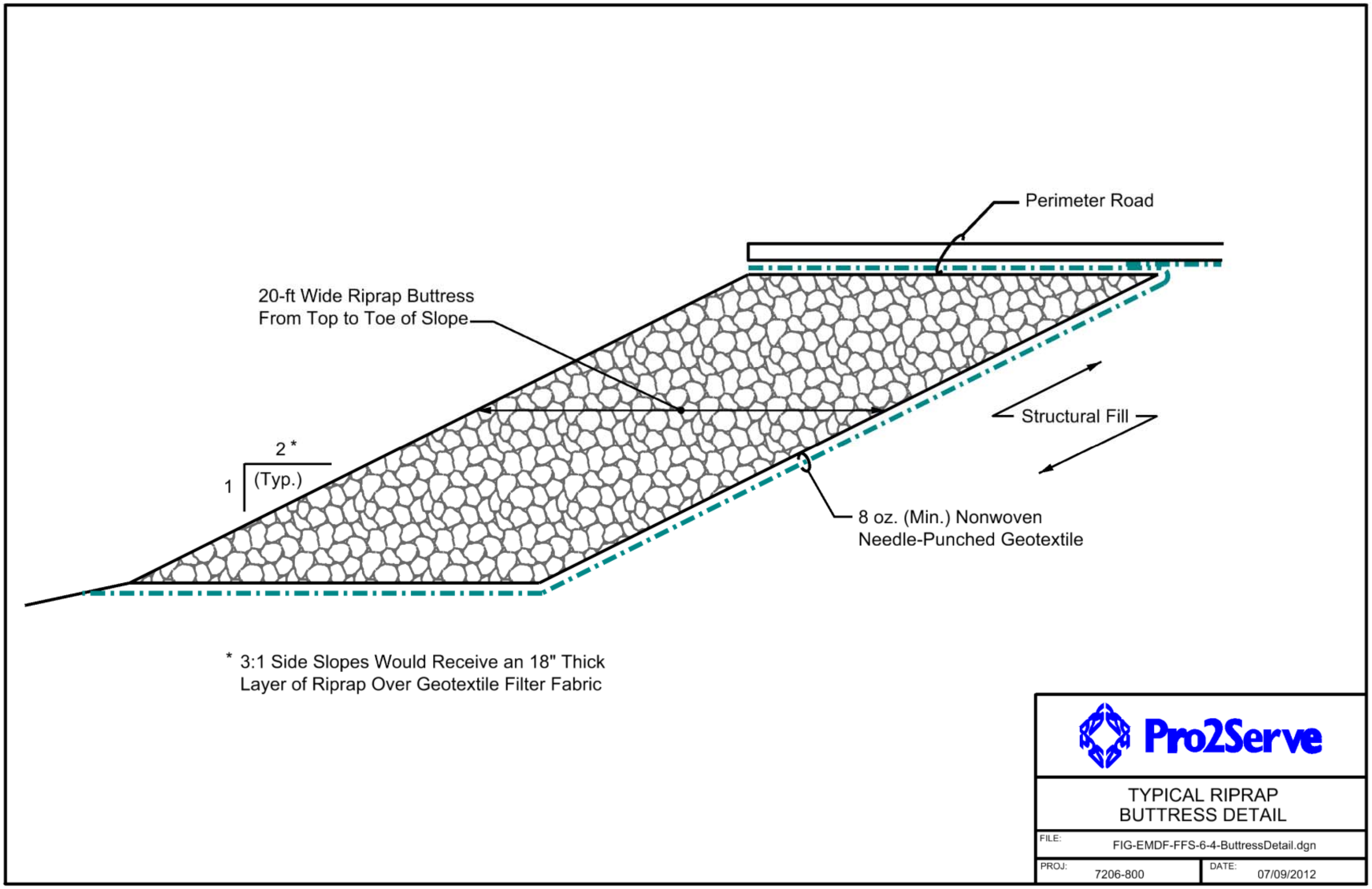

Figure 6-4. Typical Riprap Buttress Detail

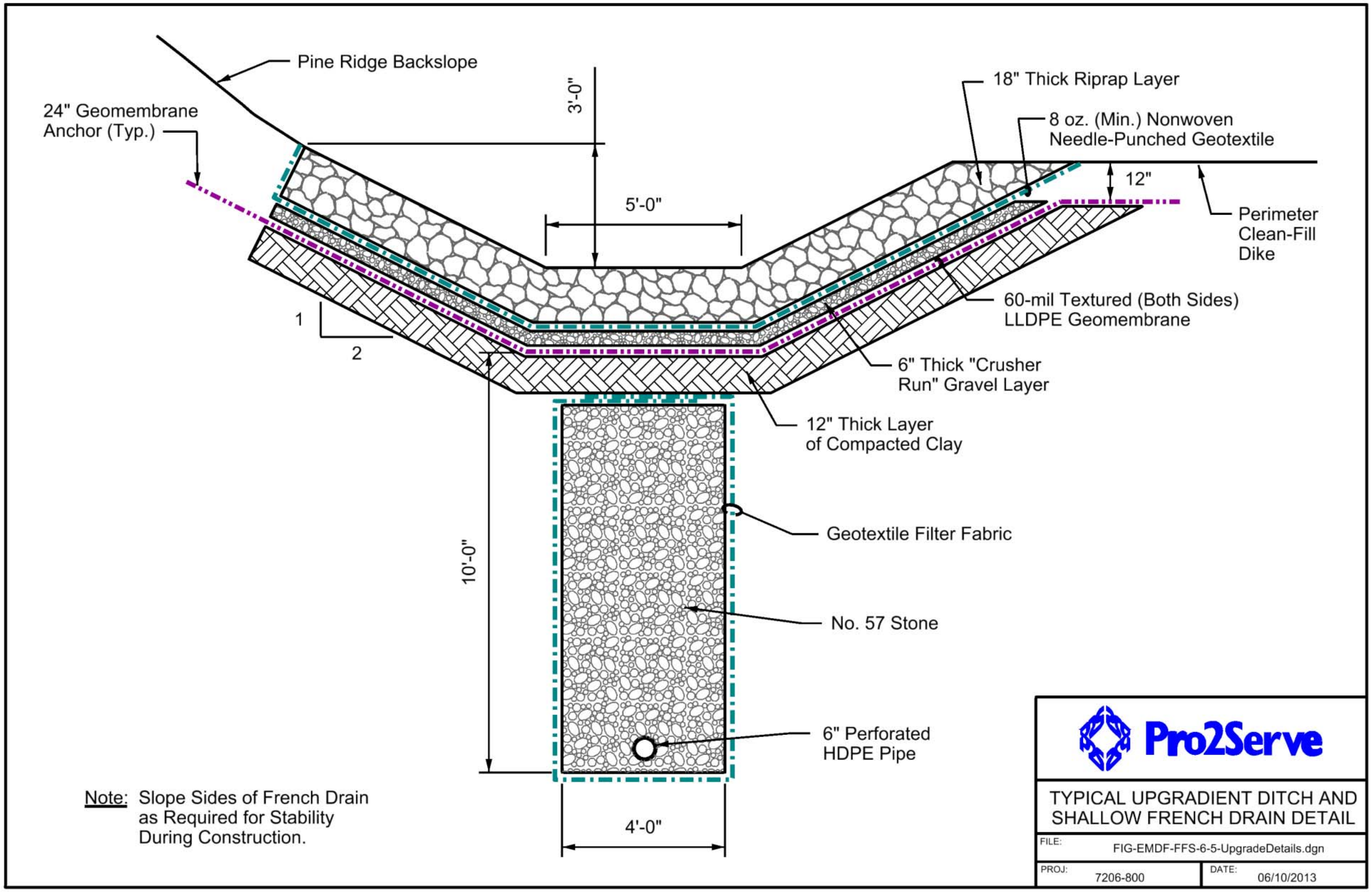

Figure 6-5. Typical Upgradient Ditch and Shallow French Drain Detail

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 Soil 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 and for the 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 fluid, 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 leachate collection and removal system (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.
- LCRS – In order to enhance slope stability and constructability, the design components of the LCRS would be somewhat different on the floor of the landfill than on the side slopes.

  <u>Floor of Landfill</u>

  - Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per yd^2, and used as a separator between the protective soil layer and leachate collection drainage stone.
  - Leachate Collection Drainage Layer – 12 in. thick (minimum) layer of hard, durable, inert (non-limestone) granular material, preferably rounded to subrounded, and having a hydraulic conductivity greater than or equal to 1×10^{-2} cm per second. Perforated high-density polyethylene (HDPE) pipes (i.e., leachate collection piping) would be installed in this layer to provide additional flow capacity. 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.

  <u>Side Slopes</u>

  - 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 – 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 approximately less than or equal to 1×10^{-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.
- 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 for a 1 ft thick layer of granular material with saturated hydraulic conductivity of 1×10^{-2} cm per second. The geocomposite drainage layer would be sloped to drain to perforated HDPE pipes (i.e., leak detection piping). This layer would be used to detect and remove any leachate that may leak through the primary geomembrane liner. Little or no leachate would be expected to be captured by this system during the operation or post-closure periods.
- Secondary Geomembrane Liner – 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 would direct leachate into 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 1×10^{-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.

  EMWMF has shown that even with the geomembrane layer separating the LCRS and LDRS layers, a considerable amount of leachate is still collected with the LDRS layer. This is not uncommon for landfills in general. A geosynthetic clay liner layer between the leachate collection and leachate detection layers has been added for the EMDF conceptual design with the intent of decreasing this volume of water. The use of a GCL layer between the two leachate drainage layers is consistent with the liner system that was used for Fernald and the system that is currently proposed for Portsmouth.

Geologic Buffer Layer: As discussed in Section 3 of Appendix E, it is anticipated that the depth to the historical high water table would be less than 50 ft below the bottom of the landfill liner system. Therefore, a waiver from the TSCA 50 ft geologic buffer requirement (40 CFR 761.75[b][3]) would be requested from the regulators based on "equivalent protectiveness".

The EMDF conceptual design includes at least a 10 ft thick geologic buffer between the landfill liner and groundwater table per TDEC Rule 0400-1-7-.04(4)(a)(2). This ARAR is cited in Table E-3 in Appendix E. 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 ≤ 1.0×10^{-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, bedrock, or combinations of these geologic materials, depending on measured in situ hydraulic conductivity and layer thickness.

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.

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 construction is that a landfill can be successfully constructed over a tributary in EBCV. With the exception of the latest published report (FY 2011), all of the annual detection monitoring reports for EMWMF that have been issued since the construction of the EMWMF underdrain in February of 2004 indicate that groundwater levels have been at or below the bottom of the geologic buffer. Modeling conducted for the latest report showed a small area under Cell 4 where the groundwater table extended approximately 1 ft into the geologic buffer. However, this anomaly is currently being investigated as it is not supported by groundwater level data from nearby pneumatic piezometers. The latest published report states that "the EMWMF underdrain continues to control the water level beneath Cell 3 to an elevation well below pre-underdrain conditions." Comparing this to the groundwater levels prior to the underdrain construction, when water levels were predicted to have been in contact with the upper 5 feet in some areas of the geologic buffer, groundwater suppression using an underdrain has been successful for EMWMF. An underdrain system is necessary within a tributary channel to provide a flow path for groundwater immediately below the landfill and prevent upwelling, since tributaries are natural discharge areas for groundwater.

An extensive underdrain system would be required beneath the landfill within the portion of NT-3 to be filled and beneath the landfill where other valleys containing springs and seeps are located. The intent of this underdrain system would be to intercept potentially upwelling groundwater 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 where the underdrain section is located on the site. 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. These backfilled existing channels would behave hydraulically as underdrains to allow shallow groundwater discharge preferably to surface water on the downgradient side of the landfill. The underdrain system would be designed to prevent clogging and would be sized to accommodate the flow rates of the intercepted groundwater, based on field measurements and groundwater modeling.

The underdrain would be installed down into the native residual soil/weathered bedrock and would provide a lower pathway for groundwater movement than currently exists. The upgradient shallow French drain would intercept and divert shallow, perched groundwater (which flows down slope during storm events) around the landfill. Construction of the landfill would eliminate groundwater recharge within the footprint of the landfill. Consequently, these measures would collectively lower groundwater levels and reduce groundwater fluctuations beneath the landfill.

The facility underdrain ensures the water table would not rise above the underdrain and into the geologic buffer. However, the underdrain system would 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 groundwater system and migrate downgradient in the aquifer zone, some leachate would be captured in the underdrain system and discharge into surface water. Underdrain discharge points would be included in annual detection monitoring plans as groundwater sampling points as has been done for 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 F).

With groundwater monitoring at the discharge points for the underdrain, the underdrain could function as a tertiary LDRS. Thus, if a leak in the liner system occurred, collection of groundwater would be simplified.

Leachate Collection and Transfer System: As previously stated, the perforated leachate collection and detection piping (see Figure 6-7) would collect leachate draining from the waste. The perforated collection pipes would connect to solid double wall pipes that extend through the clean-fill perimeter dike. As was done for the EMWMF (DOE 2001a), redundant perforated collection pipes would be installed at slightly higher levels than the primary collection pipes to provide an added factor of safety against clogging. The solid pipes would penetrate the liner, and would be sealed to the geosynthetic layers to prevent leakage through the penetration. Other features (e.g., anti-seep collars, plastic water stops in the dike sealed to the solid pipe) would be installed to further reduce the potential for leakage along the outside of the pipe. The solid double wall pipes from the collection system and detection system in each cell would connect to manifolds that flow to leachate storage tanks. If necessary, lift stations and pumps would be used to assist in transferring leachate to the storage tanks. Flow meters would be installed to measure the leachate volume from each collection and detection pipe during disposal activities, cap construction, and during the long-term maintenance period following capping and closure. Leachate generated from the landfill would be properly collected, characterized, and transported to a permitted treatment facility on the ORR, or, if it meets discharge criteria, would be discharged to an on-site outfall.

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 vectors. This layer, referred to as daily cover or intermediate cover, may be stripped, stockpiled, and reused prior to placement of subsequent layers of waste, as practicable, to conserve air space within the landfill.

Cover System: After support facilities 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 13 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.

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.
- Granular Contour/Vent Layer – 1 ft thick (minimum) layer of No. 57 stone which serves 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.
- 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 include gas vent flaps (i.e., small diameter openings in the geomembrane with cover flaps) for venting landfill gas that accumulates within the underlying granular contour/vent layer.

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.
- Accommodate settling and subsidence to maintain the cover's 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 requirements listed above follow the TDEC requirements set forth in TN RULE 0400-02-11-.17, subparagraph (2)(d) that "covers must be designed to minimize to the extent practicable water infiltration, to direct percolating or surface water away from the disposed waste, and to resist degradation by surface geologic processes and biotic activity." 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 ratio of four horizontal to one vertical (4:1) or flatter. 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 13 ft thick, multilayer final cover system would be comprised of the following layers starting from the top of the waste and moving upward:

- Gas Vent/Collection 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 is part of the Interim Cover System to provide a working and contouring surface, but then later functions as a gas collection layer for the Final Cover System. It is 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.

- Compacted Clay Layer – 1 ft thick (minimum) layer of unamended, native clay soil or amended soil compacted to produce an in-place hydraulic conductivity less than or equal to 1×10^{-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 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 $\leq1\times10^{-7}$ cm per second) unamended 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 1×10^{-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 1×10^{-9} cm per second.
- Geomembrane Layer – 40 mil thick linear low-density polyethylene 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., size No. 57 crushed limestone gravel) with sufficient transmissivity to drain the cover system and satisfy the requirements of the infiltration analysis.
- Biointrusion Layer – 3 ft thick layer of free-draining, 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 – 5 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, 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 would 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. If unvented, the accumulation of these gases beneath the landfill cover could reduce the stability of the cover system and create a potentially explosive environment. Thus, as a minimum, the landfill cover would include a passive gas collection and venting system to collect and remove gases that accumulate beneath the landfill cover. 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. In the conceptual design, this layer is referred to as the granular contour/vent layer. It serves the dual purpose of providing a contouring fill and gas vent layer. The contouring fill establishes uniform contours upon which to construct the overlying layers of the cover system.

6.2.2.5 Support facilities

A brief description of support facilities for the EMDF is provided below. 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 infrastructure for the EMWMF and being in close-proximity to existing utilities. For the conceptual design, it is assumed the EMDF 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
- Weigh scale
- Guard shacks

The following new support facilities would be constructed:

- Parking areas
- Laydown/storage/staging areas
- Material stockpile area
- Spoils areas (temporary and permanent)
- Guard shacks

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 the 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 the 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 in the southern extents of the BY/BY, and to avoid excavating for construction of support facilities.

The planned haul road extension under the UPF project will impact wetland areas. In kind, in place mitigation of this loss is planned through expansion and/or creation of wetland acreage at several locations within the Bear Creek watershed (B&W 2010). The southern part of the proposed EMDF footprint will potentially impact three of these planned wetland expansion areas 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.

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 transported to a wastewater treatment facility, 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.

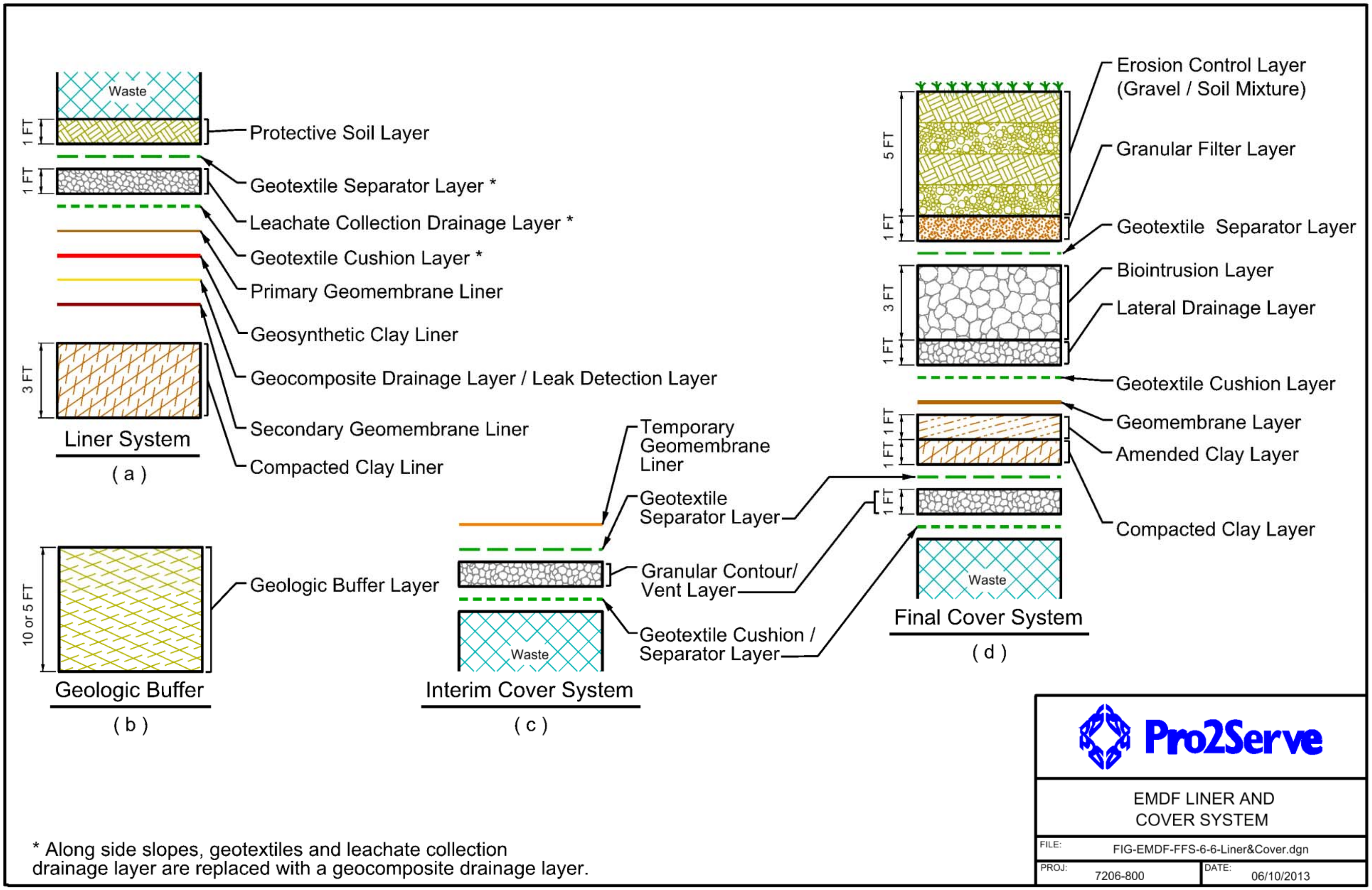

Figure 6-6. EMDF Liner and Cover Layers

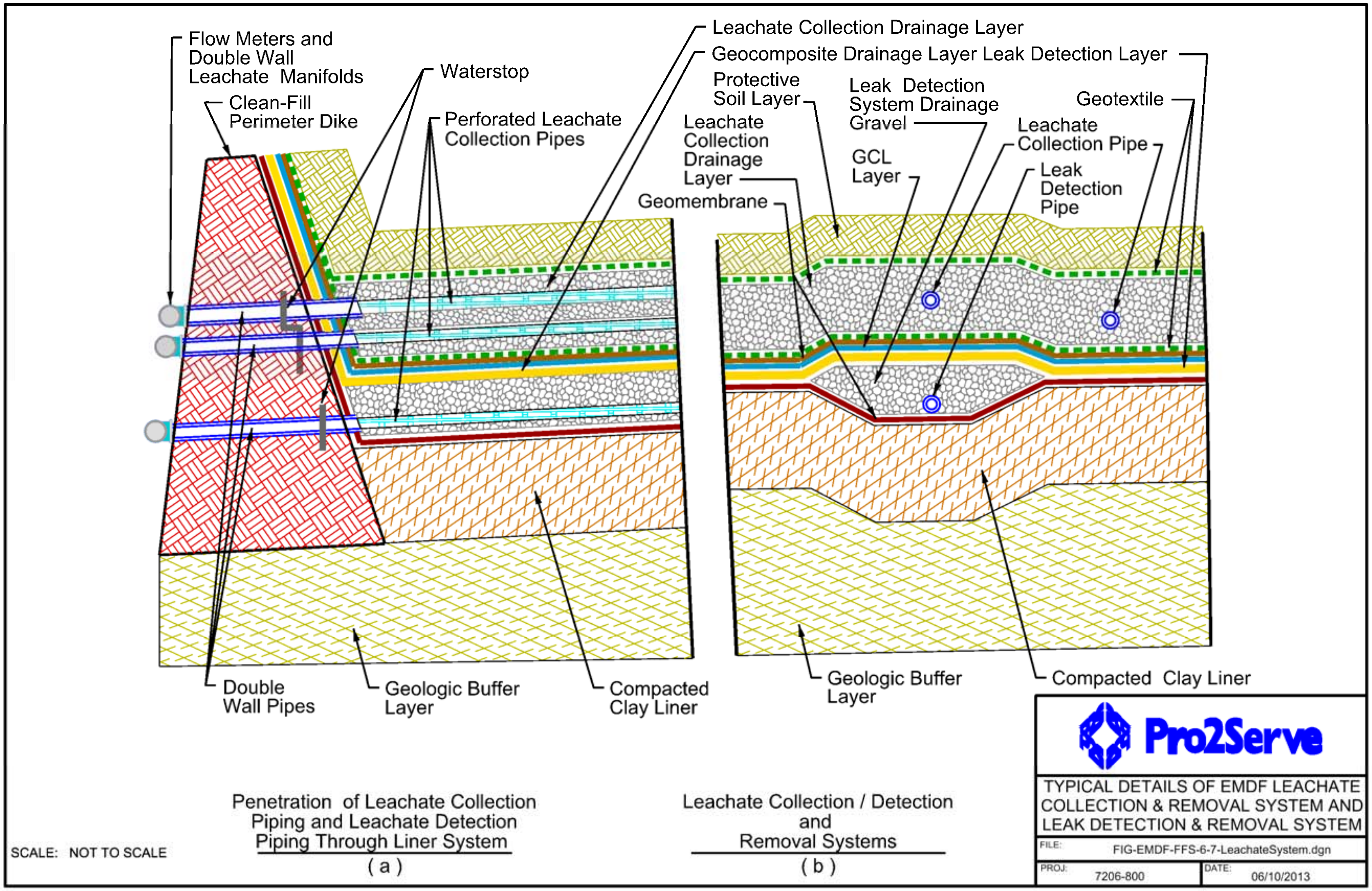

Figure 6-7. Typical Details of EMDF Leachate Collection and Removal System and Leak Detection and Removal System

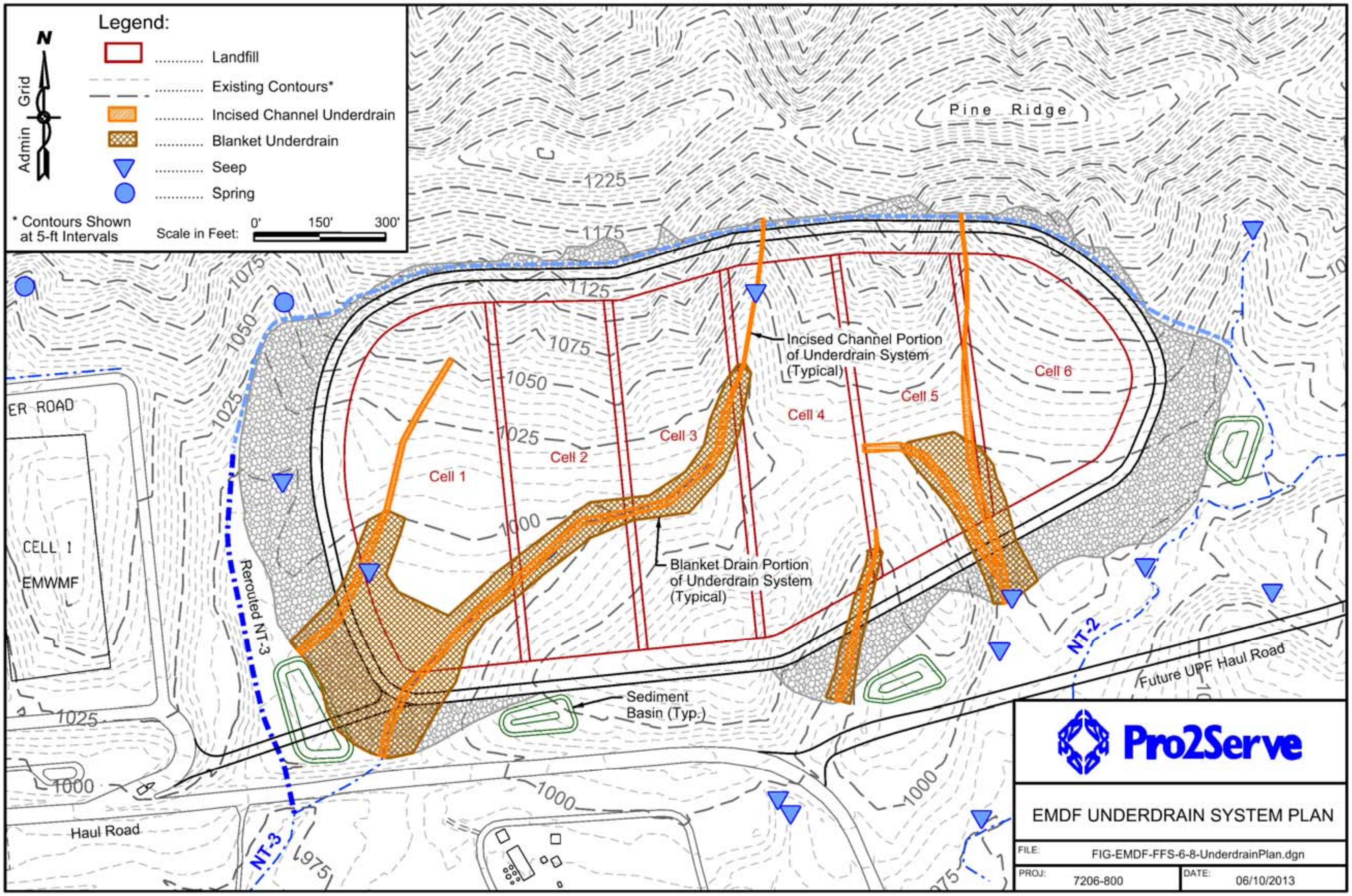

Figure 6-8. EMDF Underdrain System Plan

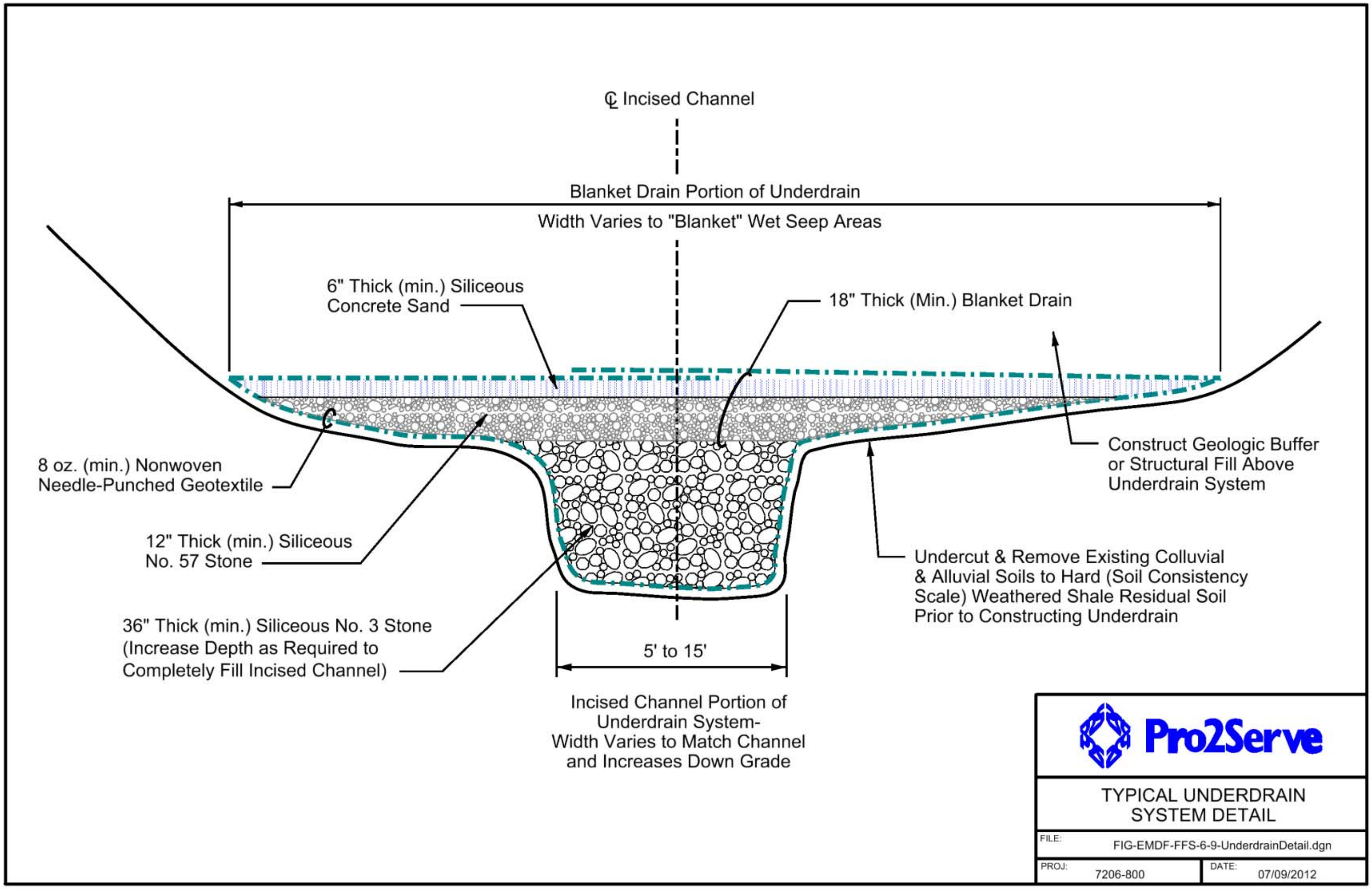

Figure 6-9. Typical Underdrain System Detail

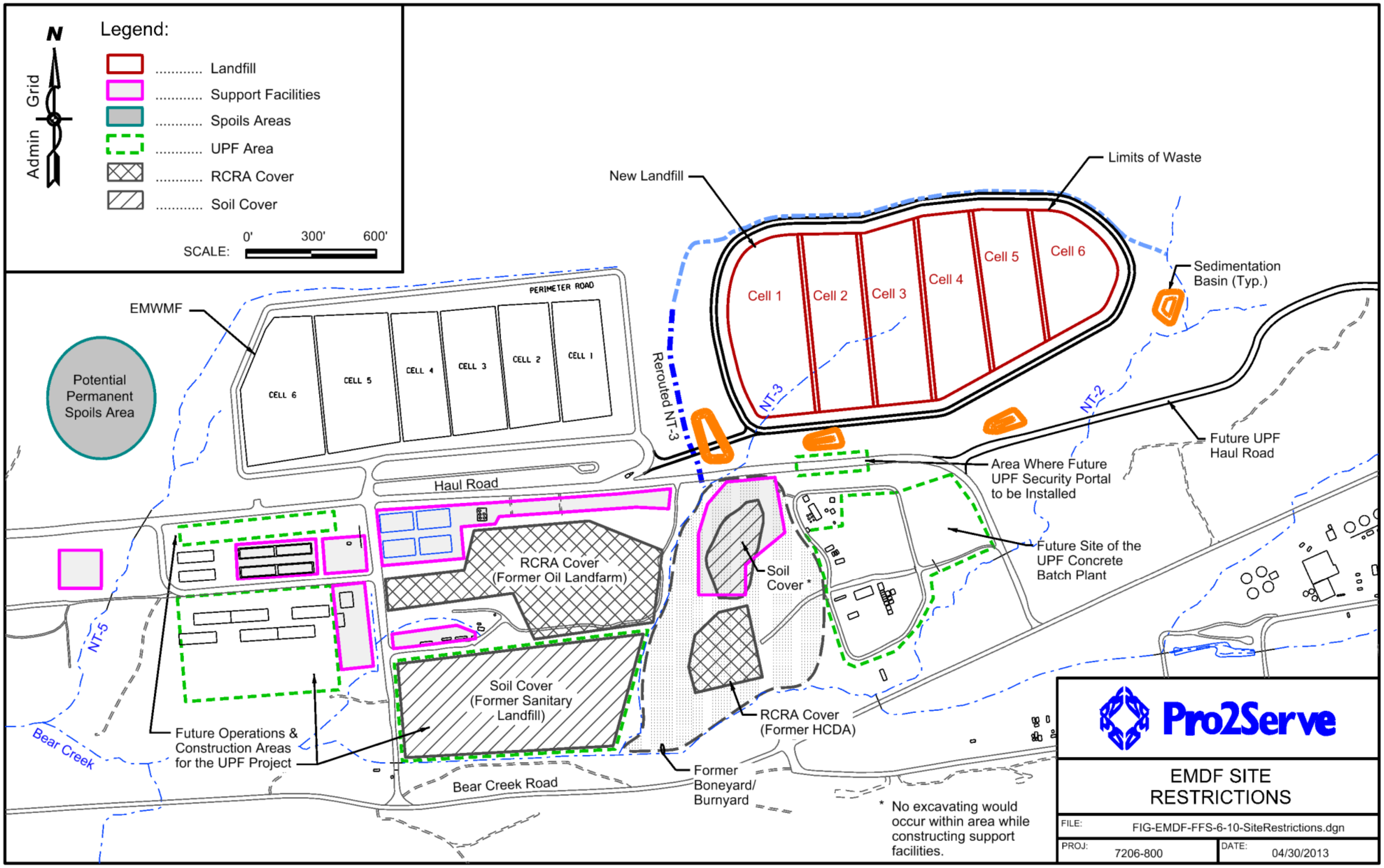

Figure 6-10. EMDF Site and Surrounding Facilities

6.2.2.6 EMDF conceptual design approach

A conceptual final cover grading plan for the EMDF landfill in EBCV is shown in Figure 6-11; landfill cross-sections are depicted in Figure 6-12. The conceptual design for the EMDF would provide a disposal capacity[12] of approximately 2.5M yd^3. With this layout, the approximately 48-acre landfill footprint (computed to outside edge of grading for perimeter clean-fill dike) would be oriented in a roughly east-west direction. 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, of which approximately 60 to 70 acres would remain permanently committed (see Figures 6-2 and 6-10). The total area of disturbance at any point in time would be reduced by phased construction, reuse of construction spoil, implementation of BMPs, and other detailed design considerations. A new larger culvert would be constructed to carry NT-3 and runoff from the EMDF beneath the 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 the 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 the EMDF. A secondary access road would be constructed along the southern side of the 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 the EMDF.

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 a historical waste management (brownfield) area, proximity to EMWMF, and the area available to feasibly construct a facility (see Appendix C). 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 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 groundwater modeling. Design groundwater modeling will demonstrate the landfill is sited a sufficient distance away from NT-2 to protect human health and the environment. Post-construction groundwater 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 groundwater, 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 Figures 6-2 and 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.

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[12]The assumed allowance of 25% uncertainty applied to waste volume estimates described in Chapter 2 corresponds to a projected disposal capacity need of approximately 2.5M yd^3.

- 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 tied into existing grade along the north side of the landfill. Using a flatter backslope was undesirable since it would create an excessively high cut slope that would not "daylight" until intersecting 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 unreasonably steep. A maximum roadway grade of 8% was set to control this and also controlled how far up Pine Ridge the northern edge of the landfill could be positioned.

Phased Construction Approach: The EMDF conceptual design allows the ability to construct the landfill in phases. The landfill would have six cells and construction of the landfill would be constructed from west to east. This approach promotes using gravity drainage for piping systems and keeps brownfield areas consolidated if it is decided in the future that later phases of the landfill construction are not needed.

It is anticipated each construction phase would build two cells of the landfill. 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 1 and part of the rough grading that would be required for Cells 3 & 4 (Phase 2) would be completed in Phase 1 to direct surface water runoff away from the newly constructed Cells 1 & 2 and towards the NT-2 drainage area.

Predicting Seasonal High Groundwater Elevations: Since existing groundwater data for the new site is limited, a reasonable but conservative estimate for the seasonal groundwater level was developed in order to set the bottom of the proposed landfill. The EMDF landfill bottom was established to leave a 10 ft buffer between the bottom of the liner system and the estimated seasonal high groundwater elevations.

The conceptual design of the bottom of the EMDF landfill is conservatively based on a potentiometric surface estimated from data obtained from *The Y-12 Groundwater Protection Program Location Information Database* (B&W 2012). There are no known wells or boring data within the proposed EMDF footprint; however, there are wells and groundwater data in adjacent areas east and west of the site. Seasonal high groundwater 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 maximum groundwater elevations from *The Y-12 Groundwater Protection Program Location Information Database* were plotted for the area around the proposed site. The locations of the existing drainageways within the proposed EMDF site were then noted and assumed to be where the groundwater table would either surface or be very shallow during seasonal high conditions. For the higher elevations of the proposed site, the seasonal high groundwater elevations were predicted by assuming they would be similar to nearby wells at the same ground surface elevation and in the same geologic formation.

As described in Section 6.2.2.4, construction of the landfill with facility underdrains, an upgradient geomembrane-lined diversion ditch, and upgradient shallow French drain would cause the groundwater table to drop beneath the landfill. The conceptual design conservatively takes no credit for lowering of the water table after construction of the landfill.

Data Gaps and Uncertainties: As previously stated, there are no known wells or boring data within the proposed EMDF footprint. However, the areas immediately adjacent to the site have been well characterized. The conceptual design for the EMDF is based on groundwater, geologic, and geotechnical data obtained immediately east and west of the EMDF site and in other locations in EBCV in similar geology. These data are deemed sufficient for formulating a conceptual 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, site-specific characterization data would be gathered as an early action in support of detailed design.

6.2.2.7 Leachate/contact water storage

The EMWMF leachate storage tanks and contact water basins and modular tanks will be used for the new landfill for collection and holding of leachate and contact water generated by the EMDF. These systems include connections to transport tanker loading stations if it is necessary to transport the wastewater to the ORNL PWTC for treatment and discharge (see Figure 6-2). 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. Collection and transfer of leachate is 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. After capping and closure of the landfill, leachate volumes would gradually decline because infiltration of precipitation into the waste would be virtually eliminated. Leachate stored within the waste would drain into the leachate collection system over time and be collected at a much lower rate.

The portion of precipitation that falls within an open, active cell potentially coming in contact with the waste materials and collecting on the floor of the cell (referred to as “contact water”, but may meet the definition of contaminated storm water in 40 CFR 445.2[b]) would be pumped out of the active cells and stored temporarily in lined basins located near the landfill. While in the basin, the contact water would be sampled and tested to determine whether it is contaminated. If the results of the analytical tests indicate the contact water meets discharge requirements, it would be released to the storm water detention basin. If contaminated, the contact water would be transferred to one of the two tanker truck loading stations for transporting to the PWTC. It is recognized that “contact water” could be defined as leachate in some instances where the storm water comes into contact with waste. There are, however, other instances where the water collected within a cell above the protective soil layer has not come in contact with the waste. Managing the water collected above the liner system separately from leachate is intended to reduce leachate management costs. This is done by separating the leachate that has percolated through the waste and into the LCRS from the contact water that may or may not have touched the waste at all. Even though the contact water is managed separately from the leachate, contact water is potentially contaminated and is, therefore, tested using the same standards as leachate. Discharge criteria for contact water, and any other potentially contaminated water, are defined by the relevant subsections within DOE Order 458.1(4) and TDEC Rule 1200-04-03. These are listed in detail in Appendix E within Table E-3 under the Wastewater Discharge section.

6.2.2.8 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 and discharged. 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. Final design for the EMDF should take into consideration the need to manage multiple storm events and also consider that this is a more specialized construction project than what is typically being evaluated.

After EMDF capping and closure, contact water would no longer be generated and the leachate generation would decline to a very low flow rate. Long-term collection and storage of leachate would continue with trucking as-needed to the ORNL PWTC or other appropriate treatment facility on the ORR.

6.2.2.9 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 the EMDF.

Process modifications that may be considered for the EMDF include geochemical immobilization technologies designed to retard movement of contaminants, in-cell solid waste treatment, and waste volume reduction processing. 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.

Geochemical Immobilization: PWAC are presented in this RI/FS based on conceptual facility design and assumed receptor exposure conditions (see Appendix F). For calculating the PWAC, wastes are assumed conservatively to be disposed of throughout the waste layer without segregation. However, geochemical immobilization of soluble waste radiological constituents with long half lives or other 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 in the waste disposal layer.
- Placing pulverized concrete in the waste layer to maintain a higher pH and promote geochemical stability of uranium minerals.

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.

On-site Waste Treatment: For some waste streams, it may be more efficient for treatment to meet LDRs or other WAC to be implemented at the EMDF site. In the case of waste treated by grout stabilization, the additional weight greatly increases the costs for transporting the treated waste from the generator site to the disposal facility. Mobile processing equipment would be available at the EMDF and located adjacent to the active disposal cell. Treatability studies and other quality assurance steps would be implemented to ensure effective waste treatment.

Combining Contact Water and Leachate: Depending on the chemical characteristics of both the contact water and leachate, it may be feasible to drain the contact water directly into the LCRS, combining the contact water with the leachate and managing both fluids as one waste stream (i.e., leachate). This could be accomplished by cutting small “windows” through the protective soil layer within the floor of the landfill cell and backfilling the “windows” with free-draining granular soil, thus, enabling contact water to drain rapidly into the LCRS. The “windows” could be covered with a replaceable geotextile to prevent sediment from entering the LCRS. This fluid management approach would have the advantage of simplifying landfill operations (since based on EMWMF experience much effort is expended managing contact water during landfill operations) and eliminating the costs of pumping contact water from the landfill cells and transferring it to the contact water basins and modular tanks. Implementation of this process modification would require increasing the temporary storage capacity for leachate via RCRA-compliant, double-lined basins, tanks, and associated piping and verifying the LCRS design could accommodate the increased inflow of contact water. A disadvantage of this approach would be the potential for significantly increasing leachate treatment costs if, for instance, the contact water meets discharge criteria, but the leachate does not (or vice versa) and combining the two waste streams would result in a larger combined volume that must be treated before release.

Volume Reduction Processing: This modification involves the use of volume reduction (VR) equipment to conserve EMDF disposal capacity. The study of potential VR options in Appendix B indicates a potential for significant disposal capacity and cost savings for the EMDF through VR. However, the majority of the VR activities/technologies discussed in Appendix B are applied at the project level, and are not therefore considered as process modifications.

Table 6-1 summarizes the potential benefits of VR activities for on-site disposal. Performing size-reduction of debris would significantly reduce the quantity of clean fill necessary for placing the some types of debris, and would allow debris such as masonry and concrete to be used to replace clean fill. Volume reduction equipment such as heavy duty mobile shredders, concrete crushers, and shearing machines (like a supercompactor used previously at ETTP) could be deployed for on-site processing of waste materials. Cost estimates in Appendix B indicate a cost of about $38.6M to deploy the equipment with possible savings in EMDF construction, operations, and transportation of up to $65.8M and a potential reduction in disposal capacity needs by up to two disposal cells (over 800,000 yd^3 disposal capacity). It was also estimated that recycling of metals from heavy equipment and structural steel could result in millions in cost savings and conserving over 70,000 yd^3 of EMDF disposal capacity. As described further in Appendix B, the recycling of demolition materials from radiological facilities remains a complex issue.

VR measures would typically be evaluated and implemented at the program or project level and be deployed at the demolition site where the waste material is generated. However, it may be advantageous to deploy specific VR machines at the EMDF site, which would constitute a facility modification. Mobile shredders and crushers could be deployed adjacent to the disposal cells. The process modification, therefore, might not require the additional expense of stockpiling and transporting the size-reduced product to the cell. The size-reduced product could be moved from the discharge conveyor and placed directly in the cell. Table B-3 in Appendix B indicates that VR processing of concrete and masonry alone could increase the EMDF cell capacity by over 600,000 yd^3 if the crushed concrete requires no clean fill material and if 50% of the crushed concrete is used to replace clean fill for debris placement. Additionally, the total investment necessary to deploy shredders and crushers would be less than the $38.6M necessary to deploy all the equipment discussed in Appendix B (See Table 7, Attachment B of Appendix B). The end result of VR processing would be the same mass of waste material occupying a smaller landfill volume.

6.2.3 Waste Acceptance Criteria

The characteristics of future CERCLA waste generated are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002. Appendix F describes modeling and calculations performed to develop a PWAC for the EMDF that meets applicable risk and dose criteria.

Operations at the EMDF, specifically the handling of leachate and contact water, preclude the possibility of accepting listed RCRA waste at the landfill. Therefore, the WAC for the facility will specify that no listed wastes are accepted.

Table 6-1. Summary of Volume Reduction Benefits

Parameter	Activity		
	Size Reduction	**Recycling**	**Segregation**
Basis	Shredding, crushing, and shearing operations are deployed at multiple sites as a programmatic effort.	Recycling of 25% of metal debris (44,104 tons)	Debris is segregated and diverted to the ORR Landfill.
Cost of Method	$38.6M	$5M for characterization and transportation	The cost of additional facility characterization and field surveys, and the cost of selective removal activities.
EMDF Cost Savings	Scenario A:$26.7M Scenario B: $65.8M	$9.6M from sale and EMDF clean fill savings	Reduced landfill construction and operations costs.
EMDF Capacity Gained	Scenario A: 475,281 yd^3 Scenario B: 830,258 yd^3	70,622 yd^3	Equivalent to as-disposed volume of segregated waste and associated fill.
Additional Potential Benefits	Increased landfill density with additional capacity gain of 68,419 yd^3; lower equipment maintenance costs		
Additional Notes		Assumes commercial value of $0.15/lb for metals. Implemented on the project level.	ORR Landfill construction costs are significantly lower than for EMDF. Implemented on the project level.

6.2.4 Construction Activities and Schedule

Figure 6-13 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. Groundwater monitoring wells and surface water weirs would be installed as part of the early actions to support remedial design. Also, 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; 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; 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. 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. Interim caps over the Phase I cells would be installed during Phase II when Phase I disposal activities are completed. Phase III would include additional site preparation, construction of Cells 5 and 6, interim capping of Phase II cells, and interim capping of Cells 5 and 6 after the cells are filled.

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 groundwater 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 groundwater 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 onsite 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.

6.2.5 Operations and 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, 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 leachate and contact water; storm water management, etc. Facility maintenance would include providing daily cover over the emplaced waste, as required; maintaining roadways, buildings, equipment, utilities, and other facilities; and leachate and contact water management. Waste disposal operations would be similar to those at the EMWMF.

Leachate would be transferred to temporary storage tanks and contact water would be transferred to lined basins as previously described. Filled or partially filled tanks and basins would be sampled to determine contaminant concentrations. If contaminant levels exceed direct discharge criteria, the water would be transferred to one of the two tanker loading stations for transport to the PWTC.

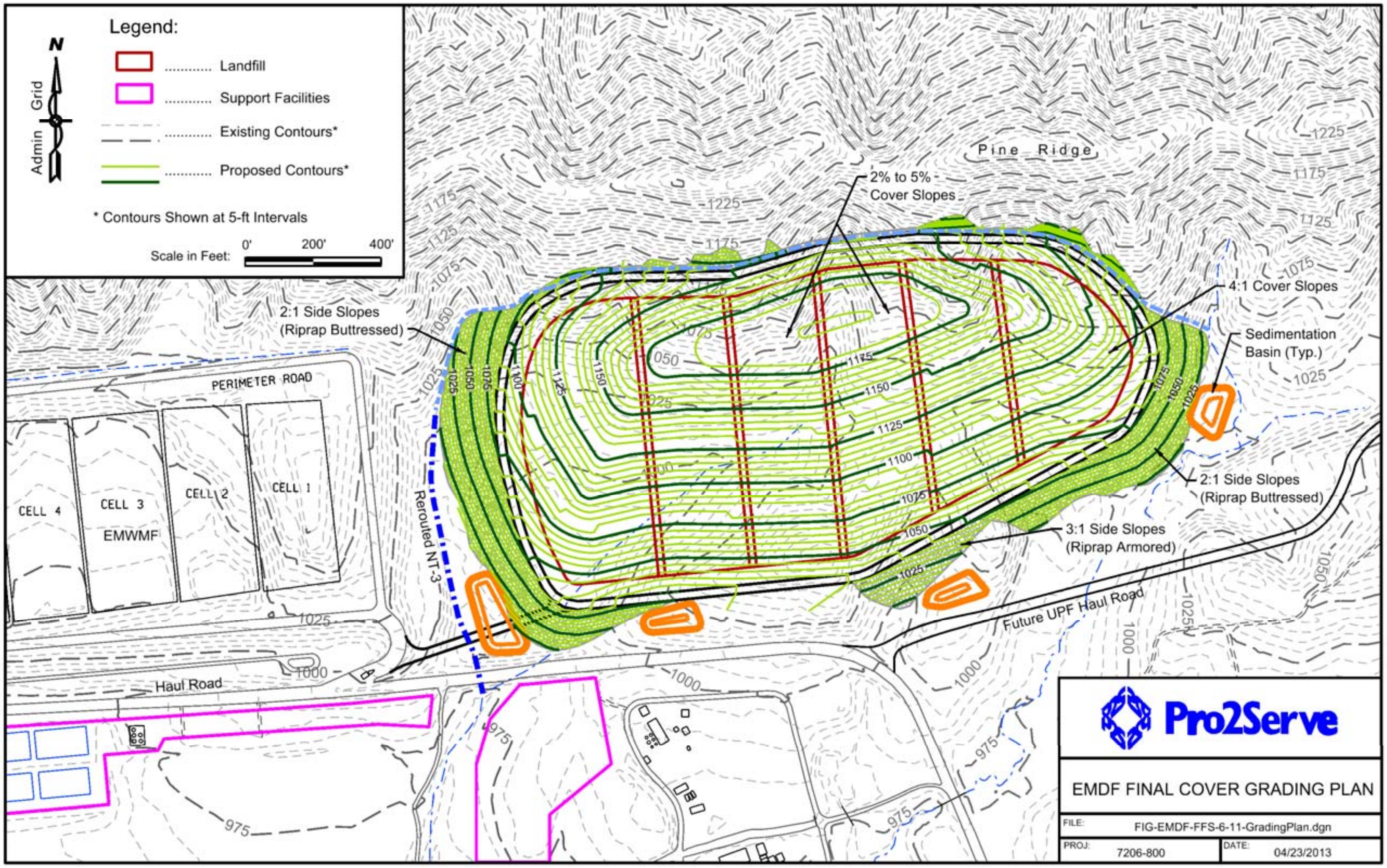

Figure 6-11. EMDF Final Cover Grading Plan

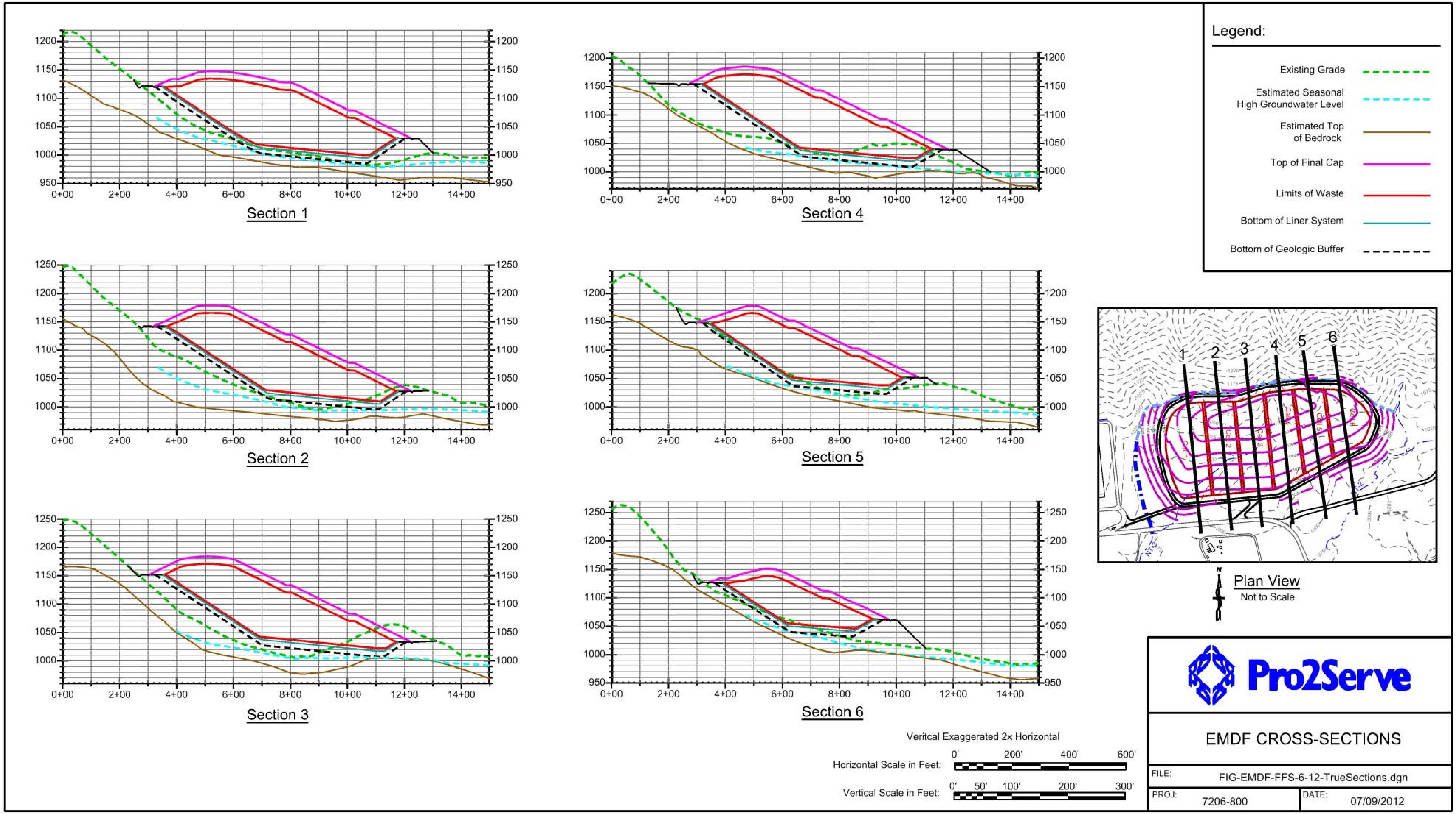

Figure 6-12. EMDF Cross-sections

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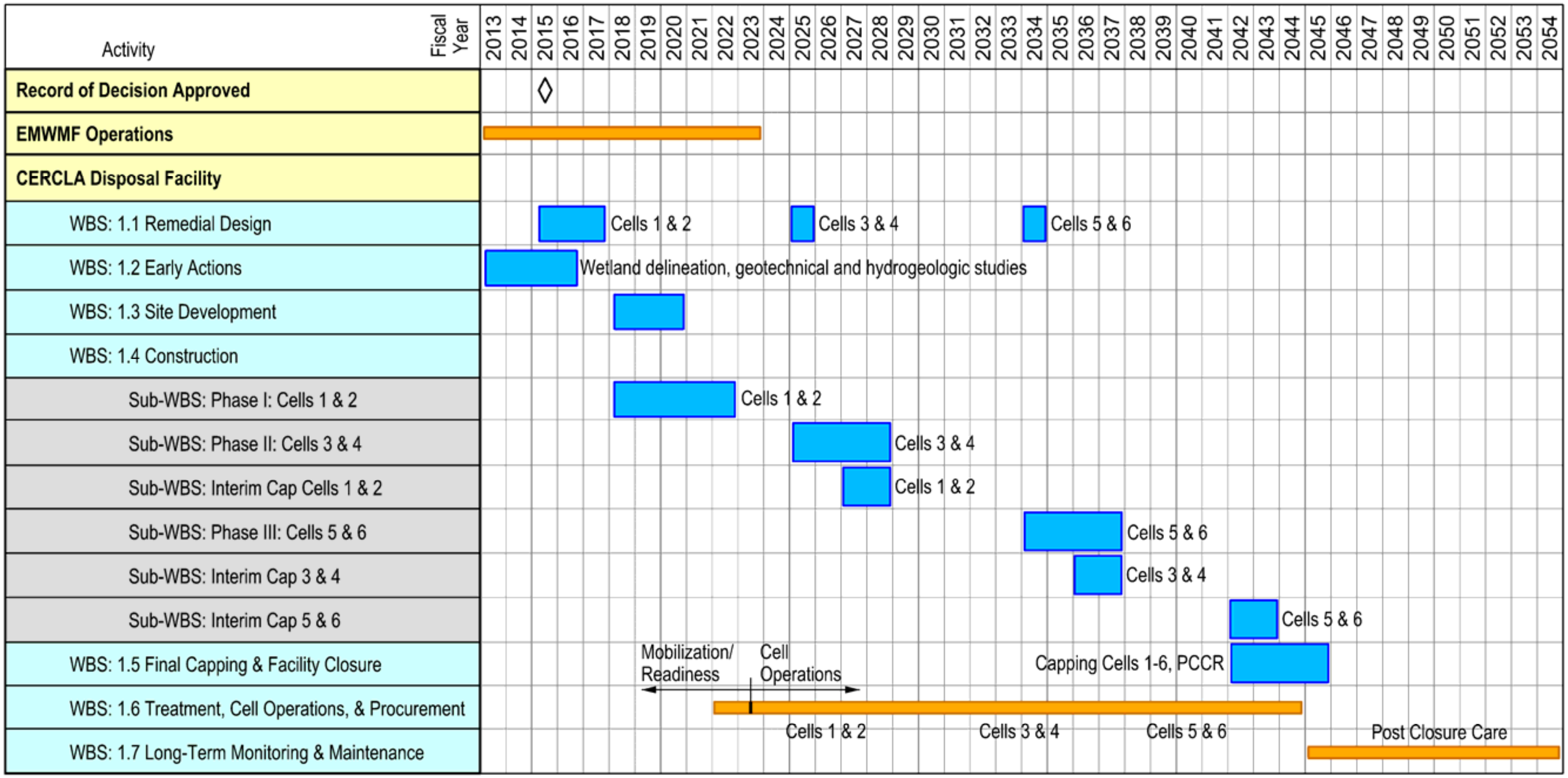

Figure 6-13. On-site Disposal Alternative Schedule

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 the EMWMF.

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

- Preparing and implementing worker protection 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 design and during construction, and restoring habitat, as needed, in consultation with appropriate state and federal agencies.
- Limiting the number of active working face 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 groundwater monitoring before, during, and after facility construction and operation and implementing appropriate contingency plans if any adverse effects were detected.
- For on- or off-site disposal, transporting waste in closed 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.

Similar measures would be in place at off-site disposal facilities, and costs are assumed to be included in disposal fees.

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.

6.2.8 Closure

After completion of waste disposal, closure activities would include final capping (i.e., construction of the final cover system). 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. Leachate tanks would be removed over time, and the storage system would be decommissioned after rates of leachate generation diminish. 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 groundwater 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 the 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

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 would be performed for an indefinite period 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 is beyond the scope of this document, but would necessarily be determined and incorporated into the ROD.

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 system, 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 transfer facilities, including transport to, and treatment of, leachate at an appropriate facility on the ORR (e.g., the PWTC at ORNL).

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 the haul road, (3) monitoring seepage emanating from the facility underdrain, and (4) groundwater monitoring. 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 groundwater 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 an early indication of liner system failure. If a failure in the liner system occurred, while contaminant leachate could percolate into the groundwater system and migrate downgradient in the aquifer zone, some leachate would be captured in the underdrain system and discharge into surface water. Also, natural groundwater flow paths are toward the tributaries, so that contaminants reaching shallow groundwater would enter the streams as base flow.

Groundwater monitoring would take advantage of the bedrock joint systems believed to underlie NT-2 and NT-3. As discussed in Appendix C, these joints help to direct groundwater 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 up gradient wells, and with indicator parameter monitoring, would meet the substantive RCRA monitoring requirements of 40 CFR 264.97 and 40 CFR 264.98.

Groundwater 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.

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 treatment required to meet the 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.

Table 6-2. Summary of EMWMF Lessons Learned

Topic	Lesson Learned Description	Reference Section
Action Leakage Rates (ALRs)	It is best to use actual site and material specific data when calculating this value and not the general EPA equations and guidance. The EMWMF ALR was estimated far too low.	6.2.2.1 Remedial Design
In-Cell Clean Fill for Void Filling	EMWMF overestimated the availability of contaminated soil for filling void spaces and general placement of waste. The design of the needed void space should take into account the use of clean fill and operations should be prepared for the need to use clean fill.	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 groundwater 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 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 Disposal Facility
Composite Liner between LCRS and LDRS	EMWMF has shown that with only a geomembrane liner separating the LCRS and LDRS layers a significant volume of leachate is seeping through the LCRS and collected by the LDRS. The final liner design should consider the use of a composite liner between the LCRS and LDRS comprised of a geomembrane liner with underlying GCL to reduce the volume of leachate entering the LDRS. This would require adding a GCL to the design of the liner system.	6.2.2.4 Disposal Facility
Underdrains	Underdrains can be successfully utilized in managing existing groundwater at sites, but should be appropriately designed in advance. Of landfill operations. Underdrains can provide a back-up LDRS and should be part of the groundwater monitoring plan for the facility.	6.2.2.4 Disposal Facility
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.	6.2.2.8 Storm Water Management
Preclusion of RCRA Listed Waste	Not having all components of a landfill facility RCRA compliant reduces flexibility if waste streams unexpectedly change. The contact water management system at EMWMF lacks double containment and therefore prohibits the placement of RCRA Listed Waste within the landfill.	6.2.2.9 Process Modifications

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. For CERCLA actions that transfer wastes off-site, permits are required at 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 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 2023 through FY 2043 with a 25% uncertainty applied.

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)	LLW	Debris	1,479,503
	LLW and LLW/TSCA	Soil	487,210
		NNSS (Non-Classified) SUBTOTAL	**1,966,713**
NNSS (Classified)	LLW	Debris	0
NNSS (Classified, Mixed)	LLW	Debris	1,469
		NNSS (Classified) SUBTOTAL	**1,469**
Energy*Solutions*	LLW/RCRA	Debris	57,107
		Soil	14,969
		Energy*Solutions* SUBTOTAL	**72,076**
		TOTAL	**2,040,257**

6.3.2 Description of Representative Disposal Facilities

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, NV. LLW/RCRA (mixed) waste would be shipped for treatment and disposal at Energy*Solutions*, Clive, UT. The disposal facilities are described in the subsections that follow.

6.3.2.1 Energy*Solutions*, Clive

Energy*Solutions* is located in Clive, UT, approximately 75 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
- PCB radioactive waste
- Asbestos contaminated waste
- Mixed waste
- 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. Energy*Solutions* offers a variety of mixed waste treatment processing 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 degrees Celsius 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 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*)
- 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 hazardous 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, sealands, 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

EnergySolutions is capable of receiving both truck and rail shipments. The existing rail spur at the ETTP truck-to-rail 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 Material
- PCB certification – information about the type of PCB waste included

For waste streams requiring treatment (other than macroencapsulation) 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, NV, approximately 65 miles northwest of Las Vegas, NV. The facility is licensed and permitted to receive the following waste types for disposal:

- LLW
- TRU waste
- 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 solely 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, AZ and then transferred to trucks for final delivery to NNSS. The existing rail spur at the ETTP is available for use 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 Order 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 Off-site Disposal Description

Figures 6-14 and 6-15, respectively, show the off-site disposal activities and responsible entities for waste shipments to Energy*Solutions* 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, AZ. All classified waste LLW shipments to NNSS would be by truck transport. LLW/RCRA (mixed) waste would be shipped by rail for treatment and disposal at Energy*Solutions*, Clive, UT. Appendix G contains the cost estimate and additional assumptions for the Off-site Disposal Alternative.

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; local waste transport; and interim storage, as required, for waste not meeting disposal facility WAC.

6.3.3.1 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.

6.3.3.2 Packaging

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.

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 LLW/RCRA waste being treated and disposed at Energy*Solutions* or classified LLW waste disposal at NNSS. Intermodals used for LLW/RCRA waste treatment and disposal at Energy*Solutions* would be disposed of with the treated waste. Classified waste shipped to NNSS would also be disposed in non-returnable containers.

6.3.3.3 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 truck-to-rail transfer facility at the 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 before placement on the trucks. LLW/RCRA waste would be transported to the truck-rail transfer facility at ETTP for rail shipments to Energy*Solutions*. Non-classified LLW and LLW/TSCA waste would be transported to the truck-to-rail transfer facility at ETTP for rail shipment to Kingman, AZ and subsequent transfer to trucks for transport to NNSS.

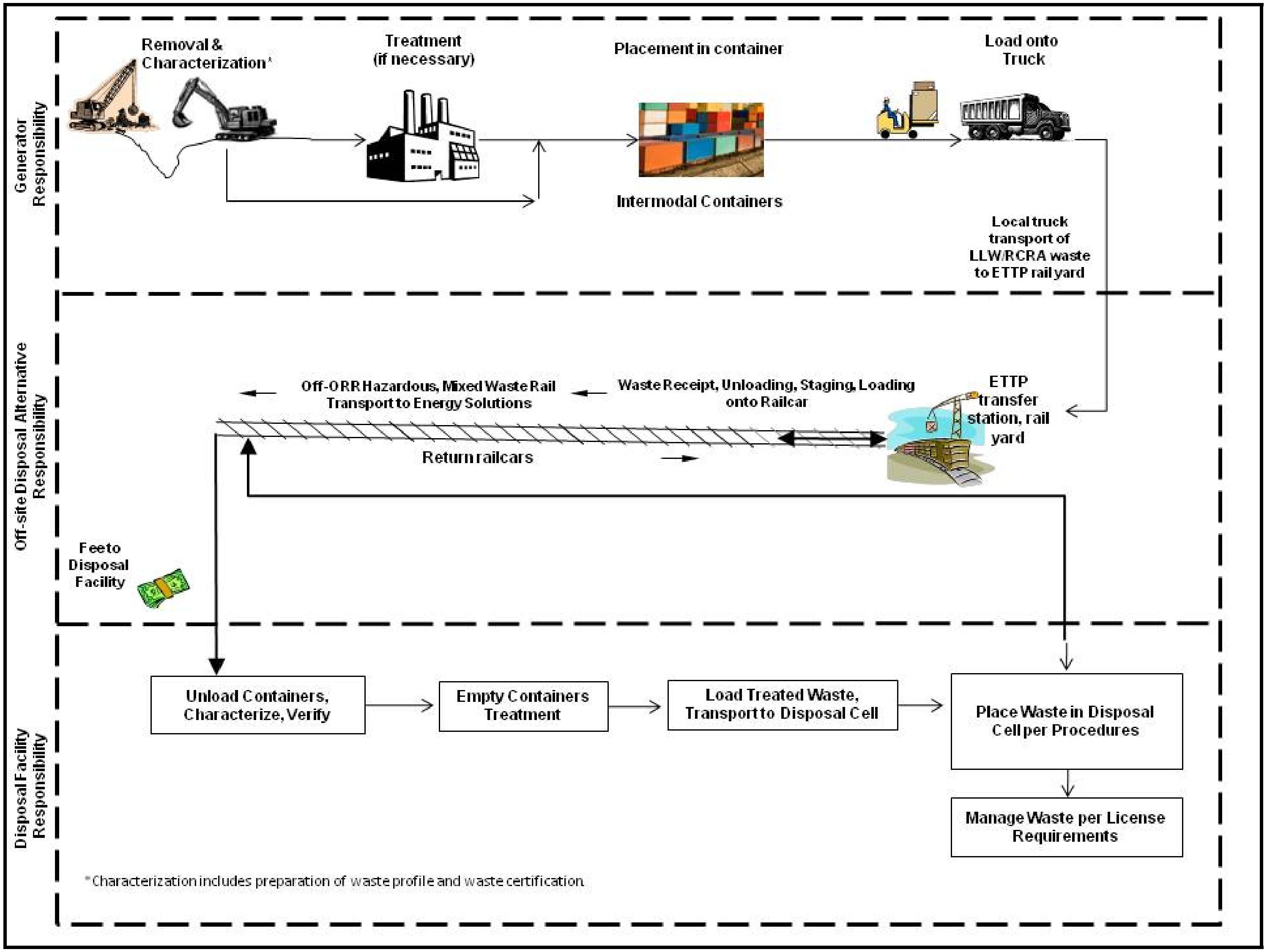

Figure 6-14. Schematic of Responsibilities for Waste Shipments to EnergySolutions for Off-site Disposal Alternative

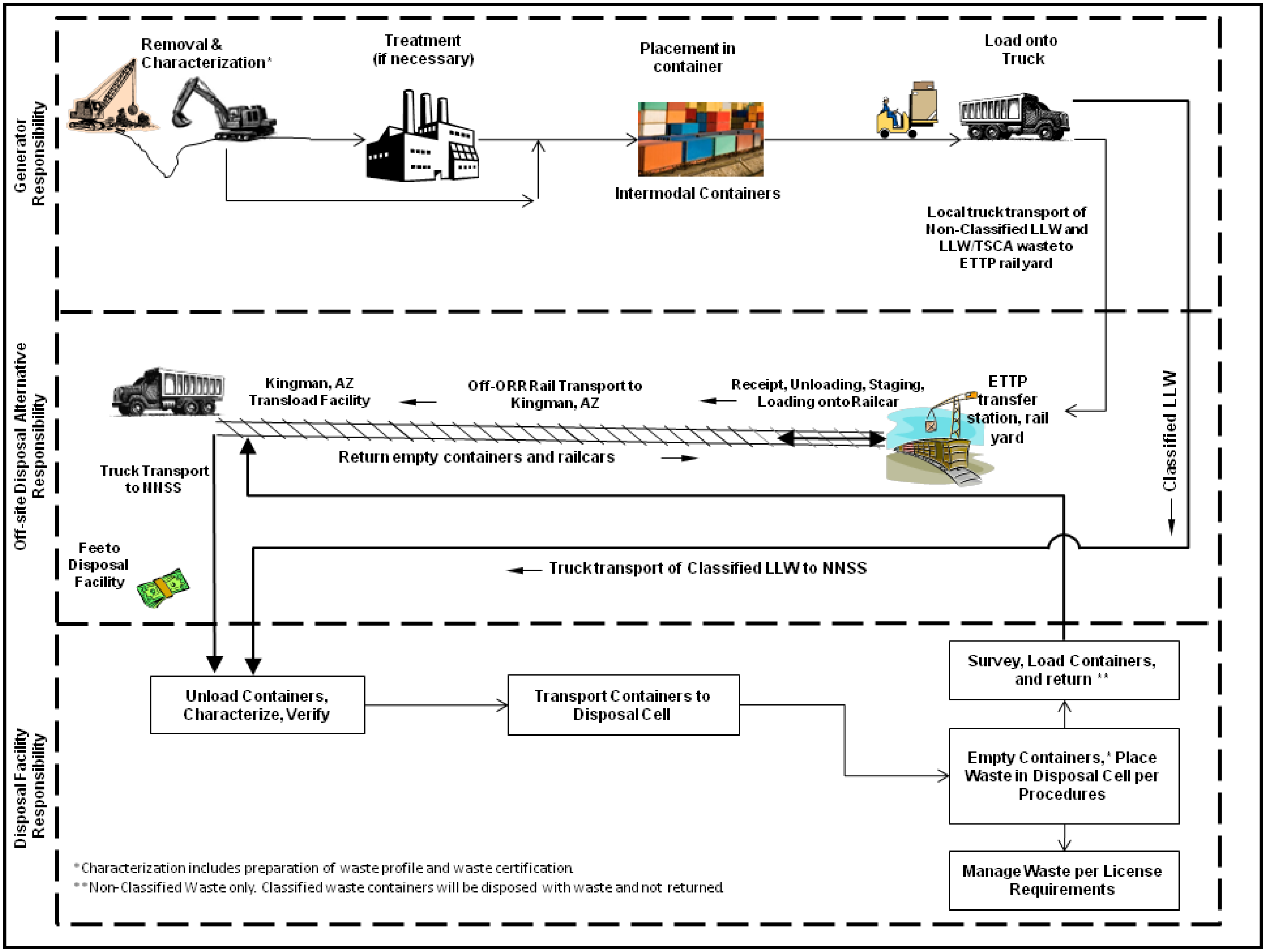

Figure 6-15. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative

6.3.3.4 Truck-to-rail transfer facility at ETTP

Rail transportation of waste is assumed for all non-classified waste being shipped for off-site disposal. The existing truck-to-rail waste transfer facility at ETTP would facilitate the transfer and staging of waste containers from trucks to railcars. No capital improvements would be required at ETTP to handle loaded intermodal containers. Wastes in intermodal containers delivered by truck from generator sites would be staged at an existing docking area and loaded onto ABC railcars on the rail spur next to the docking area 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.

Approximately 167,130 intermodal containers would be transported from the individual remedial sites to the rail transfer facility at ETTP. Each railcar would carry either six or eight intermodal containers resulting in 817 railcar loads to Energy*Solutions* in Clive, UT and 22,247 railcar loads to Kingman, AZ for truck transfer to NNSS.

It is assumed that DOE would lease dedicated railcars. 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.

6.3.3.5 Off-ORR transportation

All LLW/RCRA (mixed) waste would be transported in intermodal containers by rail and disposed at the Energy*Solutions* facility in Clive, UT. The assumed rail route to Energy*Solutions* (see Figures 6-16 and 6-17) 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. 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, KY, 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, IL. The route continues west through Illinois and crosses into Iowa at Burlington. The route continues through Lincoln, NE; Denver, CO; and Grand Junction, CO before arriving in Clive, UT. Based on 817 railcar loads to Energy*Solutions*, approximately 1.1M railcar miles (1.8M railcar km) would be traveled between Oak Ridge, TN and Clive, UT. The total number of actual train loads would depend on the number of railcars per train.

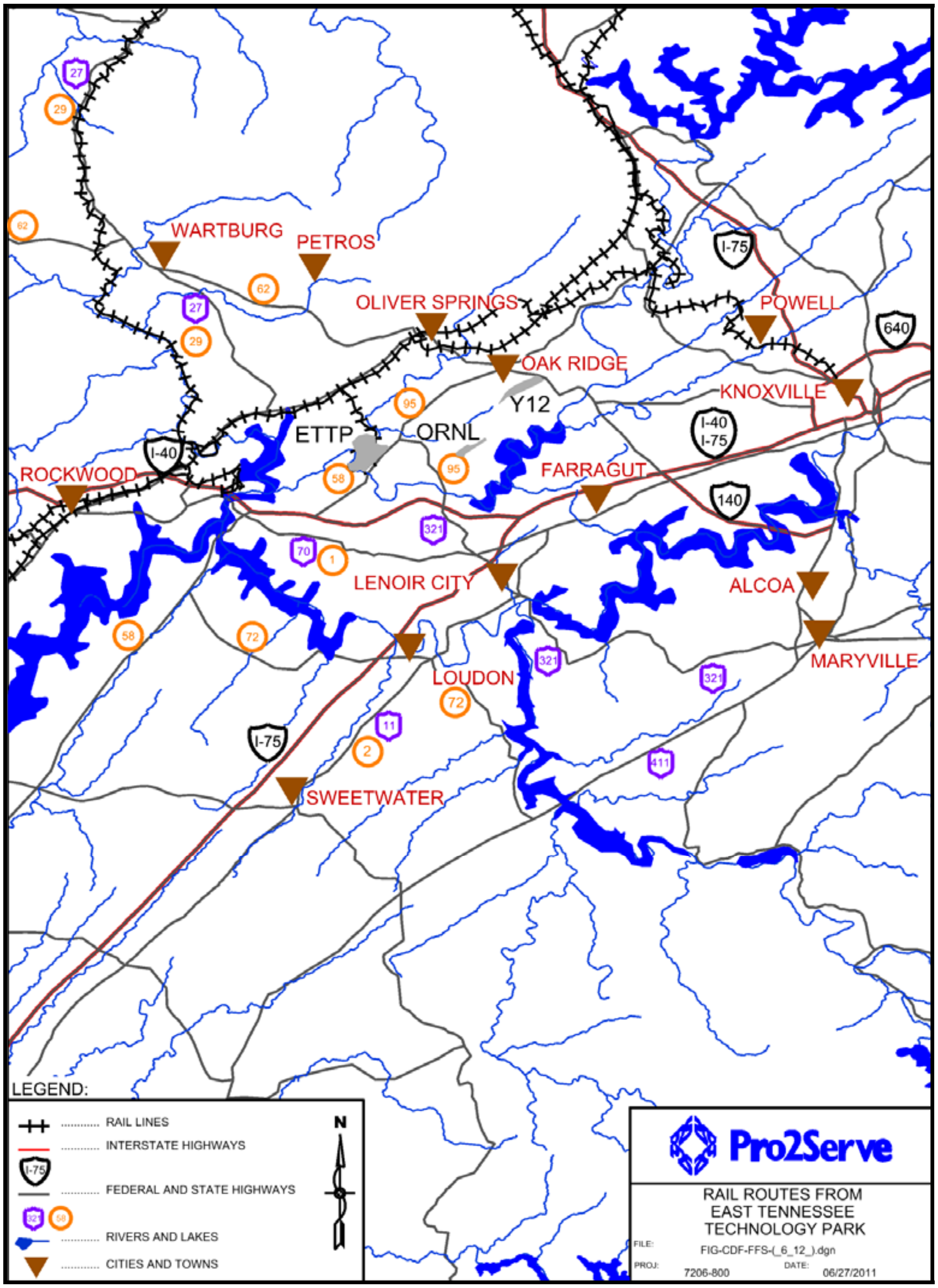

Figure 6-16. Rail Routes from ETTP

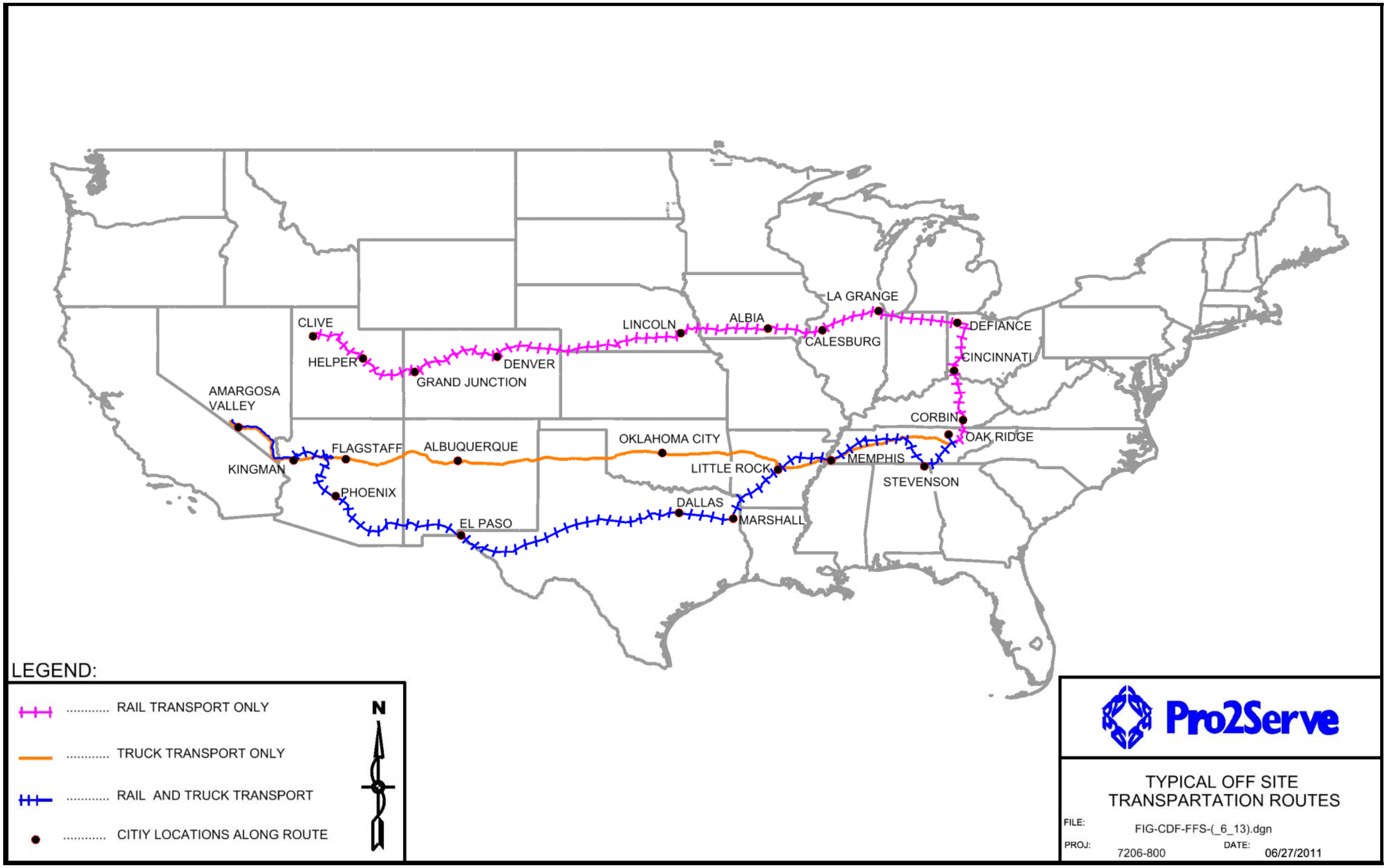

Figure 6-17. Typical Off-site Transportation Routes

For non-classified LLW and LLW/TSCA waste, this RI/FS assumes rail shipment to a transfer facility at Kingman, AZ. The assumed rail route to Kingman, AZ (see Figures 6-16 and 6-17) 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, AR, Dallas, TX, El Paso, TX, and Phoenix, AZ. In Phoenix the cargo transfers to the BNSF line and continues north through Flagstaff, AZ before arriving in Kingman, AZ. Based on 22,247 railcar loads to Kingman, AZ, approximately 53M railcar miles (86.0M railcar km) would be traveled between Oak Ridge, TN and Kingman, AZ. The total number of actual train loads would depend on the number of railcars per train.

At Kingman, AZ, intermodals would be transferred from railcars to trucks for the trip to NNSS in Nye County, NV. The assumed truck route from Kingman, AZ to NNSS (see Figure 6-17) is approximately 214 miles (343 km) long. Based on 99,834 truckloads, approximately 21,364,476 truck miles (34,382,706 truck km) would be traveled between Kingman, AZ and NNSS. On the return trip, trucks would carry empty intermodals back to Kingman, AZ for transfer to railcars and the return trip to Oak Ridge, TN.

A 40-day round trip is assumed for rail transportation to Clive, UT or Kingman, AZ. The lease fee would be paid monthly. The number of railcars leased would change as the rate of waste generation changed.

For classified LLW waste, truck transportation is assumed for the trip from Oak Ridge, TN 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 67 truckloads, approximately 137,752 truck miles (221,690 truck km) would be traveled between Oak Ridge, TN and NNSS.

From Oak Ridge, TN the intermodals would be loaded onto trucks and the trucks routed to Nashville, TN. From Nashville the truck would proceed thru West Memphis, AR, and Oklahoma City, OK. After passing thru Oklahoma City the truck would pass thru Vega, TX, Kingman, AZ and then arrive at Amargosa Valley, NV.

6.3.3.6 Disposal

Both the Energy*Solutions* 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 NNSS 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* for treatment/disposal as well as classified LLW shipped to NNSS for disposal would be packaged in purchased (non-returnable) intermodal containers.

Table 6-3 provides the estimated volumes that would be disposed at Energy*Solutions* 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 yd^3 for estimating purposes (NNSA 2008). In general, disposal fees at Energy*Solutions* depend on the classification of the waste (e.g., LLW or mixed waste), the type of the waste (e.g., soil, debris, etc.) and packaging. Mixed LLW/RCRA waste is assumed to undergo treatment to meet LDRs at Energy*Solutions* prior to disposal. Mixed waste treatment by macroencapsulaton is assumed for purposes of the RI/FS.

6.3.3.7 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.

6.3.3.8 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.

6.3.3.8.1 Disposal at WCS

WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, TX. 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 opened and bulk transport of debris and soil is allowed with non-containerized disposal. Non-containerized disposal at WCS is currently not allowed and will require approval of a license amendment.

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. Operation of the FWD facility is expected to begin in 2012.

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 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-gal drums fit in a cylindrical MCC. Rectangular MCCs are 9 ft, 6 in. long x 7 ft, 8 in. wide x 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, TX is approximately 1,177 miles compared to about 1,862 for Energy*Solutions* and about 2,085 to NNSS. Consequently, transportation costs are expected to be lower for WCS by about two-thirdss relative to Energy*Solutions*. The difference in transportation costs will be somewhat less than one-third, since the assumed shipments to the NNSS would not change. DOE recently entered into a contract with WCS, but disposal fee information is not yet available for Federal waste shipments. If disposal rates are comparable to Energy*Solutions*, WCS overall off-site disposal costs would be competitive with other off-site facilities.

6.3.3.8.2 Transportation by gondola

Currently not feasible, but possible with infrastructure upgrades, the lowest cost form of transportation of CERCLA waste to off-site disposal facilities is likely to be by rail using gondola carriers. Standard gondolas have a volume capacity of about 100 yd^3 and supergondolas have a volume capacity of about 230 yd^3. This form of transportation would require construction of a transload station at the ETTP capable of loading gondolas from dump trucks. NNSS is not accessible by rail and transload stations near NNSS are not equipped for unloading loose debris or soil from gondolas to highway transport containers. WCS can also receive waste by rail, but currently does not have the capability to unload gondolas. 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 for both is about 110 tons.

6.3.3.8.3 Volume reduction prior to off-site disposal

VR of demolition materials through the use of size reduction equipment would substantially increase bulk density of the waste and reduce the number of off-site shipments. The cost effectiveness of size reduction would depend upon the type of material, quantity of material, and contamination levels, as well as the ability to deploy VR equipment on a programmatic basis.

Appendix B describes a plan that would deploy VR equipment for large demolition projects located at ORNL, ETTP, and Y-12. Deployment of this equipment is estimated to cost about $38.6M to allow VR processing for about 922,992 yd^3 of material. This assumes that VR is deployed on a programmatic basis such that the same machines or facilities are used for multiple demolition projects. Uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement this approach.

The avoided shipping volume would be expected to be more than 313,767 yd^3 which is equivalent to an avoided cost of $251M in 2012 dollars. The unit cost for off-site disposal decreases from $1,155 to $812 per yd^3 when VR processing is deployed on a programmatic basis. VR savings would be lower on a project basis. See Appendix B for additional information about the feasibility and cost effectiveness of deploying VR equipment for off-site disposal.

6.3.3.8.4 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 EnergySolutions 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 requirements 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 provide 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 E 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. Substantive requirements of DOE Orders serve as TBC requirements that, when specifically incorporated in a CERCLA ROD, become enforceable.

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 G. 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 G) at 25% for the On-site Disposal Alternative total cost and 20% 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 G.

Operations costs include (1) long-distance transportation costs and fees paid to off-site disposal facilities and (2) waste handling and placement, facility maintenance, and monitoring during On-site Disposal Operations, as well as (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 over the period of activity as determined by the project schedule.

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 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 is on 20,000 acres and encompasses the majority of the ORR (see Section 1.2.1 of Appendix C). 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, including DOE Orders, with the exception of a water quality discharge criteria ARAR (TDEC ambient water quality criteria [AWQC]) and two hydrologic conditions ARARs for which waivers would be requested (see Sections 7.2.2.2.1 and 7.2.2.2.3 below and Section 3 in Appendix E). Waste treatment is not included as part of this alternative. Waste generators at remediation sites would be responsible for treating wastes, if required, to ensure that wastes meet on-site EMDF WAC.

7.2.2.2.1 Chemical-specific ARARs

Chemical-specific ARARs and TBC guidance provide health- or risk-based concentration or discharge limitations in various environmental media (i.e., surface water, groundwater, 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 and TBC guidance 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 environment are presented in Appendix E. 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 requirements for how activities will be conducted 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 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 whether and to what extent aquatic impacts would occur. In addition, 10 CFR 1022 requires that the effects of any actions taken in wetlands or a floodplain be considered 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 onsite 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, contact water and leachate, will be collected and sampled. A waiver would be requested to allow discharge of contact water and leachate (to surface water) found to meet TDEC AWQC for Fish and Aquatic Life (TDEC 1200-04-03-.03(3)) rather than Recreation AWQC (TDEC 1200-04-03-.03(4)), for the periods of active landfill operation and post-closure dewatering. Therefore, the waiver would be requested based on 40 CFR 300.430(f)(ii)(C)(1), as an interim measure.

Facility design would also incorporate TSCA requirements for a chemical landfill to accommodate wastes containing PCBs at concentrations $\geq$ 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.

A waiver would also be requested from the TDEC requirement that restricts building a LLW disposal unit over any point where groundwater discharges to the ground surface (TDEC 0400-20-11-.17[1][h]). The conceptual design includes an extensive underdrain system, shallow upgradient French drain, and upgradient geomembrane-lined diversion ditch, and a landfill liner composed of multiple impermeable layers, which are designed to mitigate the hydrologic conditions at the site.

Waivers from the TSCA and TDEC hydrologic conditions requirements would be requested on the basis of demonstrated equivalent or superior protectiveness of the design. 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. Appendix E 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 2046. 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 1×10^{-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 F) 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 magnitude of residual risk for off-site disposal facilities is further addressed in Section 7.2.3.3.

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. 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 to extend for at least 200 years, as well, for design purposes. 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.

Workers and the public will be protected from direct exposure by a landfill final cover system that would prevent airborne releases and direct contact with or exposure to the waste, as well as provide shielding for radiation. The design thickness and multiple layers of the final cover system (approximately 13 ft), including a 3 ft thick biointrusion layer is expected to warn people of, and discourage people from, inadvertent penetration of the landfill and exposures to waste. Excavating through the landfill cap would require heavy equipment or many laborers; if this occurred, the intrusion would be intentional. 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 expected environmental conditions, including possible erosion and earthquakes, for the foreseeable future. This is not unreasonable since, for example, many British hill forts more than 2,000 years old are essentially uneroded. 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. A Performance Assessment will be conducted, in part, to assess the capability of the landfill design to protect from inadvertent intrusion. If the Performance Assessment identifies areas needing improvement, these can be incorporated into the final design.

Because sinkhole development presents challenges to long-term landfill integrity, site-selection criteria preclude construction of the 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 karst surface features on the south flank of Pine Ridge as further discussed in Appendix C 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 the EMDF and use of local groundwater. Active institutional controls would continue for an indefinite period and land use (e.g., ROD or deed) restrictions would be permanent. 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 the EMDF. Cleared land over the 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 revegetated 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 growth of deep-rooted trees, but would not prevent their establishment over the long-term. Plant uptake of contaminants could become an exposure pathway if roots penetrate the cap, but these contaminants would be unlikely to impact biotic resources. The cap integrity could be degraded by uprooting of trees, possibly exposing waste that might impact fauna through contaminant release.

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 NT-3 and at least one draw/ravine that flows into NT-2, would be permanent and irreversible because the landfill would be constructed over them. Neither of these areas of water flow 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 would significantly decrease following closure of the 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 the 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 groundwater from leachate migrating from the EMDF in the long-term could also eventually impact surface water quality (see Appendix F for modeling results).

Groundwater Resource Impacts: Design, construction, and maintenance of the EMDF would prevent or minimize contaminant releases to groundwater. These control elements include a multilayer cap to minimize infiltration and biointrusion; a liner that includes synthetic and clay barriers, and 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 groundwater resulting from contaminants migrating from the EMDF are provided in Appendix F. PWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF site.

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 the EMDF. Operation of the on-site EMDF is expected to continue approximately 22 years through FY 2044 with closure activities completed in FY 2046 (waste generation is assumed to occur during 21 of those 22 years, ending in FY 2043). 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 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 accidents. High-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 the 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 D.

A single route transportation analysis was completed for the On-site Disposal Alternative. Individual receptors (maximum exposed individuals [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 5.31×10^{-4} to 1.15×10^{-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 2.77×10^{-8} to 1.37×10^{-1}. Even though it is assumed that the majority of on-site travel will occur on a dedicated haul road, there would be people living and working within the zone of consideration for the risk model and thus off-link was considered in the on-site analysis. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimated 0.88 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 D 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 µg/m^3 for the 24-hour averaged PM_{10} has been established by the 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 µg/m^3 for all activities. See Appendix D 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 4.26×10^{-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 3.71×10^{-7} was determined, taking into account the facility operational lifecycle and the tornado probability. Appendix D provides detailed information for this assessment.

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 DOT and 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. Short-term effects for off-site disposal or storage of candidate waste not meeting disposal facility WAC would be as discussed for the Off-site Disposal Alternative in Section 7.2.3.4.

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 D).

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 C-17 in Appendix C, 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. Prior to the start of the on-site action, a field wetlands delineation survey would be conducted as necessary along streams and other low-lying portions of the landfill site and adjacent areas, such as existing roadways and work support areas where construction would take place, to determine the areal extent of wetlands. Wetland boundaries would be mapped using civil land surveying techniques, the results of which would be incorporated in planning and implementation, including mitigation of adverse impacts.

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. The 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 the 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 the 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. The potential for impact to surface water resources from the migration of contaminants from the EMDF in groundwater 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.

Groundwater Resource Impacts: Groundwater 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 the 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 the 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 would be performed as necessary to identify threatened and endangered species within areas of potential site disturbance before construction begins. If these species were found, plans to mitigate adverse impacts would be developed and implemented in compliance with endangered, threatened, or rare species ARARs listed in Table E-2 of Appendix E.

Construction of the 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 the 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 the EMDF would not differ from those currently existing due to the operations of the EMWMF. Trucks used to transport wastes to the EMDF from ORR would use a dedicated haul road and avoid publicly accessible routes. The increase in noise at the 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 6-13 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 2015, respectively, followed by facility construction. Waste disposal operations are estimated to begin in FY 2023 for approximately 22 years until FY 2044 when facility closure activities would begin. Waste generation is assumed to occur during 21 of the 22 years of operation. Facility closure activities would end in FY 2046. The post-closure period after FY 2046 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. 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) requires that a performance assessment be used to demonstrate the performance objectives in the Order for disposal of radioactive wastes are met. For CERCLA sites, it is DOE policy to use the CERCLA process to demonstrate attainment of these 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 performance assessments and composite analyses or appropriate CERCLA documents as described in Section II of the LFRG Charter. Through its efforts, the LFRG supports the issuance of Disposal Authorization Statements for low-level radioactive waste disposal facilities and activities. The LFRG also assists in other duties associated with LLW disposal authorizations as assigned by senior managers of EM.

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 the 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; however, any substantive provisions of any permits (e.g., ARAP) that would be required would be considered ARARs. The 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 E). NRC licensing would not be required because DOE is exempt from NRC licensing requirements; however the EMDF would be designed to meet substantive NRC LLW landfill requirements per TDEC implementing regulations at Rules of the TDEC 0400-20-11 et seq. that are identified as ARARs with one exception. 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 the EMWMF, have been constructed and are operating today, demonstrating their viability. Construction and operation of the EMDF would involve no unusual or unprecedented conditions or technologies.

Future remedial actions at the 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 F), 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 groundwater or erosion of the cap and exposure of the waste to the environment.

All release pathways at the EMDF would be monitored through leachate collection, leachate detection monitoring, surface water and groundwater monitoring, and physical inspection of external EMDF conditions. The conceptual site model (Appendix E) and groundwater modeling results (Appendix F) indicate that groundwater and surface water under and near the site can be adequately characterized, modeled, analyzed, and monitored, as required by TDEC Rule 0400-20-11-.17(1)(b). Should releases to groundwater go undetected, groundwater in the immediate vicinity of the 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. The 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 bids could be expected for procurements necessary to develop the 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 \$817M (2012 dollars) and \$547M (present worth). The cost estimate is based on a conceptual design that yields an approximate landfill waste disposal capacity (i.e., air space volume[13]) of 2.5M yd^3. A 25% contingency has been assumed, and is included in this estimate. Details are provided in Appendix G.

[13] The EMDF conceptual design of 2.5M yd^3 includes 25% uncertainty (see Chapter 2 and Appendix A).

The estimated total project cost of $817M in 2012 dollars correlates to:

- An estimated cost of $327 per unit volume of waste disposal capacity for the EMDF in 2012 dollars ($817M divided by 2.5M yd^3 disposal capacity = $327 per yd^3 disposal capacity).
- An estimated cost of $400 per unit volume of as-generated waste for the EMDF in 2012 dollars ($817M divided by 2.04M yd^3 as-generated waste[14] = $400 per yd^3 as-generated waste). 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 performance monitoring needs for the indefinite 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. 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 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 G provides further description of the total project costs and assumptions for the candidate site.

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 the 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 the 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 the 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 the 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, while forested and undeveloped, is adjacent to a brownfield area where the existing EMWMF and former waste disposal sites are located. Any future development in that area would

[14] The as-generated waste volume includes 25% uncertainty (see Chapter 2 and Appendix A).

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. Location of the EMDF at this site co-locates the waste disposal facilities in an area that is already monitored.

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 C-1 in Appendix C). The EBCV site is located in Zone 3, with an agreed upon future land use goal of "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 the EMDF at the proposed site and corresponding conceptual design capacity are summarized in Table 7-1. 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 7-1. 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	2.5M 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 kept permanently cleared of trees, 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.

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 7-1). 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 the 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 the EMDF would not result in any significant cumulative impacts to the 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. Groundwater would not be used for construction or operation of the 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. Removal of contamination and waste from these sites may result in positive long-term environmental effects by reducing the potential for exposure to and migration of contaminants, although 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 long-term 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* and NNSS facilities are located in isolated, arid environments with few 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. The considerable transportation distances required for off-site disposal would result in an increased potential for accidents that could result in 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 E). 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), Rules of the TDEC 1200-1-11-.03 and .04, and DOE Orders 435.1 and 460.1C. DOE requirements to characterize and certify wastes before transport off-site would be triggered. Because DOE Order 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 used for this alternative would be 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 nonsubstantive 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 and NNSS are both located in an arid environment, isolated from population centers. Low long-term risk to human health results from their remote location, very low precipitation, and greater depth to groundwater. The Energy*Solutions* and NNSS facilities use conventional, durable designs and materials to effectively isolate the waste. The arid climate at both 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 D.

For the transportation risk analysis, several routes were evaluated: a route for classified waste that travels by truck to the 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, UT for disposal. And a third route 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, AZ where it would be transferred to truck to make the final travel to the NNSS for disposal. 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 9.90×10^{-4} to 6.52×10^{-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 1.44×10^{-4} to 2.80×10^{-1}. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 22.7 total incidents of illness, trauma, or death. 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 D 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, AZ 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 D.

Duration of the Off-site Disposal Alternative: For the Off-site Disposal Alternative, waste disposal operations are estimated to begin in FY 2023 after EMWMF reaches maximum capacity and continue through FY 2043, a duration of approximately 21 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 could 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,* 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* receiving facility 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 E) 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 Order 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; however, the likelihood is considered minimal.

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* 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 23 years at both facilities. 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 cost for the Off-site Disposal Alternative is \$2.356 Billion (B) (2012 dollars) and \$1.556B (present worth). The cost estimate is based on the estimating methodology described in Section 7.1.7 and the technical scope and assumptions described in Chapter 6. A 20% contingency has been assumed, and is included in this estimate. Details are provided in Appendix G.

The estimated total project cost of \$2.356B in 2012 dollars correlates to an estimated cost of \$1,155 per unit volume of as-generated waste in 2012 dollars (\$2.356B/2.04M yd^3 as-generated waste[15] = \$1,155 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. Also, 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 G provides a detailed description of the total project cost 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.

[15] The as-generated waste volume includes 25% uncertainty (see Chapter 2 and Appendix A).

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, UT landfill is essentially uninhabited desert. The NNSS disposal site is entirely contained within the DOE Nevada Site, and there are no public areas within three 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 nonrenewable 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* 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 7-2 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, causing injuries or fatalities.

Table 7-2. 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 ARARs, and all but two location-specific ARARs. CERCLA Section 121(d)(4) waivers would be requested for two hydrologic condition ARARs 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 closure of the landfill.	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, more humid 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 ,while also better containing, 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, ORR CERCLA wastes will be outside of direct DOE control and oversight.
Rating	*1*	*4*	*5*

Table 7-2. 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 fewer 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 would be greater than for the On-site Disposal Alternative. Only minor, incremental environmental effects would occur at the existing off-site facilities.
Rating	*2*	*5*	*3*
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. The On-site Disposal Alternative provides a greater level of certainty than the Off-site Disposal Alternative that long-term disposal capacity would be available.
Rating	*0*	*5*	*4*

Table 7-2. 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.	Estimated total project cost is $708M (2012 dollars) and $499M (present worth). Cost per yd^3 of as-generated waste disposed is $323 (2012 dollars)	Estimated total project cost is $1.992B (2012 dollars) and $1.408B (present worth). Cost per yd^3 of as-generated waste disposed is $910 (2012 dollars)
Rating	*0*	*5*	*1*
Summed ratings	**5**	**32**	**27**

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.

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 would increase 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 two location-specific ARARs, (1) the TSCA hydrologic requirement that specifies a buffer of at least 50 ft above the historical high water table and (2) the TDEC hydrologic requirement to not have any groundwater to surface discharge points within the disposal unit footprint, and the action-specific ARAR that requires discharges to surface water meet TDEC AWQC for recreational use. "Equivalent protectiveness" and "Interim Measure" waivers per 40 CFR 300.430(f)(ii)(C) would be requested as described in Appendix E.

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 the EMDF over the long term depends on success of the facility's waste containment features, characteristics of waste placed in the 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. 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 F).

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* and NNSS in the long-term may be more reliable at preventing exposure than on-site disposal on the ORR. Energy*Solutions* and NNSS are in an arid environment that reduces the likelihood of contaminant migration or exposure via groundwater or surface water pathways. Fewer receptors exist in the vicinity of Energy*Solutions* 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 the 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 7-3 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. A breakdown of the risks for the individual routes travelled, accident versus routine travel, and fatal/non-fatal statistics is provided in Appendix D.

Table 7-3. 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	Radiological Risk Range	Vehicle-related Risk
Maximum Exposed Individuals	5.31×10^{-4} to 1.15×10^{-2}	0.88	9.90×10^{-4} to 6.52×10^{-2}	22.7
Collective Population	2.77×10^{-8} to 1.374×10^{-1}		1.44×10^{-4} to 2.80×10^{-1}	

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 the 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 HA 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* 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. 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, and could 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 is considered minimal at both representative facilities, NNSS (a DOE facility) and Energy*Solutions* (a non-DOE, commercial facility). However, given the 30 years of anticipated CERCLA waste generation, the On-site Disposal Alternative provides a 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 2.9 times that of the On-site Disposal Alternative. Estimated total project cost for the On-site Disposal Alternative at the proposed EMDF site in EBCV is $817M (2012 dollars) and $547M (present worth). For the Off-site Disposal Alternative, the estimated total project cost is $2.356B (2012 dollars) and $1.556B (present worth).

These estimated total project costs in 2012 dollars correlate to an estimated $400 per yd^3 as-generated waste (2012 dollars) for the On-site Disposal Alternative and an estimated cost of $1155 per yd^3 as-generated waste (2012 dollars) for the Off-site Disposal Alternative, with the same assumed uncertainty of 25% in waste volumes for each alternative, a 25% contingency applied to the On-site estimate, and a 20% contingency applied to the Off-site estimate.

Fuel surcharges that may be incurred during transportation of the waste to off-site disposal facilities are not included in the Off-site Disposal Alternative cost estimate. Also, rail transportation, which is approximately 11% less expensive than truck transport, is assumed for the majority of shipments.

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 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.

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 forested and 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 the Off-site Disposal Alternative ($2.356B [2012 dollars] or $1.556B [present worth]) is approximately 2.9 times the estimated project cost of the On-site Disposal Alternative ($817M [2012 dollars] or $547M [present worth]).

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APPENDIX A:

WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION DATA

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CONTENTS

FIGURES

TABLES

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) 2013 to FY 2043 by material type and by waste type, respectively. The base as-generated waste volume estimates include no applied uncertainty.

Table A-1 shows the annual base as-generated waste volume estimate for FY 2013 to FY 2043 by material type, waste type, and year. Table A-2 provides the total base as-generated waste volume estimate for FY 2013 to FY 2043 by project, material type, and waste type, per the WGF, with subtotals for the following timeframes:

- FY 2013 - FY 2023 — FY 2023 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 2023 - 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 2023 - FY 2043) with 25% uncertainty that is the basis for the Off-site Disposal Alternative waste shipments. The calculation, by year, is given by:

$AG * 1.25 \quad = \quad AG25$

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.

$\sum AG25 \quad = \quad AG25_{total}$

Annual AG25 are summed for all years (FY 2013 to FY 2043) to obtain the total, 2.04 million (M) total yd^3 of waste ($AG25_{total}$).

1.2 "AS-DISPOSED" WASTE VOLUME ESTIMATE

Prediction of AD waste volumes for the RI/FS uses a methodology that starts with the AG waste volume estimates. Figure A-3 is a schematic showing the calculations used to obtain the final AD volume from the AG 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 AD 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	As-disposed waste volume (AD) 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 AD 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, 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 (2.18M yd^3) is reached in FY 2023 and a new Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste disposal facility becomes operational in FY 2023. 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.

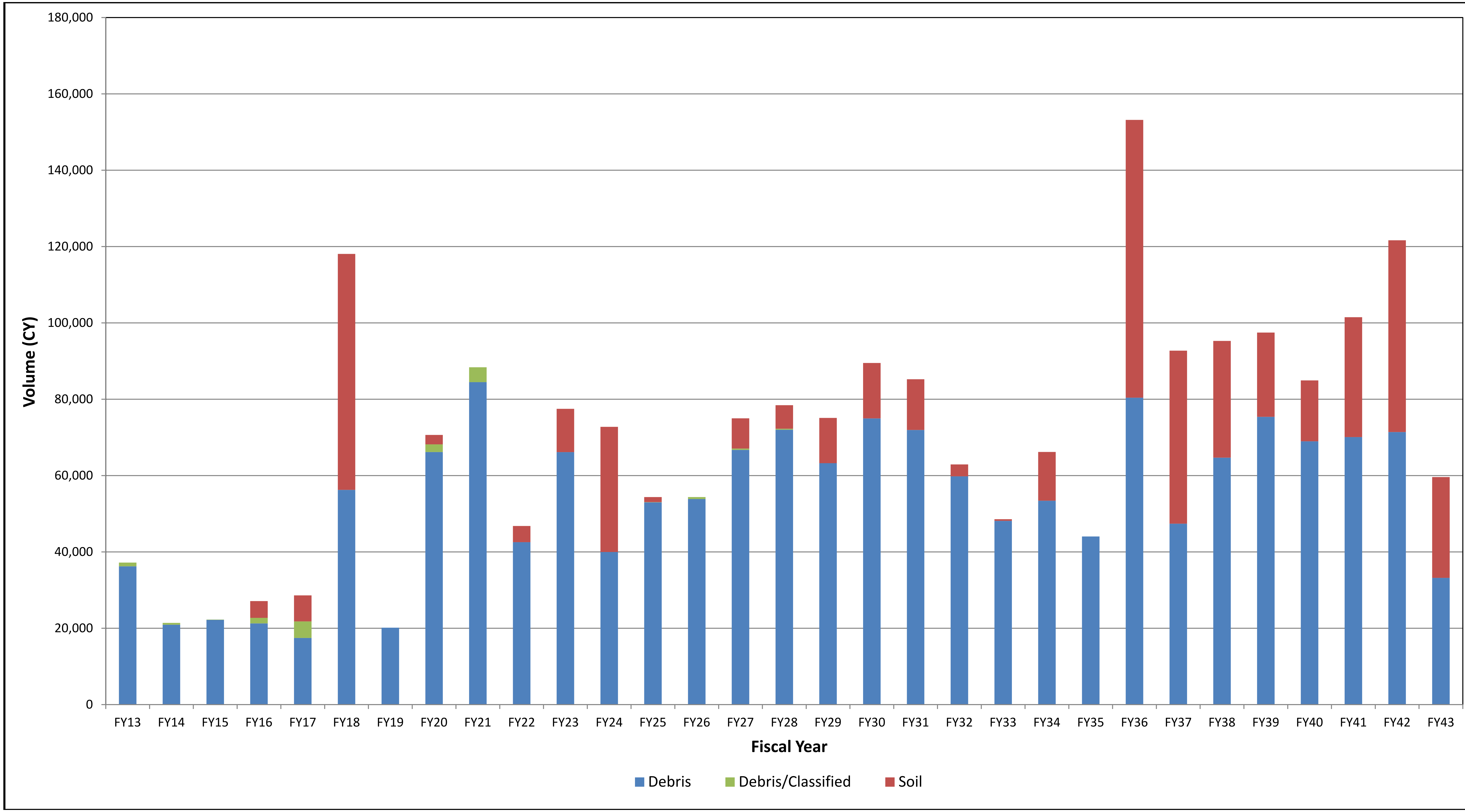

Figure A-1. Base As-generated Waste Volume Estimate by Material Type (FY 2013-FY 2043)

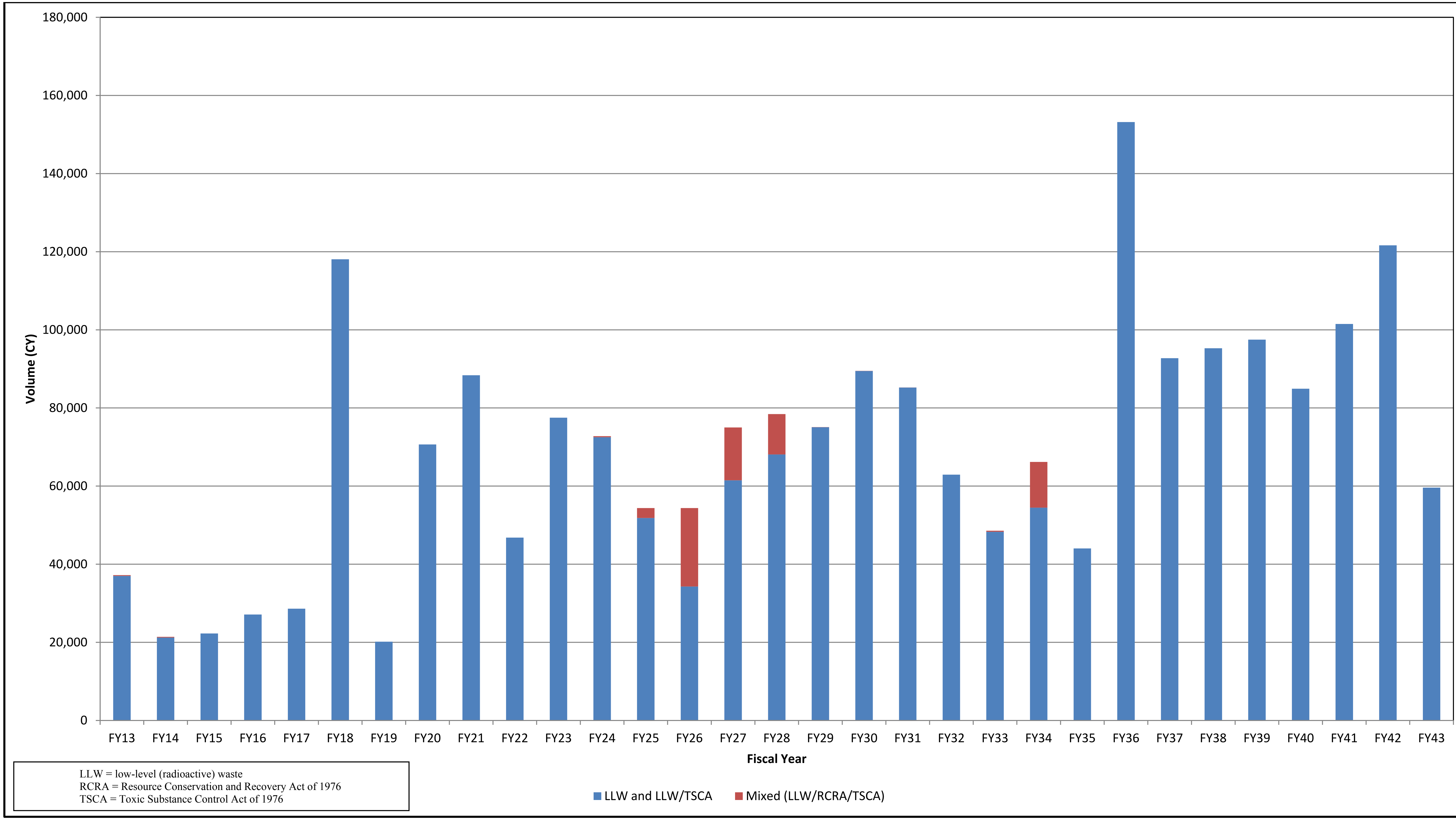

Figure A-2. Base As-generated Waste Volume Estimate by Waste Type (FY 2013-FY 2043)

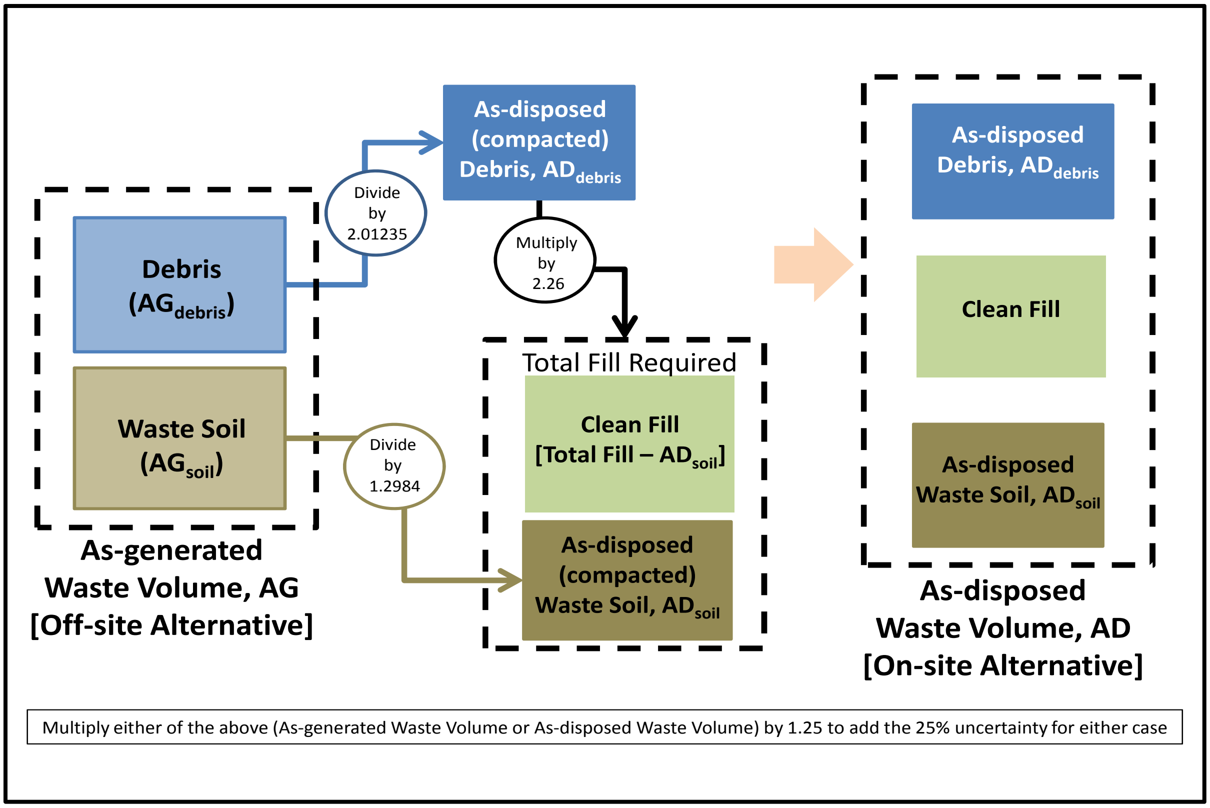

Figure A-3. Schematic of Calculations to Determine As-disposed Waste Volumes

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.

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*.

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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.

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 D) 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:

Activity_{ij} = Activity of radionuclide *i* in pCi, for WL *j*

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:

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.

$$C_i = \text{Activity}_i / [(\text{Weight}_{tot} * (453.6 \text{ g/lb})] \qquad \text{and} \qquad \text{Weight}_{tot} = \sum \text{Weight}_j$$

where:

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.

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Table A-1. Base As-generated Waste Volume Estimate (FY 2013-FY 2043)

As-generated Waste Volume Estimate (yd^3)												
Waste Type	**Material Type**	**FY2013**	**FY2014**	**FY2015**	**FY2016**	**FY2017**	**FY2018**	**FY2019**	**FY2020**	**FY2021**	**FY2022**	**FY2023**
LLW (includes LLW/TSCA)	Debris	36,039	20,732	22,181	21,291	17,464	56,265	20,164	66,178	84,478	42,559	66,152
	Debris/Classified	966	476	91	1,451	4,331			2,006	3,892		
	Soil				4,375	6,820	61,803		2,467		4,242	11,348
	TOTAL	**37,005**	**21,208**	**22,272**	**27,117**	**28,615**	**118,068**	**20,164**	**70,651**	**88,370**	**46,801**	**77,500**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	200	200									
	Debris/Classified											
	Soil											
	TOTAL	**200**	**200**									
TOTAL		**37,205**	**21,408**	**22,272**	**27,117**	**28,615**	**118,068**	**20,164**	**70,651**	**88,370**	**46,801**	**77,500**

As-generated Waste Volume Estimate (yd^3)												
Waste Type	**Material Type**	**FY2024**	**FY2025**	**FY2026**	**FY2027**	**FY2028**	**FY2029**	**FY2030**	**FY2031**	**FY2032**	**FY2033**	**FY2034**
LLW (includes LLW/TSCA)	Debris	39,717	50,527	34,290	53,535	61,945	63,221	74,938	71,924	59,806	48,148	53,415
	Debris/Classified											
	Soil	32,787	1,313		7,933	6,158	11,847	14,519	13,290	3,117	154	1,061
	TOTAL	**72,504**	**51,840**	**34,290**	**61,468**	**68,103**	**75,068**	**89,457**	**85,214**	**62,923**	**48,302**	**54,476**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	269	2,470	19,574	13,200	10,072	39	39	23			
	Debris/Classified		64	508	342	261						
	Soil										263	11,712
	TOTAL	**269**	**2,534**	**20,082**	**13,543**	**10,332**	**39**	**39**	**23**		**263**	**11,712**
TOTAL		**72,773**	**54,374**	**54,372**	**75,011**	**78,435**	**75,107**	**89,496**	**85,237**	**62,923**	**48,565**	**66,188**

As-generated Waste Volume Estimate (yd^3)											
Waste Type	**Material Type**	**FY2035**	**FY2036**	**FY2037**	**FY2038**	**FY2039**	**FY2040**	**FY2041**	**FY2042**	**FY2043**	**Total FY13-FY43**
LLW (includes LLW/TSCA)	Debris	44,045	80,407	47,406	64,701	75,384	68,995	70,084	71,420	33,207	1,620,618
	Debris/Classified										13,213
	Soil		72,783	45,330	30,580	22,096	15,936	31,414	50,221	26,401	477,995
	TOTAL	**44,045**	**153,190**	**92,736**	**95,281**	**97,480**	**84,931**	**101,498**	**121,641**	**59,607**	**2,111,826**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris										46,085
	Debris/Classified										1,175
	Soil										11,975
	TOTAL										**59,235**
TOTAL		**44,045**	**153,190**	**92,736**	**95,281**	**97,480**	**84,931**	**101,498**	**121,641**	**59,607**	**2,171,061**

LLW = low-level waste
RCRA = Resource Conservation and Recovery Act of 1976
TSCA = Toxic Substance Control Act of 1976

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2013- FY 2043)

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 (FY13-43) (yd^3)
		FY13-23 (EMWMF)	FY23-43 (EMDF)	Total LLW	FY13-23 (EMWMF)	FY23-43 (EMDF)	Total Mixed			
2026 Complex	Debris		10,012	10,012					10,012	**10,012**
2026 Complex (previous General Maintenance Facilities)	Debris		166	166					166	**166**
2528 Complex	Debris		484	484					484	**484**
3019 A & Ancillary Facilities D&D	Debris		62,674	62,674					62,674	**62,674**
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		22,710	22,710					22,710	**22,710**
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		13,856	13,856					13,856	**13,856**
9206 Complex Legacy Material Disposition (LMD)	Debris		1,634	1,634					1,634	**1,634**
9212 Complex	Debris		103,770	103,770					103,770	**103,770**
9212 Complex LMD	Debris		9,801	9,801					9,801	**9,801**
9213 and 9401-2 Demolition	Debris		8,000	8,000					8,000	**8,000**
9731 LMD	Debris		1,485	1,485					1,485	**1,485**
Alpha 5 LMD	Debris	259		259				259		**259**
Alpha-2 Complex	Debris		50,952	50,952					50,952	**50,952**
Alpha-2 LMD	Debris		22,038	22,038					22,038	**22,038**
Alpha-3 Complex	Debris		24,892	24,892					24,892	**24,892**
Alpha-3 LMD	Debris		12,216	12,216					12,216	**12,216**
Alpha-4 Complex	Debris		35,436	35,436		45,246	45,246		80,682	**80,682**
Alpha-4 Complex	Debris/ Classified					1,175	1,175		1,175	**1,175**
Alpha-5 Complex	Debris		122,623	122,623					122,623	**122,623**
Balance of Site Facilities	Debris	25,115		25,115				25,115		**25,115**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2013- 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 (FY13-43) (yd^3)
		FY13-23 (EMWMF)	FY23-43 (EMDF)	Total LLW	FY13-23 (EMWMF)	FY23-43 (EMDF)	Total Mixed			
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 4 LMD	Debris	9,000		9,000				9,000		**9,000**
Beta-1 Complex	Debris		40,460	40,460					40,460	**40,460**
Beta-1 LMD	Debris		6,460	6,460					6,460	**6,460**
Beta-3 Deactivation Only	Debris		7,256	7,256					7,256	**7,256**
Beta-3 LMD	Debris		10,761	10,761					10,761	**10,761**
Beta-4 Complex	Debris	3,818	68,176	71,994				3,818	68,176	**71,994**
Beta-4 LMD	Debris	3,793		3,793				3,793		**3,793**
Biology Complex	Debris		29,088	29,088					29,088	**29,088**
	Soil		5,069	5,069					5,069	**5,069**
BV Chemical Development Lab Facilities	Debris		1,189	1,189					1,189	**1,189**
BV Inactive Tanks & Pipelines	Debris		405	405					405	**405**
	Soil		158	158					158	**158**
BV Isotope Area Facilities	Debris		6,102	6,102					6,102	**6,102**
BV Isotope Area Facilities (3038)	Debris		1,825	1,825					1,825	**1,825**
BV Isotope Area Facilities (3026 C&D Hot Cell)	Debris		1,889	1,889					1,889	**1,889**
	Debris					15	15		15	**15**
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**
BV Tank Area Facilities	Soil		182	182					182	**182**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2013- 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 (FY13-43) (yd^3)
		FY13-23 (EMWMF)	FY23-43 (EMDF)	Total LLW	FY13-23 (EMWMF)	FY23-43 (EMDF)	Total Mixed			
Central Neutralization Facility Closure	Debris	4,406	1,337	5,743				4,406	1,337	**5,743**
Central Stack East Hot Cell Complex	Debris		5,257	5,257					5,257	**5,257**
Central Stack West Hot Cell Complex	Debris		5,011	5,011					5,011	**5,011**
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**
ETTP Property/Materials Management	Debris	22		22				22		**22**
Fire Station Complex	Debris		812	812					812	**812**
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	31,516	4,445	35,960				31,516	4,445	**35,960**
	Debris/ Classified	500		500				500		**500**
K-25 Facility D&D (ETTP)	Debris	57,006		57,006				57,006		**57,006**
	Debris/ Classified	1,533		1,533				1,533		**1,533**
K-27 Deactivation Waste	Debris	1,106		1,106				1,106		**1,106**
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 NaF Traps	Debris	30		30				30		**30**
K-27 Tie Lines	Debris	540		540				540		**540**
K-31 Facility	Debris	85,338		85,338				85,338		**85,338**
K-33 Building Slabs and Soils	Debris	1,294		1,294				1,294		**1,294**
LLLW Complex	Debris		1,773	1,773					1,773	**1,773**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2013- 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 (FY13-43) (yd^3)
		FY13-23 (EMWMF)	FY23-43 (EMDF)	Total LLW	FY13-23 (EMWMF)	FY23-43 (EMDF)	Total Mixed			
Material Difference 114 - PBS 40	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**
ORNL Non-HF Well P&A	Debris		10	10					10	**10**
ORNL Remaining Non-HF Well P&A	Debris		14	14					14	**14**
ORNL Soils & 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	576		576				576		**576**
ORNL Water Quality Program	Debris	20		20				20		**20**
Poplar Creek Facilities	Debris	14,687		14,687				14,687		**14,687**
	Soil	8,918	2,016	10,934				8,918	2,016	**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		91	91					91	**91**
Steam Plant Complex Legacy Material Disposition	Debris		80	80					80	**80**
Tank Facilities Demolition	Debris		3,000	3,000					3,000	**3,000**
TSCA Incinerator Facilities	Debris	4,171	1,214	5,385				4,171	1,214	**5,385**
TWPC Complex	Debris		3,106	3,106					3,106	**3,106**
UEFPC Remaining Slabs and Soils	Debris		276,640	276,640					276,640	**276,640**
UEFPC Remaining Slabs and Soils	Soil		156,902	156,902					156,902	**156,902**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2013- 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 (FY13-43) (yd^3)
		FY13-23 (EMWMF)	FY23-43 (EMDF)	Total LLW	FY13-23 (EMWMF)	FY23-43 (EMDF)	Total Mixed			
UEFPC Sediments - Streambed and Lake Reality	Soil					11,975	11,975		11,975	**11,975**
UEFPC Soils	Soil		3,154	3,154					3,154	**3,154**
UEFPC Soils 81-10 Area	Debris					280	280		280	**280**
	Soil		33,350	33,350					33,350	**33,350**
Y-12 Surveillance & Maintenance / Environmental Monitoring	Debris				400		400	400		**400**
Zone 2 Remedial Action	Debris	96,169	8,927	105,096				96,169	8,927	**105,096**
	Soil	79,309	1,562	80,871				79,309	1,562	**80,871**
TOTAL VOLUME		**538,455**	**1,573,371**	**2,111,826**	**400**	**58,835**	**59,235**	**538,855**	**1,632,206**	**2,171,061**

LLW = low-level waste; RCRA = Resource Conservation and Recovery Act of 1976; TSCA = Toxic Substance Control Act of 1976

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Table A-3. As-generated Waste Volume Estimate (FY 2023-FY 2043) with Uncertainty

As-generated Waste Volume Estimate (yd^3)												
Waste Type	**Material Type**	**FY2023**	**FY2024**	**FY2025**	**FY2026**	**FY2027**	**FY2028**	**FY2029**	**FY2030**	**FY2031**	**FY2032**	**FY2033**
LLW (includes LLW/TSCA)	Debris	16,487	39,717	50,527	34,290	53,535	61,945	63,221	74,938	71,924	59,806	48,148
	Debris/Classified	0	0	0	0	0	0	0	0	0	0	0
	Soil	2,828	32,787	1,313	0	7,933	6,158	11,847	14,519	13,290	3,117	154
	TOTAL	**19,316**	**72,504**	**51,840**	**34,290**	**61,468**	**68,103**	**75,068**	**89,457**	**85,214**	**62,923**	**48,302**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	0	269	2,470	19,574	13,200	10,072	39	39	23	0	0
	Debris/Classified	0	0	64	508	342	261	0	0	0	0	0
	Soil	0	0	0	0	0	0	0	0	0	0	263
	TOTAL	**0**	**269**	**2,534**	**20,082**	**13,543**	**10,332**	**39**	**39**	**23**	**0**	**263**
TOTAL		**19,316**	**72,773**	**54,374**	**54,372**	**75,011**	**78,435**	**75,107**	**89,496**	**85,237**	**62,923**	**48,565**
25% Uncertainty		**4,829**	**18,193**	**13,594**	**13,593**	**18,753**	**19,609**	**18,777**	**22,374**	**21,309**	**15,731**	**12,141**
Total with Uncertainty		**24,145**	**90,966**	**67,968**	**67,965**	**93,764**	**98,044**	**93,884**	**111,870**	**106,546**	**78,654**	**60,706**

As-generated Waste Volume Estimate (yd^3)												
Waste Type	**Material Type**	**FY2034**	**FY2035**	**FY2036**	**FY2037**	**FY2038**	**FY2039**	**FY2040**	**FY2041**	**FY2042**	**FY2043**	**Total FY23-FY43**
LLW (includes LLW/TSCA)	Debris	53,415	44,045	80,407	47,406	64,701	75,384	68,995	70,084	71,420	33,207	1,183,602
	Debris/Classified	0	0	0	0	0	0	0	0	0		0
	Soil	1,061	0	72,783	45,330	30,580	22,096	15,936	31,414	50,221	26,401	389,768
	TOTAL	**54,476**	**44,045**	**153,190**	**92,736**	**95,281**	**97,480**	**84,931**	**101,498**	**121,641**	**59,607**	**1,573,371**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	0	0	0	0	0	0	0	0	0	0	45,685
	Debris/Classified	0	0	0	0	0	0	0	0	0	0	1,175
	Soil	11,712		0	0	0	0	0	0	0	0	11,975
	TOTAL	**11,712**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**58,835**
TOTAL		**66,188**	**44,045**	**153,190**	**92,736**	**95,281**	**97,480**	**84,931**	**101,498**	**121,641**	**59,607**	**1,632,206**
25% Uncertainty		**16,547**	**11,011**	**38,297**	**23,184**	**23,820**	**24,370**	**21,233**	**25,375**	**30,410**	**14,902**	**408,051**
Total with Uncertainty		**82,735**	**55,056**	**191,487**	**115,920**	**119,101**	**121,849**	**106,164**	**126,873**	**152,051**	**74,509**	**2,040,257**

LLW = low-level waste
RCRA = Resource Conservation and Recovery Act of 1976
TSCA = Toxic Substance Control Act of 1976

Table A-4. As-disposed Waste Volume Estimate

Total As-Disposed (CY)	ACTUALS 2003-2012	FORECASTED																
		FY2013	FY1014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023*	FY2023**	FY2024	FY2025	FY2026	FY2027	FY2028
Debris	462,176	18,488	10,638	11,068	11,301	10,830	27,960	10,020	33,883	43,914	21,149	24,680	8,193	19,870	26,368	27,019	33,333	35,917
Waste used as fill	369,070	0	0	0	3,370	5,253	47,600	0	1,900	0	3,267	6,562	2,178	25,252	1,011	0	6,110	4,743
Clean Fill	436,231	41,784	24,043	25,013	22,171	19,224	15,590	22,646	74,675	99,245	44,529	49,215	16,338	19,655	58,580	61,063	69,223	76,430
Total waste plus fill	1,267,477	60,272	34,681	36,081	36,842	35,307	91,149	32,666	110,457	143,159	68,946	80,457	26,709	64,777	85,959	88,083	108,666	117,089
25% Uncertainty Allowance (Total Waste + Clean Fill)		15,068	8,670	9,020	9,211	8,827	22,787	8,167	27,614	35,790	17,236	20,114	6,677	16,194	21,490	22,021	27,166	29,272
Total with uncertainty	**1,267,477**	**75,340**	**43,351**	**45,101**	**46,053**	**44,134**	**113,937**	**40,833**	**138,072**	**178,949**	**86,182**	**100,571**	**33,387**	**80,972**	**107,449**	**110,103**	**135,832**	**146,361**
Cumulative On-site Waste Disposal	**1,267,477**	**1,342,817**	**1,386,168**	**1,431,269**	**1,477,322**	**1,521,456**	**1,635,393**	**1,676,226**	**1,814,298**	**1,993,247**	**2,079,429**	**2,180,000**	**2,213,387**	**2,294,358**	**2,401,807**	**2,511,910**	**2,647,743**	**2,794,104**

FY 2023: New Disposal Facility - Cells 1 and 2 Start Operations

EMWMF Reaches Maximum Capacity
EMWMF Maximum Capacity= 2,180,000 yd^3

Total As-Disposed (CY)	FORECASTED																
	FY2029	FY2030	FY2031	FY2032	FY2033	FY034	FY2035	FY2036	FY2037	FY2038	FY2039	FY2040	FY2041	FY2042	FY2043	Total (FY03-43)	Total EMDF (2023-2043)
Debris	31,436	37,259	35,753	29,719	23,926	26,544	21,887	39,957	23,558	32,152	37,461	34,286	34,827	35,491	16,502	1,297,565	611,457
Waste used as fill	9,124	11,182	10,236	2,401	321	9,838	0	56,057	34,912	23,552	17,018	12,274	24,195	38,680	20,333	746,438	309,417
Clean Fill	61,921	73,022	70,566	64,765	53,752	50,151	49,466	34,245	18,328	49,112	67,643	65,212	54,514	41,529	16,960	1,946,842	1,072,475
Total waste plus fill	102,481	121,463	116,554	96,885	78,000	86,532	71,353	130,259	76,798	104,816	122,122	111,772	113,536	115,700	53,795	3,990,845	1,993,349
25% Uncertainty Allowance (Total Waste + Clean Fill)	25,620	30,366	29,139	24,221	19,500	21,633	17,838	32,565	19,200	26,204	30,530	27,943	28,384	28,925	13,449	680,842	498,337
Total with uncertainty	**128,102**	**151,829**	**145,693**	**121,107**	**97,500**	**108,165**	**89,191**	**162,823**	**95,998**	**131,020**	**152,652**	**139,715**	**141,920**	**144,625**	**67,244**	**4,671,687**	**2,491,687**
Cumulative On-site Waste Disposal	**2,922,206**	**3,074,035**	**3,219,727**	**3,340,834**	**3,438,334**	**3,546,499**	**3,635,690**	**3,798,513**	**3,894,511**	**4,025,531**	**4,178,183**	**4,317,898**	**4,459,818**	**4,604,443**	**4,671,687**		

FY 2030: New Disposal Facility - Cells 1 and 2 Full (822,900 CY), Cells 3 and 4 Start Operations

FY 2038: New Disposal Facility - Cells 3 and 4 Full (951,180 CY), Cells 5 and 6 Start Operations

FY 2043: New Disposal Facility - Cells 5 and 6 Full (725,920 CY), EMDF Closure Begins

EMWMF = Environmental Management Waste Management Facility
EMDF= Environmental Mangement Disposal Facility
* Denotes FY2023 Volumes designated for EMWMF
** Denotes FY2023 Volumes designated for EMDF

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**

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6. REFERENCES

DOE 2012. *Environmental Management Waste Management Facility 2012 Capacity Assurance Remedial Action Report,* March 2012, DOE/OR/01-2567&D1.

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APPENDIX B:

WASTE VOLUME REDUCTION

CONTENTS

FIGURES

TABLES

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
HPS	Health Physics Society
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

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1. INTRODUCTION

The Remedial Investigation/Feasibility Study (RI/FS) for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) disposal facility evaluates alternatives that will address disposal of CERCLA waste generated on the Oak Ridge Reservation (ORR). Waste volume reduction activities that could possibly reduce the cost of CERCLA waste disposal are investigated in this study.

Volume reduction actions could significantly impact both On-site and Off-site disposal alternatives that are evaluated in this RI/FS. For the On-site Disposal Alternative, consolidated disposal of most future-generated CERCLA waste would utilize a newly-constructed landfill facility 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 off-site to approved disposal facilities and placement of the wastes in those facilities.

2. PURPOSE AND SCOPE

The purpose of this Appendix is primarily to review and assess different approaches for reducing the volume of the CERCLA waste to be disposed in the EMDF or off-site disposal facilities and to estimate the potential cost savings. The study evaluates physical treatment methods for size-reducing demolition debris and thus reducing the associated clean fill (soil) demand necessary to fill the debris void space when placed for disposal at the EMDF. Clean fill occupies a large fraction of the EMDF disposal capacity and constitutes a major fraction of the facility cost. Size reduction increases the bulk density of the waste materials making off-site disposal less expensive by allowing transportation of more material per shipping container. The study also evaluates recycling possibilities, enhanced segregation of waste, and modified project sequencing to make more efficient use of landfill capacity.

The physical treatment methods evaluated were limited to those that are typically used for commercial construction and demolition (C&D) projects or at recycling facilities by private industry. 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, saving 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 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.

To determine the cost effectiveness of the volume reduction (VR) options, the estimated cost of VR activities is compared to the anticipated cost of EMDF disposal in terms of dollars per cubic yard for on-site disposal at a proposed facility in East Bear Creek Valley. VR costs are also compared with the cost of off-site disposal for equivalent volumes of waste. Recommendations are made regarding VR approaches based on the comparison with estimated EMDF and off-site disposal costs along with appropriate qualifying statements that apply to the conditions. Assumptions are presented where uncertainties 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.

Information from the RI/FS waste volume estimate were reviewed to determine 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 left by demolition 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 to fill the void space created by placement of debris in the landfill. Sequencing of planned projects in the RI/FS waste volume estimate are based on assumptions such as funding, prioritization, and contracting that can be uncertain and subject to change.

Both recycling and enhanced segregation activities would require more intensive characterization efforts to verify that waste materials are clean enough for free-release or to meet the ORR Landfill waste acceptance criteria (WAC). This approach may also involve additional pre-demolition hazard analysis efforts to downgrade the facility hazard category from a "Nuclear" or "Radiological" facility to a non-radiological industrial facility. Recycling also carries the risk of accidentally releasing contaminated materials into the commercial market place and unintentionally exposing the public to radiation. Preventing this type of occurrence is critically important. The cost of recycling includes the cost of segregating, characterizing, and transporting off-site to a local recycling facility.

The cost effectiveness of physical VR options was evaluated by comparing the cost of implementing the VR method to the cost of on-site or off-site disposal of unprocessed material. Physical VR costs typically include capital, construction, operations, maintenance, repairs, energy (e.g., fuel, electricity), and overhead allowance. The On-site Disposal Alternative cost estimate developed for the EMDF and the Off-site Disposal Alternative cost estimate (see summary in Appendix G of this RI/FS) were used to determine potential on-site or off-site disposal cost savings for VR scenarios. VR benefits include reduced transportation costs for on-site or off-site alternatives, and reduced construction and operating costs for the on-site disposal facility.

4. WASTE MATERIALS

The buildings/structures selected for this evaluation are representative of the types of contamination present and the variety of waste that will be generated during building demolition. A breakdown of material types and quantities available for several facilities from ORNL and Y-12 Buildings based on cost estimates for D&D activities was used.

Table B-1 is a listing of projected waste streams from each representative building by material type. 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. The waste materials from all the buildings were summed to provide a representative percentage by waste type for materials to be disposed. As described in Sect. 5.2.1, the representative fractional quantities given in Table B-1 were applied against the projected as-generated waste volume estimate for debris from Appendix A to determine the total quantity of material that would benefit from VR.

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 require complex and costly containment facilities, and safety systems for VR processing. These materials will likely be addressed prior to facility demolition using existing infrastructure and localized containment. Lead brick and sheet will be separated for either recycling as shield materials or transported for off-site treatment. These materials do not comprise a significant fraction of the total EMDF capacity, nor are they in a voluminous form that would show significant benefit by compacting. ACM cannot be 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. Light steel materials such as ventilation duct, conduit, thin-walled pipe, and sheet metal siding can be shredded as well as siding, flooring, wood materials, and roof materials. 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.

Compactors for light materials typically operate using a hydraulic press to compress materials at 2,000 psi in a confined area or bale that conforms to a shape and size that is suitable for transportation and disposal. It is most beneficial for light, soft materials with a large void fraction such as plastic containers or sanitary refuse.

For heavy gauge metal materials (structural steel, large diameter, thick walled piping, process vessels, and equipment items that have a large void fraction) shearing machines such as those used in shipyards and metal recycling facilities may be used. 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 for recycle and disposal.

Table B-1. Waste Streams for Representative Buildings by Material Type

Waste Stream	Description	ORNL Facilities			Y-12 Facilities					Total Volume (yd^3)	Fraction of Total 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%
Transite	Transite	8	165	0	148	265	120	0	146	853	0.18%
Lead	Bricks, sheet	0	0	94	0	0		2	0	96	0.02%
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%
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%
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%
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%
Light gauge metals and siding	Air ductwork, <2" pipe, siding, panels	770	860	599	1,432	3,565	2,501	97	4,154	13,979	3.01%
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%
Legacy material	Containers, furniture, trash	0	0	27	838	0	0	0	48	913	0.20%
Packaged for EMWMF	Legacy containerized waste	0	0	84	0	0	0	0	0	84	0.02%
Off-site disposal	Mixed waste designated for off-site disposal	0	0	53	0	0	0	0	0	53	0.01%
Total		22,709	45,811	4,245	52,720	122,624	83,262	28,956	103,770	464,129	1.0

*Rows highlighted in green are materials amenable to VR processing, and account for 98.8% of the total.

5. VOLUME REDUCTION METHODS AND BENEFITS

The following provides a description of the VR approaches evaluated in this report. Advantages and disadvantages are discussed along with cost data collected from various sources. The discussion considers types of techniques/technologies available to perform size reduction, the cost of implementing, and the magnitude of VR that can be potentially achieved. This information is used to determine the 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 SIZE REDUCTION EQUIPMENT

Commercially available size reduction equipment is capable of reducing the size and void space associated with bulk demolition materials. This equipment is most often used at construction sites and commercial recycling facilities across the country. Many models are available in the form of stationary or mobile units that can be deployed at the demolition site. Local deployment at the demolition site takes advantage of additional cost savings associated with transportation from the demolition site to the disposal area. Rising fuel costs will continue to increase the cost of transportation and make localized VR alternatives more attractive.

Equipment used to size-reduce debris materials includes crushers, shredders, compactors, and shears. These machines could be deployed at the demolition site and are capable of processing at sufficiently high rates so as not significantly impact the demolition schedule. Demolition equipment such as excavators with cutting and crushing attachments is normally used to size-reduce materials to meet the requirements for transportation and placement in the landfill. The same equipment and size requirements are expected to be acceptable for preparing the materials for feed hoppers used for crushers or shredders. These machines can be equipped with conveyors to move the processed materials to a waste container or collection area. Excavators with various boom attachments may be used to manage the product.

5.1.1 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 (Figure B-1). 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 selected data sheets and vendor inquiry data for vendor equipment.

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-1. Shredder Cutter Assembly (SSI Shredding Systems, Inc.)

5.1.2 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 (Figure B-2). 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 selected data sheets for vendor equipment.

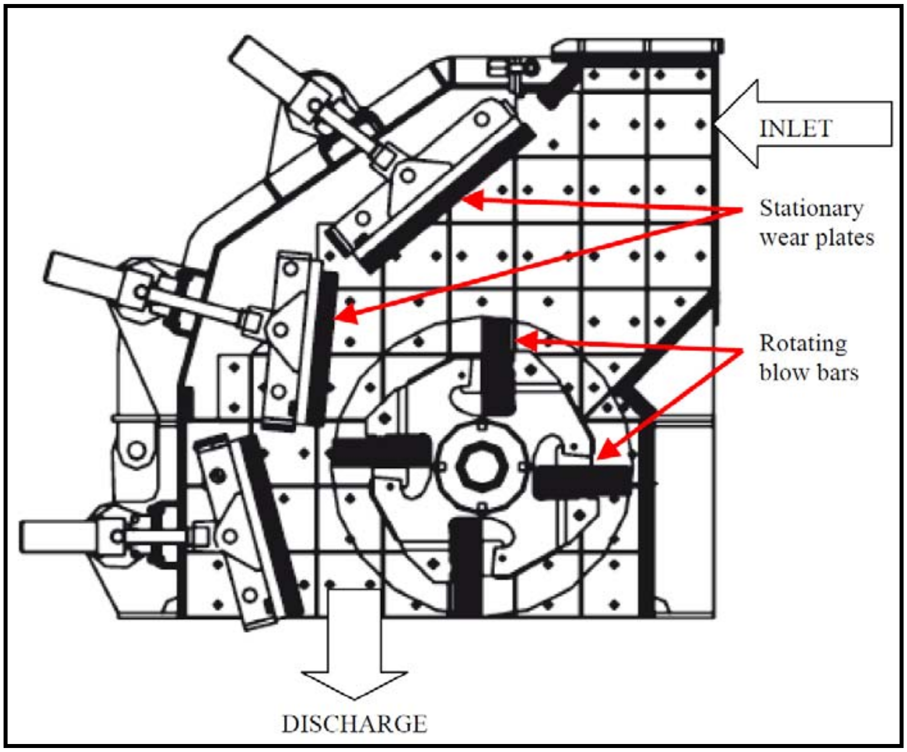

Figure B-2. Rotary Impact Crusher Components
(Striker Crushing and Screening Co.)

5.1.3 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. Personal protective equipment (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 the 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 six 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 large shearing machine deployed at the K-33 Building at ETTP 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 addressed in the next section.

5.1.4 Shearing Machines

British Nuclear Fuels Limited (BNFL) used a Harris Model BHS 2205-30 Shear designed for size-reducing scrap metal from shipyards and steel mills (otherwise known as the supercompactor) 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 said 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-3. The $13M facility (supercompactor 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 supercompactor. 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. Costs would be much lower if the processing equipment was mobile and did not require ventilation containment, however, a significant fraction of the equipment is likely to have been involved in radiological operations and/or utilized hazardous materials in the process.

Structural materials, including heavy steel structural supports and platforms are also a significant fraction of demolition materials, as shown in Table B-1. These materials are far less likely to be contaminated; therefore, a mobile compactor/shear could be deployed at much lower capital and operating costs to process structural materials into smaller volumes for EMDF disposal. This approach is worthy of additional consideration for VR for large quantities of non-contaminated heavy-gauge metals.

Recent characterization data for a large Y-12 facility (DOE 2012b) indicates widespread mercury and beryllium (Be) contamination that would curtail the use of VR methods beyond what is necessary to meet the disposal facility WAC. It would not be feasible or safe to remove this equipment from the building for a shearing operation due to the size of the equipment and potential for spread of contamination. A likely approach would involve in-place decontamination or contaminant fixation, disassembly, packaging, and removing equipment from the building for disposal prior to building demolition. The site-wide estimated quantity of heavy equipment and structural materials that would be amenable for VR processing is reduced substantially to account for this heavily contaminated equipment.

Figure B-3. BSH Shear by Harris

5.2 EVALUATION OF PHYSICAL VOLUME 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 truck at the D&D site. With continually increasing fuel costs, reducing transportation is becoming a more significant cost benefit, especially for the distances required in the Off-site Disposal Alternative. Additionally, decreasing the number of transport loads decreases roadway duration and the associated risk from traffic accidents. For EMDF disposal, the principal benefit of debris VR is the reduction in the quantity of fill material required to fill the void spaces within the material being placed in the disposal cell and the corresponding reduction in needed landfill capacity. 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 rolling over the materials. This section analyzes potential VR benefits for the On-site Disposal Alternative.

Similar to the definitions in the CARAR (DOE 2012a) completed annually for the EMWMF based on Waste Generation Forecasts (WGFs), 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.
  - 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 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 for On-site Disposal Alternative).
  - 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 it reflects compaction of the waste 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. See Chapter 2 of this RI/FS for additional information about 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. Based on this quantity, VR equipment can be sized and the full impact of processing can be determined.

5.2.1 Waste Volume Amenable to Volume Reduction Processing

As shown in Table B-1, about 98% of D&D debris materials are amenable to size reduction by shredding, crushing, or shearing. The 2001 Waste Management Program Plan (WMPP) (DOE 2001a) predicted that more than half of the debris generated in Y-12 D&D projects would be volume-reducible. The as-generated waste volume estimate data shown in Table A-2 of Appendix A was used to develop the total as-generated volume of debris that is amenable to VR processing shown in Table B-2. Table A-2 in Appendix A includes a listing of the buildings at all three ORR sites that will undergo D&D from the present date until completion of the work scope in the year 2043. The list includes yearly waste volumes and waste types for each of the facilities or facility groupings. This listing was reviewed and pared down to include only those facilities that will produce LLW debris (not soil) during the time that the EMDF is in service (2023 – 2043). This grouping was further pared down by removing all projects that produce less than 3,000 yd^3 of debris unless the project was pared with a similar project in the same proximity. Then an approximate uncertainty of 25% was applied to the as-generated volumes for consistency with the evaluations in the On-site and Off-site Disposal Alternatives (see Sect 2.2.1 of Chapter 2 of this RI/FS).

The total volume of debris from this pared list (Table B-2) with applied uncertainty provides the total estimated as-generated volume from facility demolition for VR processing, 1,384,415 yd^3, shown as "Material 1" in Table B-3. The values shown in the "Fraction of Total" column in Table B-3 are carried forward from the last column in Table B-1 for materials amenable to VR processing. These fractions of total values are used to calculate the waste stream volumes shown in the "Material 1" column of Table B-3. It was further assumed that approximately 75% of this debris would undergo processing due to logistical limitations and that only 30% of the Y-12 heavy equipment would be processed due to the presence of elevated radiological, mercury, or beryllium contamination. After applying these factors, the final estimated volume for VR processing is 922,992 yd^3, shown as Material 2 in Table B-3.

Table B-2. Projects and Debris Volumes for VR Processing

Site	WBS Project Title	Material Type	Waste Type	Volume (yd3)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
ORNL	2026 Complex	Debris	LLW	10,012	0	0	0	0	0	3,907	0	4,079	2,026	0	0	0				0	0	0	0	0	
ORNL	3019A Complex	Debris	LLW	62,674	0					216	1,065	3,106	12,253	12,204	12,253	12,253	9,324	0	0	0	0	0	0	0	
ORNL	3525 Complex	Debris	LLW	7,659	0	0	0	0				0	0	44	5,134	2,481	0	0	0	0	0	0	0	0	
ORNL	BV Isotope Area Facilities	Debris	LLW	6,102		0	0	0	394	3,145	2,563	0	0	0	0	0	0	0	0	0	0	0	0	0	
ORNL	BV Isotope Area Facilities (3038)	Debris	LLW	1,825						1,825															
ORNL	BV Reactor Area Facilities	Debris	LLW	7,076					250	1,911	1,904	1,904	1,107	0	0	0	0	0	0	0	0	0	0	0	
ORNL	BV Remaining Inactive Tanks and Pipeline	Debris	LLW	23,446	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		5,523	12,275	5,648	0	
ORNL	BV Remaining Slabs and Soils	Debris	LLW	30,024	0	0	0	0	0	0	0	0	0	0	0	683				2,048	1,992	2,123	3,909	11,407	7,862
ORNL	Central Stack East Hot Cell Complex	Debris	LLW	5,257							2,140	1,558	1,559												
ORNL	Central Stack West Hot Cell Complex	Debris	LLW	5,011									1,252	1,253	1,253	1,253									
ORNL	Beta-3 Deactivation Only	Debris	LLW	7,256	0	0	0	0	0	0	0				0	0	0	0	66	2,909	4,281	0	0	0	
ORNL	4501/4505 Complex	Debris	LLW	22,710																2,838	8,517	8,517	2,838		
ORNL	5505 Building	Debris	LLW	3,689																1,845	1,844				
ORNL	6010 and East BV Complex	Debris	LLW	44,916																5,615	16,843	16,843	5,615		
ORNL	EGCR Complex	Debris	LLW	45,811	0	0	0	0	0	0	0	0	0	0	0	0	42	5,827	4,384	25,219	10,339				
ORNL	MV LGWO Complex	Debris	LLW	7,859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		3,260	4,599	0	
Y-12	9206 Complex	Debris	LLW	13,856	0	0	0	0	0	0	1,843	7,518	4,495	0	0	0	0	0	0	0	0	0	0	0	
Y-12	9212 Complex	Debris	LLW	103,770	0	0	0	0	0	0			2,513	15,490	12,152	12,200	15,409	31,096	14,910	0	0	0	0	0	
Y-12	Alpha-2 Legacy Material Disposition	Debris	LLW	22,038							6,611	15,427													
Y-12	Alpha-3 Legacy Material Disposition	Debris	LLW	12,216												3,665	8,551								
Y-12	Alpha-2 Complex	Debris	LLW	50,952	0	0	0	0	0			3,759	7,706	10,654	15,656	13,177	0	0	0	0	0	0	0	0	
Y-12	Alpha-3 Complex	Debris	LLW	24,892	0	0	0	0	0	0	0	0					671	5,324	13,028	5,869	0	0	0	0	
Y-12	Alpha-4 Complex	Debris	LLW	35,436	0	0	1,926	15,330	10,323	7,858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Y-12	Alpha-5 Complex	Debris	LLW	122,623	0	2,215	18,492	18,195	26,725	32,928	24,068	0	0	0	0	0	0	0	0	0	0	0	0	0	
Y-12	BCV White Wing Scrap Yard Remedial Action	Debris	LLW	10,017	0	0	0	0	0	0	0	0	0	0	0	0		7,425	2,592	0	0	0	0	0	
Y-12	Beta-1 Legacy Material Disposition	Debris	LLW	6,460												6,460									
Y-12	Beta-3 Legacy Material Disposition	Debris	LLW	10,761																	10,761				
Y-12	Beta-1 Complex	Debris	LLW	40,460	0	0	0	0	0	0	0	0	0			1,155	9,822	29,483	0	0	0	0	0	0	
Y-12	Biology Complex	Debris	LLW	2,144	0	0	0	0	0	0	0	866	960	253	65	0	0	0	0	0	0	0	0	0	
Y-12	Biology Complex	Debris	LLW/TSCA	26,944	0	0	0	0	0	0	0	10,883	12,062	3,181	818	0	0	0	0	0	0	0	0	0	

Table B-2. Projects and Debris Volumes for VR Processing, Continued

Site	WBS Project Title	Material Type	Waste Type	Volume (yd3)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Y-12	9212 Complex Legacy Material Disposition	Debris	LLW	9,801									2,450	7,351											
Y-12	9213 and 9401-2 Demolition	Debris	LLW	8,000	0	0	0	0	0	0	0	2,088	3,046	2,392	474	0	0	0	0	0	0	0	0	0	
Y-12	UEFPC Remaining Slabs and Soils	Debris	LLW	276,640					13,953	8,611	20,361	21,725	19,279	4,442	0	0	0	875	11,329	15,566	11,245	22,280	44,677	57,291	25,007
K-25	K-1037 and K-1037-C*	Debris	LLW	4,458	4,458		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
K-25	Zone 2 Remedial Action*	Debris	LLW	8,950	8,945	5				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Volumes, yd^3				**1,081,745**	**13,403**	**2,220**	**20,418**	**33,525**	**51,645**	**60,401**	**60,555**	**72,912**	**70,708**	**57,264**	**47,805**	**53,327**	**43,819**	**80,031**	**46,309**	**61,909**	**71,345**	**65,298**	**67,286**	**68,698**	**32,868**
Uncertainty at 25%, yd^3				**302,670**																					
Total with Uncertainty, yd^3				**1,384,415**																					

Table B-3. Estimated EMDF Capacity Gained for Scenarios A and B

Waste Stream	Material 1: As-G Volume* (yd^3)	Fraction of Total**	Bulk Density (lb/yd^3)	Fraction Processed	Material 2: As-G Volume for Processing (yd^3)	As-D Volume for Material 2 (yd^3)	Fill for Material 1 without VR (yd^3)	Fill Basis	Fill required for fraction of Material 1 Not Processed (CF-1), (yd^3)	Processing Option	Void Fraction After Processing, %	As-G Volume of Material 2 After VR, (yd^3)
Equipment: large machine tools, large electric motors, process vessels	256,266	0.19	680	0.3	76,880	4,651	148,525	Fill ratio is 9.58 for as-disposed equipment (soil: debris)	103,967	Shear	45	38,440
Structural steel, piping	343,108	0.25	1,040	0.75	257,331	23,810	210,480	Fill ratio is 6.63 for as-disposed metals (soil: debris)	52,620	Shear	45	128,665
Concrete and masonry: Reinforced concrete, block, brick, shield walls	592,340	0.43	2,600	0.75	444,255	355,404	592,340	Fill ratio is 1.25 for as-disposed light concrete (soil: concrete)	148,085	Crusher	5	355,404 (D)
Small structures: small cooling towers, structural framing, interior and exterior finishes, wood	98,357	0.071	1,620	0.75	73,768	36,884	111,144	Fill ratio is 2.26 for as-disposed construction debris (soil: debris)	27,786	Shredder	10	44,261
Metal (light gauge): Air ductwork, <2" pipe, siding, panels	42,216	0.030	1,040	0.75	31,662	15,831	47,704	Fill ratio is 2.26 for as-disposed construction debris (soil: debris)	11,926	Shredder	10	18,997
Roofing materials: Shingles, built-up roofs, vapor barrier, insulation, roof vents, flashing	49,372	0.036	1,520	0.75	37,029	18,515	0	No fill required, self-filling	0	Shredder	10	22,217
Legacy material: Containers, furniture, trash, wood	2,756	0.002	640	0.75	2,067	1,034	2,784	Fill ratio is 2.26 for as-disposed construction debris (soil: debris)	696	Shredder	10	1,240
Total	1,384,415	**1.000**			922,992	456,128	1,112,976 (A)		345,080			609,225

As-D = As-disposed; As-G = As-generated
**Total with uncertainty from Table B-2
*From Table B-1

Table B-3. Estimated EMDF Capacity Gained for Scenarios A and B (Continued)

Waste Stream	Scenario A				Scenario B			
	Fill Ratio for VR Material 2 (Soil:Debris)	Fill Volume for VR Material 2, yd^3 (F-2)	Total Fill, yd^3 (F-1+F-2)	Basis	Fill Ratio for VR Material 2 (Soil:Debris)	Fill for VR Material 2, yd^3 (F-3)	Total Fill, yd^3 (F-1+F-3)	Basis
Equipment	2.26	10,511	114,479	Shearing reduces volume of equipment by 50% and reduces CARAR fill requirement to what is required for construction debris, 2.26.	2.26	10,511	114,479	Shearing reduces volume of equipment by 50% and reduces CARAR fill requirement to what is required for construction debris, 2.26.
Structural steel, piping	2.26	53,811	106,431	Shearing reduces volume of heavy steel by 50% and reduces CARAR fill requirement to what is required for construction debris, 2.26.	2.26	53,811	106,431	Shearing reduces volume of heavy steel by 50% and reduces CARAR fill requirement to what is required for construction debris, 2.26.
Concrete and masonry	0.78	266,127	414,212	Reduces volume by 20%. 50% of material is self-filling. Fill ratio is 50% of the CARAR requirement or 0.78 (soil:debris). 25% of crushed concrete replaces fill for other debris.	0.78	0	148,085	Reduces volume by 20%. 100% of material is self-filling. No fill required. 50% of crushed concrete replaces fill for other debris.
Small structures	1.13	35,010	62,796	Reduces volume by 40%. 50% of material is self-filling so fill ratio is reduced to 50% of the CARAR requirement for debris, or 1.13.	1.13	35,010	62,796	Reduces volume by 40%. 50% of material is self filling so fill ratio equals 50% of CARAR requirement, or 1.13.
Metal (light gauge)	1.13	15,027	26,953	Reduces volume by 40%. 50% of material is self-filling so fill ratio is reduced to 50% of the CARAR requirement for debris, or 1.13.	1.13	15,027	26,953	Reduces volume by 40%. 50% of material is self filling so fill ratio is reduced to 50% of the CARAR requirement, or 1.13.
Roofing materials	0.00	0	0	Reduces volume by 40%. No fill required.	0.00	0	0	Reduces volume by 40%. No fill required.
Legacy material	1.13	981	1,677	Reduces volume by 40%. 50% of material is self-filling so fill ratio is reduced to 50% of the CARAR requirement for debris, or 1.13.	1.13	981	1,677	Reduces volume by 40%. 50% of material is self filling so fill ratio is reduced to 50% of the CARAR requirement, or 1.13.
Total		381,467	726,547 (B)	Total fill required for Scenario A		115,340	460,420 (C)	Total fill required for Scenario B
			386,430	EMDF capacity gained if crushed concrete is 50% self-filling (A – B), yd^3			652,556	EMDF capacity gained if crushed concrete is 100% self-filling (A – C), yd^3
			88,851	Volume of crushed concrete used to replace fill at 25% (D × 0.25), yd^3			177,702	Volume of crushed concrete used to replace fill at 50% (D × 0.5), yd^3
			475,281	Total EMDF capacity gained if 50% of crushed concrete is self-filling and 25% of crushed concrete replaces fill.			830,258	Total EMDF capacity gained if all crushed concrete is self-filling (no fill required) and 50% of crushed concrete replaces fill.

5.2.2 Estimated EMDF Capacity Increase

When placing bulky waste materials such as building debris in a landfill, it is necessary to fill the voids within/between the waste with soil, soil-like waste materials, or other engineered fill materials (e.g., flowable fill) in order to reduce settlement of the waste and ensure long-term stability of the final cap placed on the landfill. In addition, the soil and soil-like waste materials must be properly compacted. Previous experience gained from operating the 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 operations has purchased clean soil from off-site borrow sources to fill void spaces in the landfill (DOE 2011a). Use of clean soil to fill void spaces is an inefficient and costly use of valuable landfill air space. Size reduction of certain waste materials, such as bulky building debris, can significantly reduce the volume of fill required for a particular waste stream (DOE 2003 and 2004).

Two scenarios have been developed for evaluating disposal cell capacity usage and cost savings to be realized through VR of waste. Both scenarios assume that the amount of debris processed is less than the amount considered amenable to VR, as described in Sect. 5.2.1 of this Appendix. This allows for the possibility that some projects will not implement VR processing due to logistical complexity or other limitations. The difference in the two scenarios involves the amount of fill required for concrete debris versus crushed concrete and also the amount of crushed concrete that may be used to replace fill material that would otherwise be required for placement of debris and equipment items. Concrete and masonry rubble is a major fraction of demolition debris, as shown in Table B-3. Therefore, VR processing of concrete could have a major impact on landfill space needs. Crushed concrete will require a lesser quantity of fill due to the reduction on void space that is occupied by the fill material. Some fraction of the concrete will be pulverized to a soil-like material that may be used in place of fill. Since the extent of void space reduction and production of soil-like concrete is unknown, Scenarios A and B were developed to evaluate both conservative and optimistic assumptions regarding the characteristics of the crushed concrete. Scenario A conservatively assumes a 50% reduction in fill requirement and 25% of the crushed concrete replaces fill. Scenario B optimistically assumes that the crushed concrete will require no fill material and 50% will be used to replace fill.

Of the debris amenable to VR, 43% is composed of concrete rubble as shown in Table B-3. The table summarizes the estimated reduction in fill requirement based on the use of size-reduction equipment. The density information used to develop the CARAR estimates indicates an as-generated void fraction of 25% for concrete, 50% void fraction for general construction debris, and over 90% void fraction for equipment and metals. It is assumed that shredding, crushing, and shearing operations will reduce the void volumes of concrete, debris, and equipment to 5%, 10%, and 45%, respectively. A revised fill requirement is determined for size-reduced debris and for debris that is not processed. Since the particle sizes will be much smaller for size-reduced material, it is assumed that a fraction of the material is self-filling and does not require additional fill material. In Scenario A, it is assumed that 50% of the processed material (concrete or debris) will be self-filling; thus, fill requirement is reduced by half of the value given in the 2011 CARAR. Based on the group of facilities analyzed, the quantity of concrete debris is almost half to the total quantity of other debris generated. Consequently, crushed concrete could be used to satisfy the fill requirement for a substantial amount of other debris (equipment, heavy structural materials, etc.). D&D material shipments to the landfill could possibly be arranged so that some of the crushed concrete might be used to replace fill. In Scenario A, it is assumed that 25% of the crushed concrete (88,851 yd^3) will be used to replace fill material. For roofing materials, the 2011 CARAR indicates these materials are self-filling and no fill is required. This is likewise assumed for shredded roofing materials. For shredded legacy materials such as trash, furniture, and wood, the fill ratio for volume-reduced materials was assumed to be the same as the construction debris value of 2.26 used in CARAR calculations. For equipment and metals, VR processing is not expected to eliminate more than 50% of the as-generated void space. Consequently, fill material will still be necessary to occupy void space in the material, although the fill requirement will be lower. In the case of Scenarios A and B, it was assumed that the fill requirement for equipment and metals would be reduced to an amount that would normally be required for as-generated construction debris (2.26:1 ratio, soil:waste). The total fill requirement is determined for as-generated, unprocessed materials and for size-reduced materials with the difference being the reduced quantity of fill required and the equivalent increase in EMDF capacity. In Scenario A, the EMDF capacity gained through VR is 475,281 yd^3.

The operational settings of crushing equipment can be adjusted to produce a range of product particle sizes. Adjusting the settings to produce a product with 90% of the material being smaller than one inch would only reduce the maximum processing capacity of the machine from 150 to 125 tons per hour, and a higher fraction of the crushed concrete could be used as fill material. It was assumed the processing rate would be limited by the speed that material could be fed to the crushing unit using an excavator and crushing to a smaller particle size would not impact the production rate or delay the operating schedule. The cost analysis for crusher operation assumed a processing rate of 50 tons per hour. At this rate, the particle size could be reduced to one inch or less and would be self-filling such that additional fill would not be required. For Scenario B, it is assumed that the crushed concrete is 100% self-filling, eliminating all fill required for concrete and giving a total EMDF capacity gain of 652,556 yd^3. It is also assumed that a larger fraction of the crushed concrete, 50% or 177,702 yd^3, would be used to replace clean fill. This increases the capacity gain to 830,258 yd^3.

5.2.3 Cost of Volume Reduction Processing

The cost of shredding and crushing D&D materials 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. Based on a review of the number, location, and schedule of D&D projects, it was assumed that multiple deployments of VR systems would be necessary. The estimate includes the assumption that one mobile shredder, two mobile concrete crushers, one stationary shear, one mobile shear, and five excavators would be procured. The mobile crusher and shredder units take advantage of the savings in transportation costs and require little effort to move to the site or relocate while on the site. The mobile shear is much heavier and would require more effort to disassemble and transport. The weight of the unit would require rental of an 80-ton crane, a concrete foundation, and about eight weeks to relocate. It is assumed that the stationary shear (also called a "supercompactor") would be installed at the Y-12 plant and would include an enclosure for contamination control. Only LLW debris would be processed in this facility. The facility would be located in close proximity to the larger planned demolition projects such as Alpha-4, Alpha-5, and Beta-4. The VR machines would be equipped with conveyors to move the processed material to a staging pile next to the unit. A dedicated excavator would be provided for each machine to place debris feed into the feed box, to fill 10-yd^3 transport trucks with processed material for transport to the EMDF, or to fill 25-yd^3 intermodal containers for off-site transport. A 150-horsepower excavator with a 7.5-ton lifting capacity was assumed to support VR operations. Of the total quantity of material to be processed by the two shears, it was determined based on Table B-2 that 71.8% of the material would be generated at the Y-12 site and would be processed by the stationary shear. The remaining 28.2% was assumed to be processed by the mobile shear.

Compaction of PPE/DAW in drums was also evaluated based on projected quantities of PPE/DAW documented in the 2011 CARAR. It was assumed that four drum crushers would be deployed and these could be easily moved between sites or projects as necessary.

Density information from the 2011 CARAR was used to determine the approximate weight of material to be processed through the VR equipment. The preferred processing rate was determined based on the average quantities of debris generated per year and also on maintaining a reasonable processing duration for a large facility D&D project. For a large facility such as 9201-5 (Alpha-5) at Y-12, a crusher operating at 60 tons per hour would complete the processing of all concrete and masonry in about 18 weeks. The crusher assumed for this operation has a maximum throughput of 150 tons per hr, but was assumed to be slowed to about 50 tons per hour when processing reinforced concrete. For the shredding operation, the average debris generation is about 4,000 tons per year, but the Alpha-5 project will generate about 6,700 tons in less than a year. A shredder operating at 10 tons per hour will process all the Alpha-5 debris in about 17 weeks. The shredder assumed for this operation has a processing capacity of 25 tons per hr, but it was assumed this rate would be reduced due to a high fraction of light voluminous debris mixed with small amounts of concrete. Both shears selected for this work have processing capacities of up to 40 tons per hr, though the actual production rate for the K-33 supercompactor project was about 16 tons per hr. The expected annual average generation rate of about 6,100 tons of heavy steel could be processed in less than 10 weeks at this rate.

The operating life of the equipment was investigated to determine if equipment replacement would be necessary at some point in the 21 years of CERCLA waste generation. Based on manufacturer discussions, these systems can be expected to operate for the duration of the 21-year time period of waste generation evaluated in the On-site and Off-site Disposal Alternatives 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 VR cost estimate.

Tables 1 through 8 in Attachment B provide a breakdown and summary of costs for procurement and operation of the shredder, crushers, shears, and excavators. The costs include the capital cost of the unit with associated engineering and procurement costs; transportation and setup; facility enclosure (if required), labor to operate the machines based on the approximate number of hours required to process the identified quantity of material from Table B-3; maintenance costs; and fuel. Overhead at 30% was applied to capital, setup, operating, and maintenance costs. Costs are based on current year 2012 costs without escalation. The total cost of equipment and operations for VR is about $38.6M, or about $42 per yd^3 of material processed (Attachment B, Table 8). As shown in Table 7, the processing cost for VR equipment varies from about $6.67 to $98.64 per yd^3 depending upon the material and process machine being used. For Scenario A (Attachment B, Table 8), the processing cost is about $81 per yd^3 for the 475,281 yd^3 gained. In Scenario B where all of the crushed concrete is self-filling and half is used to replace clean fill, the cost of VR per EMDF capacity gained drops to $46 per yd^3.

With the exception of the enclosed shear (i.e., supercompactor) at Y-12, these evaluations assume the materials are not contaminated with radiological or hazardous materials. As such, control of airborne releases is not necessary beyond normal dust control measures through general area misting with water. If materials are contaminated, containment facilities with ventilation controls would be necessary. Radiation Protection personnel would be needed to monitor facilities and personnel for contamination. Operating costs would also be impacted by the use of PPE and the associated loss in worker productivity. The vast majority of ORR D&D projects have involved open-air demolition without containment systems. In some cases, selective removal or stabilization of highly contaminated sections of the buildings has been necessary prior to demolition. Radiation monitoring and dust suppression were sufficient to control contamination releases. With or without VR equipment, contamination controls significantly increase the cost D&D activities.

5.2.4 Impact of Volume Reduction on On-site Transportation Costs

Transportation cost savings are calculated from the number of trips to the EMDF that would not be needed based on the reduced volume from implementing these technologies. It was based on an assumed cost of $220 per trip[1] and an average load of 10 yd^3.

The total estimated as-generated quantity of waste that would be VR processed is 922,992 yd^3. From Table B-3, the difference between the total volume of debris before and after VR processing is 313,767 yd^3, which is equivalent to the quantity that would not require transportation. At $220 per 10 yd^3 load, transportation cost savings are about $6.9M.

5.2.5 Impact of Volume Reduction on EMDF Construction and Operations Costs

This section describes the approach used to determine the potential cost savings associated with EMDF construction activities when VR technology is used to size-reduce concrete and debris. The revised construction cost was compared to the estimated cost in Appendix G for construction of a 2.49M yd^3 facility, a capacity sufficient to receive the projected waste volumes over a 21-year operating lifetime including approximately 25% uncertainty. 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.

VR Scenario A results in a net capacity gain of 475,281 yd^3 for the EMDF (Table B-3). This is estimated to be a 19% reduction in disposal capacity required. Scenario B results in a net capacity gain of 830,258 yd^3, which is equivalent to about a 33% reduction in required disposal capacity. The EMDF is likely to be constructed over time using a phased approach that includes two disposal cells (415,281 yd^3 average size each) per phase. With a total of three construction phases (six cells), VR activities could impact the need for cells that are in the later phases of construction. For a rough-order-of-magnitude estimate of VR cost benefits for Scenario A, construction cost elements associated with Phase III (construction of Cells 5 and 6) were revised to reflect lower costs due to elimination of Cell 6. The avoided cost for Cell 6 was obtained by summing the estimated Cell 6 construction costs, interim capping costs, and 1/6th of the final cap and closure costs for the entire facility. Costs that remain unchanged include remedial design, base topographic surveys, geotechnical testing and geological investigations, Phase I and Phase II design and construction, Phase III design, and long-term surveillance and maintenance. These cost elements are not likely to change significantly if the EMDF capacity is reduced by the equivalent of one cell. With a 19% reduced EMDF capacity for Scenario A, operating costs would be expected to be slightly lower, although the duration of operations would not change. It was assumed that total operating costs for the EMDF would be reduced by 10% due to reduced staffing requirements (not including the cost of security). Table B-4 summarizes the EMDF construction cost benefits for both Scenarios. Under Scenario A, the net avoided EMDF construction and operating costs minus the cost of VR are a total of $26,658,466.

The capacity gain for Scenario B allows for the elimination of the entire Phase III construction effort. As in Scenario A, the remaining cost elements associated with surveys, testing, design, and the leachate treatment facility will remain unchanged. With a 33% reduced EMDF capacity for Scenario B, operating costs were assumed to be reduced by 15% due to reduced staffing requirements (not including the cost of security). As shown in Table B-4, the net avoided EMDF construction and operating costs minus the cost of VR for Scenario B are a total of $65,778,025.

5.2.6 Cost Effectiveness of Volume Reduction Processing

Based on the estimated cost of VR processing and the reduced costs of EMDF construction and operations, the data favors the deployment of VR processing equipment. For an investment of $38.6M for

[1] Transportation cost basis: $250/day for the truck, $350/day for the driver, $7/hr for fuel, with an average of 3 loads delivered to the EMWMF or ORR Landfills per truck per day.

VR processing, the likely cost reduction is about $65.2M for a net savings of $26.7M. (based on Scenario A, see Table B-4). Under Scenario B, the estimated net savings is about $65.8M.

As shown in Attachment B, Table 7, the cost of VR processing varies with the type of debris and equipment used for processing. The concrete and masonry crushing operation costs the least, followed by shredding of light debris, then the shearing operations which cost the most by far to deploy. The cost of deploying both shearing machines is $28.8M and the EMDF capacity gained through reduced clean fill requirement is about 138,095 yd^3 (see Table B-3, "Clean fill for Material 1 without VR" for equipment and heavy steel [148,525 + 210,480] minus "Total clean fill required" Scenario A for equipment and heavy steel following VR processing [114,479 + 106,431]). This is equivalent to a cost per unit volume disposal capacity of about $209 per yd^3 ($28.8M÷138,095 yd^3) for the shearing operation which is greater than the estimated cost of EMDF operations at $154 per yd^3 of disposal capacity (Table B-4 total operations of $384,435,000÷2,491,687 yd^3). However, the additional EMDF capacity gain through the shearing operation allows the avoidance of construction costs for EMDF Cell 6 at $28.8M (Scenario A). In contrast to the shearing operation, the combined cost of deploying the shredder and crushers is only about $7.88M (see Appendix B, Table 7) including the cost of three excavators. By deploying the shredder and crushers, the EMDF capacity gained is over 248,334 yd^3 determined by summing the Table B-3 fill required for as-generated debris ("Fill for Material 1 without VR" for concrete and light debris [753,972 yd^3]) and subtracting the sum of the fill required for VR processed material ("Total fill required" for concrete and light debris [505,638 yd^3]) for Scenario A. The equivalent cost per unit volume for capacity gained in this case is $28.31 per yd^3 ($7.88M÷248,334 yd^3) which is far less than the cost of EMDF waste placement at $154 per yd^3.

5.2.7 PPE Compaction Benefits

Compaction of PPE/DAW in drums does not require significant space, labor, or facility support. The cost of a new drum crusher is about $15,000 and drums filled with PPE/DAW can be crushed to 20% of the initial size in minutes. The typical approach for managing PPE/DAW involves manual placement of collection bags in B-25 disposal boxes for landfill placement. The material, transportation, and clean fill requirements for disposing in B-25 boxes is about $473 per yd^3 assuming a B-25 box costs $1,500. If PPE were crushed in 55-gallon drums and five crushed drums are over-packed in an 85-gallon drum for disposal, the cost would be about $260 per yd^3. This assumes four drum crushers are deployed at a cost of $60,000. Container costs would be about $160 per over-pack and $30 per drum for refurbished drums. The additional labor costs for crushing were assumed to be $10 per drum. This is a net savings of $213 per yd^3 of as-generated PPE/DAW. The 2011 CARAR identifies a projected PPE/DAW quantity of 8,713 yd^3 from 2012 through 2033, most of which is generated during the Alpha-4 D&D and the K-25 Area D&D projects. Total savings by crushing and over packing PPE drums would be $1.8M. If, however, the PPE/DAW were packaged in 55-gallon drums instead of B-25 containers, packaging costs would be greatly reduced and it would not be cost effective to compact the drums due to the additional equipment and handling costs. The capacity gained by compacting PPE includes the smaller as-disposed volume and reduced fill requirement. The as-disposed volume of the projected 8,713 yd^3 would be about 4,357 yd^3 based on CARAR density data. Assuming six 55-gallon drums of PPE are compacted and over-packed in an 85-gallon drum, the as-generated volume for the original 8,713 yd^3 would be 2,550 yd^3. Using CARAR fill requirements of 1.35 (soil:debris) for both cases, the total capacity requirement for the original 8,713 yd^3 PPE volume with clean fill would be 16,380 yd^3. For the compacted PPE, the capacity requirement would be 6,069 yd^3 giving a net capacity increase of 10,312 yd^3.

5.2.8 Landfill Compaction Benefits

When large, coarse debris materials are placed in a disposal cell, void space is left in the waste despite the use of fill materials and compaction efforts. When the materials are shredded or crushed, the density of the landfilled materials increases. Studies at municipal landfills where size-reduction equipment is being used have indicated increased landfill capacity of 15 to 30% (CU 2009). The as-disposed volume for the material that is VR processed would be about 456,128 yd^3 (Table B-3). If the landfilled density is increased by 15% for this debris, the capacity gain would be about 68,419 yd^3, or 16% of a complete cell.

Compactors that roll over and compress the debris in the landfills are subject to significant maintenance and repair issues from the tangle of metals and other materials that can jam in the treads and other moving parts of the machines. If these materials are shredded, the amount of wear and tear on compactor equipment is expected to decline with a corresponding decrease in maintenance costs.

Table B-4. Estimate of EMDF Construction and Operations Savings for Volume Reduction Scenarios A and B

EMDF Construction and Operations	
Total Cost: $816,947,363[a]	
Capacity Increase Value Through VR	
Parameter	**Value**
EMDF Total Capacity, yd^3	2,491,687
Operating cost per yd^3 of disposal capacity	$154.29
Average Volume per Cell, yd^3	415,281
Total Cost of VR	$38,585,712
Scenario A Capacity Gain, yd^3	**475,281**
Scenario B Capacity Gain, yd^3	**830,258**
Scenario A cost reductions:	
On-Site Transportation Savings (Sect. 5.2.4)	$6,902,869
Construction of Cell 6 [b]	$19,897,809
Operations [c]	$38,443,500
Total Cost Avoided	$65,244,178
Net Cost Avoided (minus cost of VR)	$26,658,466
Scenario B cost reductions:	
On-Site Transportation Savings (Sect. 5.2.4)	$6,902,869
Construction of Phase III	$39,795,618
Operations [d]	$57,665,250
Total Cost Avoided	$104,363,737
Net Cost Avoided (minus cost of VR)	$65,778,025

[a] Detailed costs for the EMDF are found in Appendix G of the RI/FS.
[b] Not including engineering, considered sunk cost
[c] Assume 10% reduction for 20% reduction in EMDF capacity
[d] Assume 15% reduction for 33% reduction in EMDF capacity

5.3 RECYCLING

5.3.1 Regulatory Climate

The U.S. Environmental Protection Agency (EPA) is raising awareness and promoting 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 encourage 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 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 $yd^{\mathbf{3}}$ 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 efforts by heavy equipment operators to remove recyclable materials from the buildings before they were demolished. Some 106 tons of metal were removed from one large building alone, 16 tons more than the original estimate. LANL's demolition program director is quoted as saying, "Recycling metal from a demolition project reduces costs and cuts the amount of waste that goes to a landfill. We put a lot of effort into getting metal separated from the debris and making sure it isn't contaminated so it can be recycled."

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 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 the 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 about measuring 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).

One option to consider when planning D&D work for nuclear facilities would be to selectively remove materials from contaminated zones first, then re-characterize the facility and perform 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, the EPA, and the 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 requires 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.

5.3.2 Recycling Potential

The two materials that would be most beneficial to recycle would be concrete and metals. Concrete can be recycled to use as aggregate for new concrete, base material, roads, or new facilities. Demolition of concrete that is cleared for release could be crushed and screened on site, or could be transported to a recycling facility where crushing and screening could be performed. If the material were crushed and screened to meet aggregate specifications, the commercial value would be about $4.41 per ton in Tennessee, roughly equal to about $7.17 per yd^3 (USGS 2011). The crushed material would have to be moved to a location where the public could access it, so transportation costs would apply, as well as the cost of creating and maintaining a storage area for the material. The cost of crushing the material alone at about $6.67 per yd^3 (Attachment B, Table 7) is nearly equal to the commercial value, not including the additional cost of screening and losses from fines that pass through the screens. In addition, the material would no longer be available to replace clean fill at the EMDF or be used as base fill for other in-house DOE construction projects. The cost of processing and loss of other beneficial uses of crushed concrete appear to outweigh the commercial value of the product in this case, so recycling for commercial use is not recommended.

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) available for VR processing and potential recycle is about 176,415 tons. If 25% (44,104 tons) of the total quantity of metal is recycled at an average of $0.15 per lb, the commercial value is about $13.2M. Recycling will require that the material is free of contamination. Consequently, exhaustive characterization activities would be necessary to certify that the metals are clean unless it can be proven based on process knowledge that the equipment did not handle radiological or hazardous materials.

Bechtel Jacobs Company LLC (BJC) developed a cost estimate for additional contamination surveys that would be required for free-release of metals from D&D projects (BJC 2004). The approach is based on DOE 5400.5 requirements and includes radiation control technician support, PPE, survey instruments, and scanning operations. The estimated cost is $32 per yd$^{\mathbf{3}}$ of recycled material. From the CARAR density data, the bulk density of as-generated metal debris is 1,044 lb per yd$^{\mathbf{3}}$. Using this density, the cost for additional survey requirements is about $0.03 per lb. Transporting the metals to a local recycler would cost in the range of $0.02 to $0.03 per lb based on a cost of $220 per 10 yd$^{\mathbf{3}}$ transported. The total for additional surveys and transportation would be about $4.9M for 44,104 tons of material. After deducting this from the potential commercial value ($13.2M), the balance would be about $8.3M gained through commercial sale.

EMDF capacity gains are realized from metal recycling including the as-disposed volume that would have been required for the metals and the required clean-fill. For the 44,104 tons of metal estimated for recycle, the clean fill required if disposed at the EMDF would be approximately 59,459 yd^3 based on CARAR requirements. The as-disposed volume would be 25% of the Table B-3. “As-D volume for Material 2” for equipment and structural steel, or 11,073 yd^3. Adding this volume to the clean fill requirement gives a total capacity gain of 70,622 yd^3. For this quantity of material, it is assumed that incremental EMDF construction and operating cost savings would not be significant. Assuming the value of clean fill is the same as the cost of transporting at $220 per 10 yd^3, the cost savings would be $1.3M. The sum of the potential commercial value and clean fill savings is $9.6M for metal recycling.

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, especially if the facility has its own land disposal facility.

5.4 PROJECT SEQUENCING

Project sequencing refers to a scheduling approach employed to use contaminated or clean waste soil from RA projects in place of clean fill for filling the debris voids in the EMDF. The required capacity for the EMDF was estimated based on the RI/FS waste volume estimate from the time when the EMWMF fills to capacity in FY2023 through FY2043 (see Chapter 2). The estimate from Appendix A, Table A-4 indicates an as-disposed volume of waste soil of 386,771 yd^3 (including 25% uncertainty) will be generated in that time frame along with 611,457 yd^3 of debris. The quantity of fill needed for this quantity of debris is approximately 1,072,475 yd^3 assuming all of the waste soil is used to replace clean fill material. Current predictions for clean fill demand indicate that 100% of the waste soil is used to replace clean fill that would otherwise be needed for placement of the debris.

Sequencing of planned projects in the CARAR and RI/FS waste volume estimate are based on assumptions such as funding, prioritization, and contracting that can be uncertain and subject to change. As a result, the sequence of future projects identified in current plans may not be the actual sequence at the time of implementation.

Sequencing projects in a way that makes use of waste soil as fill material can result in cost benefits and reduce the disposal capacity needed. In cases where there are scheduling difficulties that interfere with the ability to utilize waste soil effectively, placement of waste soil in the landfill could be delayed until debris is placed in the landfill and waste soil can then be used to fill the debris voids in place of clean fill. In current EMWMF operations, space within the operating disposal cells is used to stockpile excess quantities of waste soil that can be utilized as fill for debris as it is delivered for placement. Operating personnel report that the use of waste soil to replace clean fill is performed when possible.

The total as-disposed volume of waste soil at 386,771 yd^3 is nearly the volume of a complete disposal cell; therefore, the consequence of not sequencing disposal of any waste soil with debris disposal would be equivalent to construction and operational cost of an additional cell, or roughly $65.2M as indicated in Table B-4 for VR Scenario A.

5.5 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.

When WGFs are developed, facility type and characterization data are used to determine waste disposition. D&D materials for facilities that are classified “other industrial” are assumed to be acceptable for the ORR Landfill. In most cases, D&D materials from facilities that are classified as “nuclear” or “radiological” 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 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. Segregation of additional wastes involves an enhanced effort and additional costs to survey and characterize radiological facilities, and perform additional separation of contaminated and clean materials. There is also additional risk associated with performing the sampling and executing the removal activities.

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.

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 deeper liner and capping system with additional geomembrane layers, an additional biointrusion layer, and an additional leachate leak detection system. These requirements would more than double the construction costs of the CERCLA landfill compared to ORR Landfills.

5.6 VOLUME REDUCTION AND 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. The use of VR equipment to size-reduce and increase the bulk density of demolition debris would 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 and costs are provided in Appendix G. This information was used as a basis for determining the economic benefit of various VR approaches.

Under the Off-site Disposal Alternative, all non-classified LLW and LLW/Toxic Substance Control Act of 1976 waste and classified LLW 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 NNSS in Nye County, NV. The remaining 3% of LLW/RCRA waste would be shipped to Energy*Solutions* in Clive, UT. For purposes of this VR comparison, shipment of LLW debris to NNSS is assumed.

Transportation for the off-site disposal estimate assumes that LLW debris would be transported by intermodal container to the truck-to-rail transfer facility at ETTP for rail shipment to Kingman, AZ and subsequent transfer to trucks for transport to NNSS. It is assumed that DOE would lease dedicated railcars. Incoming intermodal containers could be staged directly on the cars until one or more cars could be transferred to the main line and shipped.

The capacity of an intermodal container is assumed to be a maximum of 36,000 lb or 11 yd^3 and a single railcar is assumed to carry eight intermodal containers. Transportation cost for one railcar from the ETTP to Kingman, AZ is $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 the NNSS is about $1,370 per intermodal container. The intermodal containers are taken into the appropriate disposal cell, and emptied per approved procedures. Empty containers would be surveyed at the disposal facility for release and return to ORR.

The cost effectiveness of size reduction would depend upon the type and quantity of material to be shipped off site. As-generated materials that have a relatively high bulk density such as concrete and masonry may not be as cost effective to crush further because the truckload quantity would be limited by weight rather than volume. However, larger quantities of low-density materials could be shipped per truckload by size-reducing, increasing the bulk density, and increasing the quantity and weight shipped per truckload. These materials include equipment with large void fraction, large diameter ductwork and pipe, structural steel, light framing, siding, small tanks, asphalt shingles and other roofing materials, containers, furniture, trash, and wood. An analysis was performed to determine those materials that would benefit from VR processing prior to off-site disposal. Table B-5 summarizes the analysis. 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 assuming a maximum volume of 11 yd^3 and maximum net weight of 36,000 lb per intermodal. 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. The cost per unit volume for Off-site Disposal was applied to the avoided shipment volume, to determine the final cost savings.

The results indicate that decreasing the void fraction of these materials could reduce the number of shipments required for a given mass by a large margin. The avoided shipping volume would be expected to be more than 313,000 yd^3 which is equivalent to an avoided cost of over $263M in 2012 dollars (after subtracting the VR processing costs). This reduces the unit costs for off-site shipment from $962.44 per yd^3 to $677.07 per yd^3, or nearly 30%.

Comparing on-site and off-site unit costs indicates a substantial difference in favor of on-site disposal. The unit rate for on-site disposal was determined by dividing the total cost of the EMDF at $816,947,363 (from Table B-4) by the total as-generated volume of debris and soil 2,040,257 yd^3 from Appendix A, Table A-3, resulting in a unit cost of about $400 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 and clean fill required. The unit cost of air space is given by the total EMDF cost divided by the total as-disposed air space of 2,491,686 yd^3 giving \$327.87 per yd^3. Table B-6 applies this unit cost to the as-disposed volume of waste types with fill requirements. Unit costs are higher for materials that occupy more landfill air space due to higher ratios of as-disposed to as-generated volumes and significant fill requirements.

A similar evaluation was performed to determine on-site disposal costs by waste type including VR processing. The VR conditions defined in Table B-3 for both Scenarios A and B were used in the evaluation and the cost per unit of EMDF air space was determined by dividing the reduced EMDF cost by the reduced landfill capacity required as a consequence of VR processing. The estimated Scenario A cost savings, \$26,658,466, subtracted from the initial EMDF cost, \$816,947,363, gives \$790,288,897. For Scenario B, the new reduced cost is \$751,169,338. When these revised costs are divided by the reduced capacity values (2,076,406 yd^3 for Scenario A and 1,661,125 yd^3 for Scenario B), the unit values of EMDF air space are \$380.60 per yd^3 for Scenario A and \$452.21 per yd3 for Scenario B. These air space values are somewhat higher than the initial air space value of \$327.87 per yd^3, mainly due to the reduced landfill capacity over which the costs are applied and because it was conservatively assumed that the cost of many work elements (remedial design, early actions, leachate treatment, cell security operations, long term monitoring, and project management) would not change as a consequence of VR processing, and also due to the additional cost of VR. The revised EMDF unit cost was applied to the estimated as-disposed volumes for the various waste types after VR processing with the revised clean fill requirements. The unit cost for each waste type was determined by dividing the original as-generated volume by the total cost of air space for each waste type as shown in Table B-7. In general, materials that have a large void fraction have lower unit costs because the ratio of air space cost to As-G volume is relatively low. Materials that have a lower void fraction or are self-filling have higher unit costs because the ratio of air space cost to As-G volume is higher. The unit costs for the waste types generally follow the same increasing trend as the overall EMDF unit costs as VR processing reduces landfill air space. An exception to this is concrete and masonry debris because it was assumed VR would allow the material to replace fill material, thus reducing the air space cost to As-G volume ratio.

Similar to On-site disposal, the cost of off-site disposal varies by waste type. To determine transportation costs by waste type, the cost data used in Appendix G was applied to the waste types given in Table B-5 and the cost per unit volume determined both with and without VR processing. In this case, the volume transported per intermodal containers was determined based on waste density and maximized for each waste type to minimize packaging costs and the number of shipments. Table B-8 provides a summary of unit costs in \$/yd^3 as-generated material by waste type for off-site disposal. Materials with higher density and lower void volume exhibit higher off-site disposal costs because shipments are weight limited and lesser volumes can be transported per shipment. Table B-9 provides a summary of the unit costs in \$/yd^3 as-generated material for both on-site and off-site disposal with and without VR processing. In almost all cases, off-site disposal costs are significantly higher than on-site disposal costs. The exception is legacy material due to its lower initial bulk density and the ability to transport greater quantities per trip after VR processing. The results indicate that waste management strategies that attempt to conserve EMDF capacity through off-site disposal are unlikely to be cost effective.

Table B-5. Estimate of VR Cost Benefit for Off-site Disposal Alternative

Description	As-G Bulk Density (lb/yd^3)	As-G Volume for Processing* (yd^3)	Weight, Tons	Volume After Size-Reducing Material (yd^3)	Size Reduction Basis	Bulk Density After VR (lb/yd^3)	Net Weight** Per Intermodal Container with 11 yd^3 As-G Material	Net Weight** Per Intermodal Container with 11 yd^3 VR Material	Additional Weight Per Intermodal (lb)	Additional Weight Overall (lb)	Equivalent As-G Off-site Disposal Volume Avoided (yd^3)
Thick walled steel, large machine tools, large electric motors, process vessels	680	76,880	26,139	38,440	50% size reduction	1,360	7,480	14,960	7,480	26,139,084	38,440
>2" pipe, structural steel, crane structures	1,040	257,331	133,812	128,665	50% size reduction	2,080	11,440	22,880	11,440	133,812,103	128,665
Reinforced concrete, concrete block, brick, shield walls	2,600	444,255	577,532	355,404	20% size reduction	3,250	28,600	35,750	7,150	231,012,630	88,851
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	1,620	73,768	59,752	44,261	40% size reduction	2,700	17,820	29,700	11,880	47,801,721	29,507
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	1,040	31,662	16,464	18,997	40% size reduction	1,733	11,440	19,067	7,627	13,171,259	12,665
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	1,520	37,029	28,142	22,217	40% size reduction	2,533	16,720	27,867	11,147	22,513,638	14,812
Containers, furniture, trash, wood	640	2,067	662	1,240	40% size reduction	1,067	7,040	11,733	4,693	529,245	827
Totals:		922,992	842,503	609,225						474,979,680	313,767

Off-site Disposal Cost per yd^3 (2012 dollars)	$962.44
Off-site Disposal Savings, 2012 dollars	$301,981,701
Total VR Costs for Materials	$38,585,712
Net transportation costs avoided:	$263,395,989
Off-site Disposal Cost per yd^3 with VR (2012 dollars)	$677.07

* From Material 2 in Table B-3
**Assumes 36,000 maximum net weight per intermodal.

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Table B-6. On-site Disposal Cost by Waste Type without Volume Reduction

Description	As-G Volume (yd^3)	As-D Volume (yd^3)	Clean fill required for As-G Volume (yd^3)	Basis	As-disposed Volume for Waste and Clean Fill, (yd^3)	Cost of EMDF Airspace for Waste and Clean Fill	Cost per yd^3 of As-G Material
Thick walled steel, large machine tools, large electric motors, process vessels	256,266	15,504	148,525	Clean fill ratio is 9.58 for as-disposed equipment (soil: debris)	126,897	$41,605,631	$162.35
>2" pipe, structural steel, crane structures	343,108	31,747	210,480	Clean fill ratio is 6.63 for as-disposed metals (soil: debris)	189,607	$62,166,240	$181.19
Reinforced concrete, concrete block, brick, shield walls	592,340	473,872	592,340	Clean fill ratio is 1.25 for as-disposed dense concrete (soil: concrete)	918,127	$301,025,607	$508.20
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	98,357	49,179	111,144	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	132,537	$43,454,691	$441.80
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	42,216	21,108	47,704	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	56,885	$18,650,999	$441.80
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	49,372	24,686	0	No clean fill required, self-filling	24,686	$8,093,781	$163.93
Containers, furniture, trash, wood	2,756	1,378	3,115	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	3,714	$1,217,825	$441.80
Totals	1,384,415	617,473	1,113,307		1,452,454		

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Table B-7. On-site Disposal Cost by Waste Type with Volume Reduction

Description	Initial As-G Volume (yd^3)	As-G Volume for VR Processing (yd^3)	As-D Volume for VR Processed Material (yd^3)	As-G Volume, not VR Processed, (yd^3)	As-D Volume for Material not VR Processed (yd^3)	Scenario A				Scenario B			
						Clean Fill for VR and Non-VR Material (yd^3)	As-D Volume of VR and Non-VR Material with Clean Fill (yd^3)	Cost of EMDF Air Space	VR and EMDF Disposal Cost per yd^3 of As-G Material	Clean Fill for VR and non-VR Material (yd^3)	As-D Volume of VR and Non-VR Material with Clean Fill (yd^3)	Cost of EMDF Air Space	VR and EMDF Disposal Cost per yd^3 of As-G Material
Thick walled steel, large machine tools, large electric motors, process vessels	256,266	76,880	4,651	179,386	10,853	114,479	129,982	$49,471,804	$193.05	116,183	131,918	$58,778,663	$229.37
>2" pipe, structural steel, crane structures	343,108	257,331	23,810	85,777	7,937	106,431	138,177	$52,590,860	$153.28	108,015	140,235	$62,484,490	$182.11
Reinforced concrete, concrete block, brick, shield walls	592,340	444,255	355,404	148,085	118,468	336,449	810,321	$308,411,735	$520.67	-30,058	450,870	$200,894,485	$339.15
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	98,357	73,768	36,884	24,589	12,295	62,796	111,975	$42,618,180	$433.30	78,959	128,870	$50,635,706	$514.81
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	42,216	31,662	15,831	10,554	5,277	26,953	48,060	$18,291,964	$433.30	33,890	55,312	$21,733,132	$514.81
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	49,372	37,029	18,515	12,343	6,172	0	24,686	$9,395,600	$190.30	0	25,054	$11,163,143	$226.10
Containers, furniture, trash, wood	2,756	2,067	1,034	689	345	1,677	3,055	$1,162,908	$421.88	1,978	3,377	$1,381,679	$501.25
Total Volumes	1,384,415	922,992	456,128	461,423	161,345	648,784	1,266,258			308,968	935,635		

Table B-8. Off-site Disposal Cost by Waste Type, with and without Volume Reduction

Waste Type	Waste Density, As-G (lb/yd^3)	Net Volume Shipped (yd^3)	Net Volume per Container (yd^3)	Number of Intermodal Trips	Number of Containers Purchased	Packaging Cost	Number of Round-trips	Total Transport Cost	Total Disposal Cost	VR Processing Cost/yd^3 of As-G Material	Total VR, Transport, and Disposal Cost	Cost per yd^3 of As-G material
Thick walled steel, large machine tools, large electric motors, process vessels	680	76,880	18	4,271	41	$2,820,955	534	$19,436,356	$30,119,144	NA	$52,376,456	$681.28
>2" pipe, structural steel, crane structures	1,040	257,331	18	14,296	137	$9,440,799	1,788	$65,072,466	$100,814,553	NA	$175,327,818	$681.33
Reinforced concrete, concrete block, brick, shield walls	2,600	444,255	7.2	61,702	588	$40,725,655	7,713	$280,750,585	$174,045,804	NA	$495,522,044	$1,115.40
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	1,620	73,768	11.5	6,415	62	$4,239,370	802	$29,190,904	$28,900,124	NA	$62,330,398	$844.95
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	1,040	31,662	18	1,759	17	$1,162,489	220	$8,006,606	$12,404,097	NA	$21,573,192	$681.37
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	1,520	37,029	12.3	3,010	29	$1,988,993	377	$13,715,249	$14,506,855	NA	$30,211,098	$815.88
Containers, furniture, trash, wood	640	2,067	18	115	2	$81,512	15	$538,949	$809,931	NA	$1,430,392	$691.89
Thick walled steel, large machine tools, large electric motors, process vessels		38,440	13.8	2,785	27	$1,841,397	349	$12,694,688	$15,059,572	$93.32	$36,770,099	$478.28
>2" pipe, structural steel, crane structures		128,665	9	14,296	137	$9,440,799	1,788	$65,072,466	$50,407,277	$93.32	$148,934,774	$578.77
Reinforced concrete, concrete block, brick, shield walls		355,404	5.8	61,277	584	$40,445,136	7,660	$278,819,287	$139,236,643	$7.97	$462,041,475	$1,040.04
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	2,700	44,261	6.9	6,415	62	$4,239,370	802	$29,190,904	$17,340,074	$15.38	$51,905,175	$703.63
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	1,733	18,997	10.8	1,759	17	$1,162,489	220	$8,006,606	$7,442,458	$15.38	$17,098,627	$540.04
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	2,533	22,217	7.4	3,002	29	$1,984,111	376	$13,678,662	$8,704,113	$15.38	$24,936,530	$673.43
Containers, furniture, trash, wood	1,067	1,240	17.5	71	1	$48,829	9	$326,067	$485,958	$15.38	$892,658	$431.79

Table B-9. Summary of Unit Costs* for On-site and Off-site Disposal with and without Volume Reduction

Description	On-site Disposal			Off-site Disposal	
	Unit Costs without VR	Unit Costs with VR, Scenario A	Unit Costs with VR, Scenario B	Unit Costs without VR	Unit Costs with VR
Thick walled steel, large machine tools, large electric motors, process vessels	$162.35	$193.05	$229.37	$681.28	$478.28
>2" pipe, structural steel, crane structures	$181.19	$153.28	$182.11	$681.33	$578.77
Reinforced concrete, concrete block, brick, shield walls	$508.20	$520.67	$339.15	$1,115.40	$1,040.04
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	$441.80	$433.30	$514.81	$844.95	$703.63
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	$441.80	$433.30	$514.81	$681.37	$540.04
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	$163.93	$190.30	$226.10	$815.88	$673.43
Containers, furniture, trash, wood	$441.80	$421.88	$501.25	$691.89	$431.79

*Unit Costs are in $\$/yd^3$ as-generated material

6. PREVIOUS VOLUME REDUCTION EVALUATIONS

DOE published the *Remedial Design Report for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*, Oak Ridge, Tennessee in January 2001 (DOE 2001b). In August 2001, DOE published the *Waste Management Program Plan for Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act – Generated Waste* (DOE 2001b). 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 may require additional clean soil to achieve an appropriate soil-to-debris ratio. Also, the volume of contaminated/slightly contaminated soil disposed at EMWMF should be maximized to reduce the demand for clean soil fill.

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 the EMWMF did not have adequate capacity to accommodate the projected CERCLA waste volumes and the EMWMF has since been expanded.

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. The study did not consider VR of concrete and masonry debris materials. The study was intended to replace the need for individual projects to assess the appropriateness of implementing VR technologies. Two size-reduction technologies were evaluated, including shredding and compacting. It was concluded that, at most, 100,000 yd^3 of capacity could be gained by applying size-reduction technologies to the targeted waste streams. The size reduction technologies were evaluated against a 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 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.

Since opening of the EMWMF in 2002, waste VR methods, segregation, and recycling of CERCLA wastes, have been implemented on a limited project basis. The limited implementation of waste VR technologies may be due to cost competition among bidders of individual projects and the added expense of deploying size reduction equipment for individual projects that generate relatively small volumes of waste. Cost savings and other benefits could be realized by implementation of waste VR across projects, on a programmatic level. Uncertainty factors such as funding, project sequencing, and contracting that could impact practical implementation of a multiple-project approach are a significant consideration.

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, also to primarily maximize transport efficiency but also resulting in reduction of waste volume placed in the cell.

The FEMP constructed an on-site disposal facility with a capacity of over 2.9M yd^3 for disposal of the vast majority of remediation waste, including demolition debris, generated by the closure of the former Feed Materials Production Center. The WAC for the 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; sequencing of D&D and soil remediation projects was essential to maintaining this balance. Early stages of the RAs focused almost exclusively on soil remediation; this caused most of the first cell to be filled with waste soil since D&D had not yet begun. Upon realization of this disparity, new sequencing was initiated to assure that the proper balance was kept. Additionally, Fernald did implement concrete crushing actions, especially on building foundations/slabs. This crushed concrete was used in lieu of soil as filler material.

A strong recommendation from former site personnel was to size reduce debris at the demolition site prior to transport to and placement in the disposal cell. This could be 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 WAC and to reduce transportation costs. It was also recognized that crushed concrete could be used as fill material at the EMWMF to reduce clean fill requirements. However, the concrete-based fill material had an unwanted consequence of leaching unacceptable quantities of chromium-6 (Cr^{+6}) into contact water and leachate collected on site. Treatment units were introduced in the EMWMF contact water system to reduce the Cr^{+6} ions to Cr^{+3} that precipitates and alleviates the environmental issue. In addition, landfill operations procedures were modified to require the crushed concrete be mixed or layered with soil to inhibit Cr^{+6} leaching.

Excavator attachments for size-reduction are used routinely for D&D projects; however, the primary purpose of the excavators is for building demolition and could not be used cost effectively for VR processing alone. As described previously, excavators would be required to support VR operations by size-reducing as necessary for placement in VR equipment feed hoppers.

8. SUMMARY

VR approaches and the potential benefits, based on this study, are summarized in Table B-10. The largest payback and EMDF capacity gain could be achieved with deployment of size reduction equipment on a multiple-project or programmatic basis. Projections indicate that the volume of concrete and mortar debris is a large fraction of total debris volumes and can be used to reduce the demand and cost of clean fill. Based on the predicted waste volumes, EMDF capacity gains from size-reduction operations could potentially reduce disposal capacity needs by up to two disposal cells (over 800,000 yd^3). As shown in the estimated cost of the stationary shear operation, the cost of VR processing increases substantially if the debris is contaminated to a level that requires an enclosure and contamination control measures. It is assumed in this case that only the equipment and heavy steel from demolition of Y-12 facilities would require enclosed facilities for VR. To date, most of the D&D projects executed on the ORR have been performed as open-air demolitions.

If funds are committed to additional characterization efforts, cost and capacity gains from increasing recycling, as well as segregating more material to the ORR Landfill, are also significant. Once the NRC and DOE have established a sound technical basis for survey and release for solid materials associated with radiological facility activity, recycling efforts should focus on recovery and recycle of metals. Segregation of additional wastes to the ORR Landfill is beneficial due to the lower construction costs associated with the liner and final cover systems. Additional efforts to segregate and selectively remove non-contaminated materials during D&D activities could conserve EMDF capacity and reduce disposal costs significantly.

The benefits of project sequencing are apparent from experience at other DOE sites and; therefore, are inherent in the existing plan for the EMDF. If waste soil is not used as fill material for void space within debris material, additional disposal space beyond the EMDF design capacity may be needed. The EMDF approach for waste placement must include space allowance for stockpiling waste soil for use as fill material to avoid the cost and capacity loss from the use of excessive amounts of clean fill.

VR approaches discussed could be cost effective when applied to the Off-site Disposal Alternative addressed in this RI/FS. The cost of transportation and off-site disposal exceeds the cost of VR processing. Consequently, increasing the bulk density of debris translates directly to a lesser number of costly off-site shipments and lower disposal fees for the off-site facilities.

Table B-10. Summary of Volume Reduction Benefits for the EMDF

Parameter	Volume Reduction Approach				
	Size Reduction	**Recycling**	**Compaction**	**Sequencing**	**Segregation**
Basis	Shredding, crushing, and shearing operations are deployed at multiple sites as a programmatic effort.	Recycling of 25% of metal debris (44,104 tons)	Drum compactor used for PPE and DAW	RI/FS waste volume estimate assumes virtually all waste soil is used to replace clean fill (386,771yd^3 as-disposed)	Additional debris is segregated and diverted to the ORR Landfill.
Cost of Method	$38.6M	$5M for characterization and transportation	$60,000 capital; $260/yd^3 materials and labor	Negligible	The cost of additional facility characterization, field surveys, and selective removal activities
Cost Savings	Scenario A:$26.7M Scenario B: $65.8M	$9.6M from recycling and EMDF clean fill savings	$1.8 M	$65.2M (cost avoided through assumed sequencing)	Reduced landfill construction and operations costs.
EMDF Capacity Gained	Scenario A: 475,281 yd^3 Scenario B: 830,258 yd^3	70,622 yd^3	10,312 yd^3	386,771 yd^3	Equivalent to as-disposed volume of segregated waste and associated fill.
Additional Potential Benefits	Increased landfill density with additional capacity gain of 69,438 yd^3; lower equipment maintenance costs				
Additional Notes		Assumes commercial value of $0.15/lb for metals	Compares packaging PPE in B-25 box to compaction and over-packing	RI/FS waste volume estimate soil demand is based on successful sequencing.	ORR landfill construction costs are significantly lower than for EMDF.

9. CONCLUSIONS AND RECOMMENDATION

This study indicates substantial benefits are possible if VR efforts are pursued. The paybacks are greatest if the overall EMDF capacity gained is equivalent to at least one disposal cell or 416,667 yd^3. If VR is performed in combination with efforts to characterize, recycle, and segregate a moderate amount of material, EMDF capacity gains could reach the equivalent of two full cells.

Uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement VR on multiple projects. Potential ways to address the logistics of multiple-project implementations include:

- Contract incentives for VR
- Including VR requirement in WAC of the proposed EMDF
- Deploying one VR contractor for multiple projects

Incorporating VR efforts (size reduction, recycling, enhanced characterization, and sequencing efforts) in project planning and practical field implementation could result in significant cost savings and reduced need for disposal capacity.

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ATTACHMENT A

VENDOR INQUIRY FORMS AND DATA

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). 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. 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. 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. 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. 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. Mobile units typically weigh 80,000 lb or more and are limited to thickness of 1.5 to 2 inches (without folding). Ton per hour 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.

ATTACHMENT B

VOLUME REDUCTION PROCESSING COST ESTIMATE

Table 1. Basis for Size Reduction Cost Estimate

Basis for Estimate		
Volume (yd^3)	**Weight (tons)**	**Description**
1,384,415	1,112,976	Total debris amenable to volume reduction processing, yd^3
Quantity for Processing		
144,526	105,020	Total for shredding
444,255	577,532	Total for crushing
239,963	114,845	Total for stationary shearing operation at Y-12 (54% of total)
94,247	45,106	Total for mobile shearing operations (46% of total)
922,992	842,503	Overall total for processing

Table 2. 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.
Transportation and Setup	$20,500	Assume $5K to transport; SSI tech support for one week at $100/hr with airfare and per diem ($1,500).
Labor Description	1 Operator	Operator of the shredder.
Labor Cost	$787,649	$60/hr (operating hrs + downtime).
Availability	75%	SSI
Operating hours	10,502	10 tons per hr.
Fuel	$273,052	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.	$148,341	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.
Engineering	$10,000	Specification development, sizing, capabilities, operating features; assume 100 hrs at $100/hr.
Indirect Costs	$283,948	28% of capital, setup, fuel, maintenance, and overhaul costs.
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr.

Table 3. 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)	$912,800	Quote from Eagle Crusher.
Transportation and Setup	$22,000	Assume $5K to transport; Eagle Crusher tech support for one week at $100/hr with airfare and per diem ($1,500).
Labor Description	1 Operator	Operator of the crusher.
Labor Cost	866,297	$60/hr (operating hrs + downtime).
Availability	75%	Eagle Crusher
Operating hours	11,551	50 tons per hr.
Fuel	$462,025	10 gal/hr diesel fuel or $40/hr at $4/gal diesel.
Maintenance: Changing oil and filters; rotation of wear plates.	$49,646	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	$154,116	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.
Engineering	$10,000	Specification development, sizing, capabilities, operating features; assume 100 hrs at $100/hr.
Indirect Costs	$479,876	28% of capital, setup, fuel, maintenance, and overhaul costs.
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr.

Table 4. Cost Data for Excavator Operation

Excavator Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Volvo	
Model	2010 VOLVO ECR235C	
Capacity	7.5 ton	
Capital Cost (5 units)	$1,017,500	Source of cost information: McAllister Equipment Company,. Anticipate needing five excavators at $203,500 each over the course of the operation.
Transportation and Setup	$52,500	Assume $5K to transport; Volvo tech support for one week at $100/hr with airfare and per diem ($1,500) for two units.
Labor Description	1 Operator	This excavator operator loads crushed concrete and shredded debris into transport trucks. There are dedicated operators in charge of running the crusher and shredder.
Labor Cost	2,125,744	$60/hr (operating hrs+downtime).
Availability	90%	Engineering judgment.
Operating hours	32,208	Combined hrs for shredder and crusher.
Fuel	$644,165	5 gal/hr diesel fuel or $20/hr at $4/gal diesel for 150 HP diesel engine.
Maintenance: Changing oil and filters; inspections	$132,859	Oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout.
Major overhauls	$200,000	Five major engine overhauls.
Engineering	$2,000	Specification development, sizing, capabilities, operating features; assume 20 hrs at $100/hr.
Indirect Costs	$614,107	30% of capital, setup, fuel, maintenance, and overhaul costs.
Procurement	$1,500	Procurement documents, Quality Assurance inspections, vendor qualifications, etc.; assume 20 hrs at $75/hr.

Table 5. Cost Data for Stationary Shear Operation

Stationary Shear Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Harris	
Model	BHS-30-1123-B	
Rated Capacity	30 Tons/hr max (2.75 cuts per minute at rated thickness)	15.75 tons per hr based on K-33 shear performance (Harris contact)
Capital Cost	$6,850,000	Quote from Harris
Transportation and Setup	$478,720	Per Harris contact, 6 months to assemble for K-33 project; assume 6 personnel and lease of crane.
Labor Description	8 personnel	One supervisor, one operator for the shear, two operators to work with the excavator operator to manage the feed and product, one maintenance technician, one facility manager, and two radiation protection technicians.
Labor Cost	$4,666,716	$60/hr (operating hrs + downtime)
Availability	75%	Per Harris contact
Operating Hours	7,292	15.75 tons per hr based on K-33 shear performance
Utility Costs	$1,176,629	1,600 HP total for electric motors of shear in addition to utility requirements for the containment enclosure
Maintenance	$524,720	Rotating and replacing knife blades and greasing the equipment and support systems occupies 6 personnel in two 12-hr shifts, once per month. Three sets of blades are replaced per year at about $10K per set (total $30K/yr). Replacing hydraulic fluid (5,000 gal per change) every 2 years using AW46 hydraulic fluid costs at $5/gal = $12.5K/yr.
Enclosure	$5,033,053	This enclosure is designed for contamination control for materials suspected to be rad contaminated at low-level criteria. The facility cannot accept mixed waste.
Engineering	$1,236,177	Assume 10% of total construction costs.
Indirect Costs	$3,695,876	30% of capital, setup, power, and maintenance costs
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr

Table 6. Cost Data for Mobile Shear Operation.

Mobile Shear Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Harris	
Model	GS-11-E-4 S/B/L	
Rated Capacity	15-40 tons/hr	15.75 tons per hr based on K-33 shear performance (Harris contact)
Capital Cost	$1,800,000	Budget quote from Harris
Transportation and Setup	$1,027,800	Assume $5K to deliver; Harris tech support for 60 days at $100/hr with airfare and per diem ($1,500). Three operating personnel required in addition to Harris rep. System relocation would occur three times, 60 days per move, and require the lease of a 80 ton crane.
Labor Description	4 personnel	One supervisor, one operator for the shear, two operators to work with the excavator operator to manage and package the product.
Labor Cost	$859,166	$60/hr (operating hrs + downtime)
Availability	75%	Per Harris contact
Operating hours	2,864	15.75 tons per hr based on K-33 shear performance
Electricity	$91,392	1,600 HP total for electric motors
Maintenance	$141,369	Rotating and replacing knife blades and greasing the equipment and support systems occupied 4 personnel in two 12-hr shifts, once per month. Three sets of blades are replaced per year at about $7K per set (total $21K/yr). Replacing hydraulic fluid (3,700 gal per change) every 2 years using AW46 hydraulic fluid costs at $5/gal = $9.25K/yr. It can be filtered and re-used in the unit for up to 10 years if necessary.
Foundation pads	$60,000	It is assumed that the materials processed by this shear are primarily non-contaminated structural steel and other heavy-walled materials. Assume three equipment pads at $20/ft^2 based on PWS project zeolite system foundation with overhead and contingency. Assume 1,000 ft^2 per pad.
Engineering	$215,700	Assume 10% of total construction costs.
Indirect Costs	$918,169	30% of capital, setup, power, and maintenance costs
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr

Table 7. Compiled Cost Data for Size Reduction Operations

VR Processing Costs					
Cost Element	**Shredder**	**Crushers (2)**	**Stationary Shear**	**Mobile Shear**	**Excavators (5)**
Equipment	$325,000	$912,800	$6,850,000	$1,800,000	$1,017,500
Transportation and Setup	$20,500	$21,000	478,720	$1,027,800	$52,500
Labor	$787,649	$866,297	4,666,716	$859,166	$2,125,744
Fuel	$273,052	$462,025	1,176,629	$91,392	$644,165
Maintenance	$327,941	$203,762	524,720	$141,369	$332,859
Facility	NA	NA	$5,033,053	$60,000	NA
Engineering	$10,000	$10,000	1,236,177	$215,700	$2,000
Indirect Costs	$283,948	$479,876	3,695,876	$918,169	$614,107
Procurement	$7,500	$7,500	7,500	$7,500	$7,500
Total cost	$2,035,588	$2,963,261	$23,669,390	$5,121,097	$4,796,375
Cost per hr, including capital	$194	$257	$3,246	$1,788	$149
Yd^3 processed	144,526	444,255	239,963	94,247	922,992
Cost/yd^3	$14.08	$6.67	$98.64	$54.34	$5.20

Table 8. Summary Volume and Cost Data for VR Operations.

Item	Volume, yd^3	Cost
Total capital costs, including equipment, setup, facility, engineering, and procurement costs		$19,110,251
Total operating costs		$13,483,486
Indirect costs		$5,991,975
Total VR costs		$38,585,712
Volume of debris processed, yd^3	922,992	$41.81 /yd^3
EMDF capacity gained for Scenario A, yd^3	475,281	$81.19/yd^3
EMDF capacity gained for Scenario B, yd^3	830,258	$46.47/yd^3

APPENDIX C:

ON-SITE DISPOSAL ALTERNATIVE SITE DESCRIPTION

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CONTENTS

FIGURES

TABLES

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
ETTP	East Tennessee Technology Park
MSL	mean sea level
NAAQS	National Ambient Air Quality Standards
ORERP	Oak Ridge Environmental Research Park
NT	Northern Tributary (of Bear Creek)
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Office
ORR	Oak Ridge Reservation
PCB	polychlorinated biphenyl
RA	Reference Area
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
S.U.	standard unit
SR	State Route
TCE	trichloroethene
U.S.	United States
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
WWSY	White Wing Scrap Yard
Y-12	Y-12 National Security Complex

1. SITE DESCRIPTION

This Appendix to the Remedial Investigation/Feasibility Study (RI/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.

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.

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.

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 State Route (SR) 58/95.

The BCV Phase I Record of Decision (ROD) (DOE 2000) divides BCV 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 C-1 The proposed EMDF site is located in Zone 3, which is an historical waste management area and has 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.

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 C-1 summarizes basic demographic data for the five-county area.

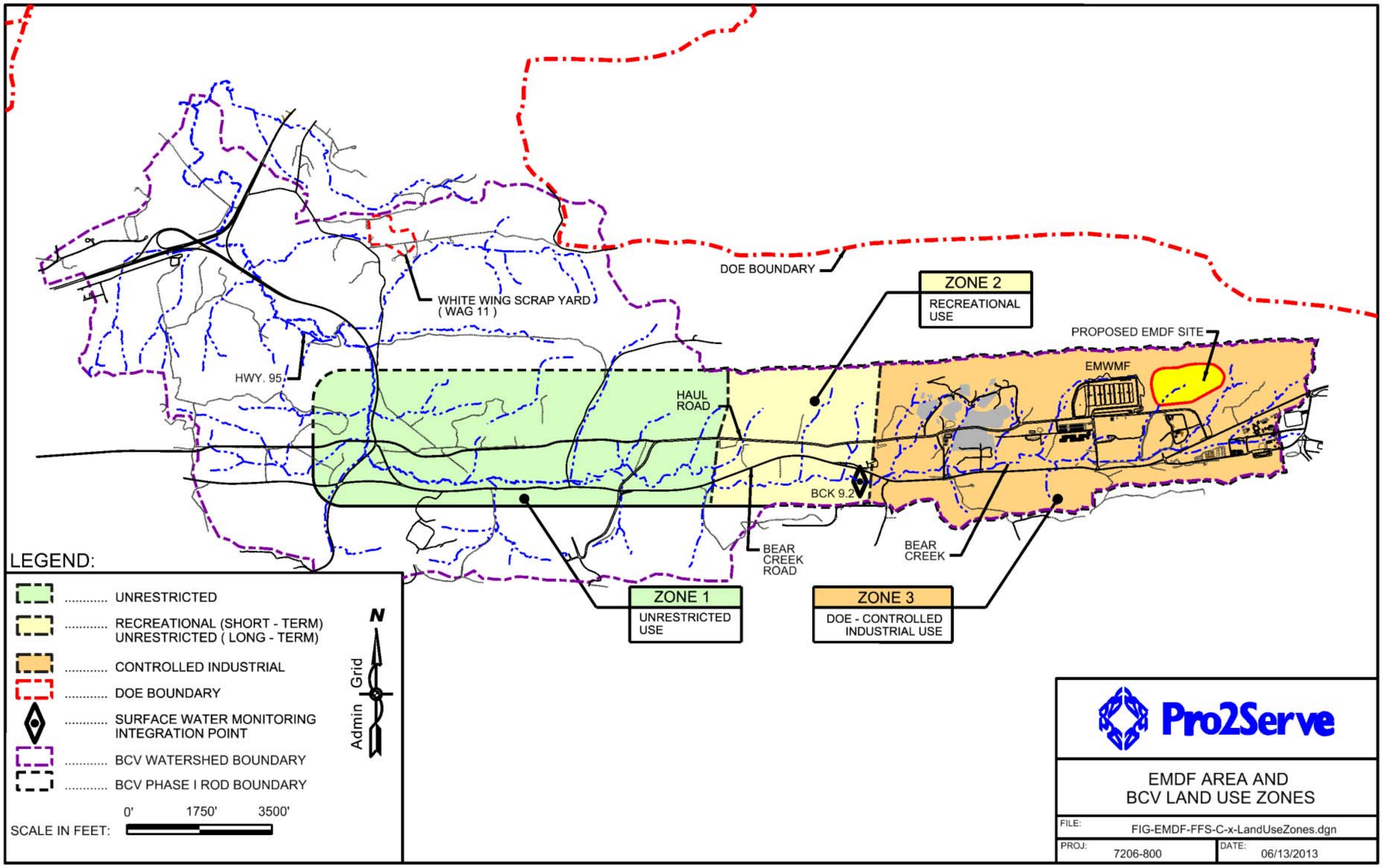


Figure C-1. Bear Creek Valley and Land Use Zones Established in the Phase I ROD

Table C-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 proposed EMDF site lies in Anderson County census tract 9801, which has no residential population. Populations of adjoining census tracts are provided in Table C-2. Counties and nearby census tracts in vicinity of the proposed EMDF are shown in Figure C-2.

Table C-2. Population Data for Adjacent Census Tracts in 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

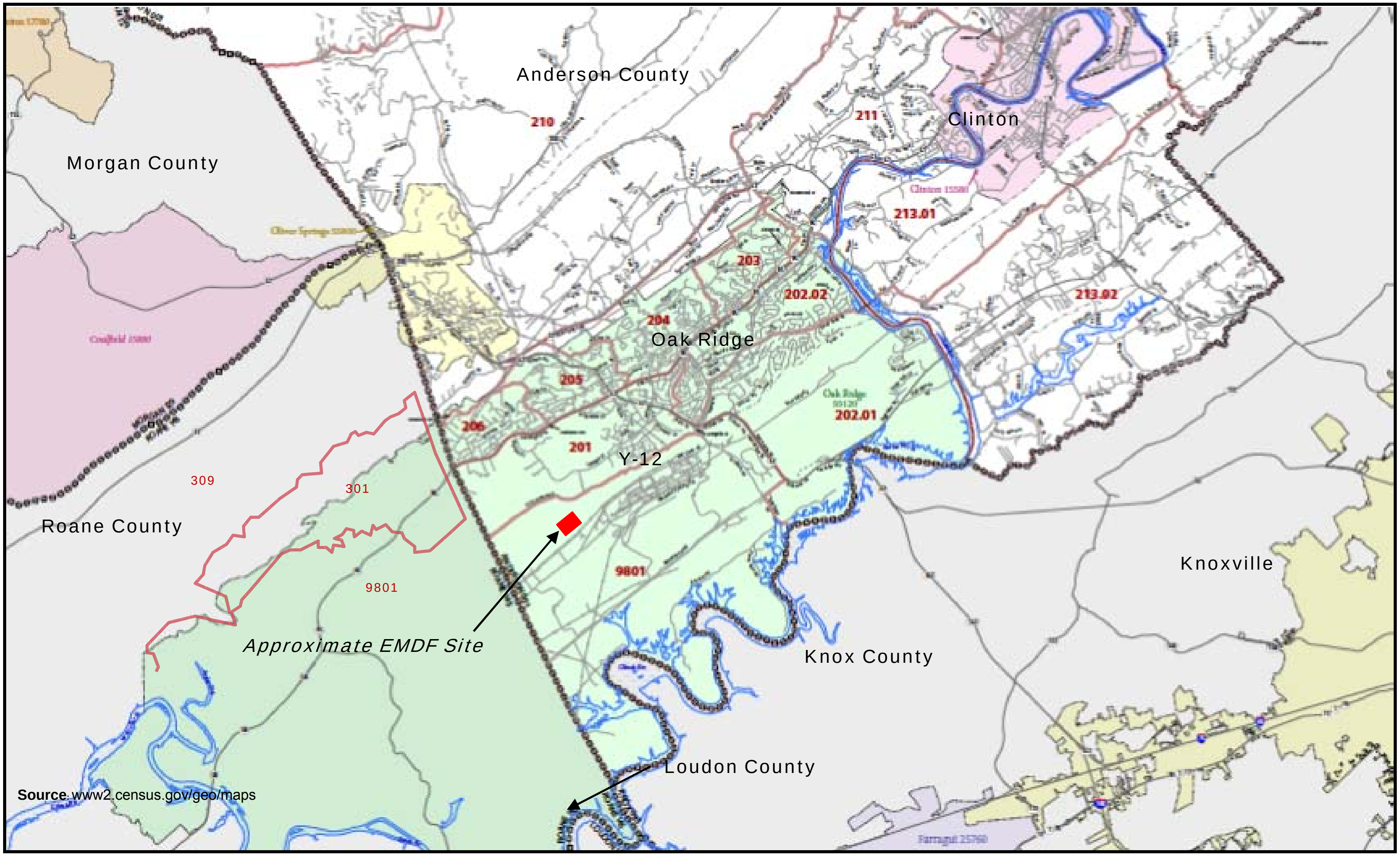


Figure C-2. Oak Ridge Reservation and Nearby Census Tracts in Vicinity of the Proposed EMDF

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 C-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 C-3.

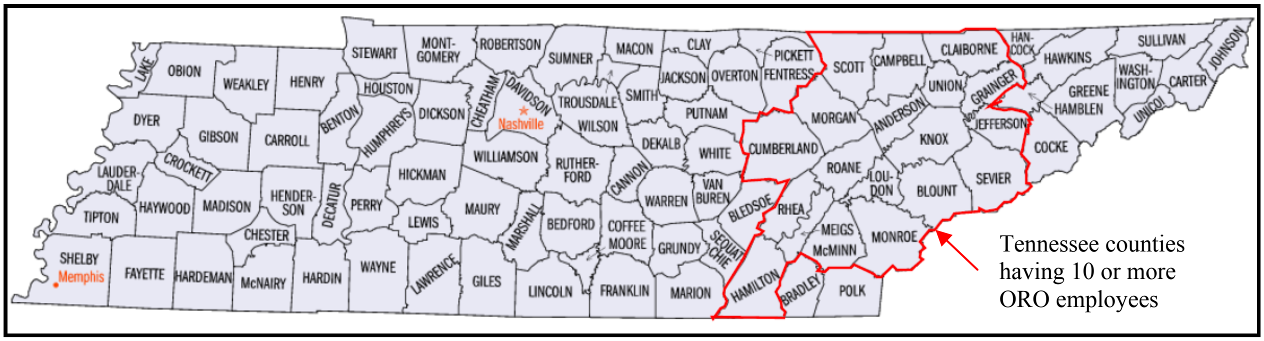


Figure C-3. Tennessee Counties in which 10 or more ORO Employees Lived during 2009

Table C-3. DOE-ORO Employees and Payroll for the Top Five Counties

County	2009 Employees	2009 Payroll
Knox	5,437	$467,457,101
Anderson	3,357	$259,963,826
Roane	2,318	$163,056,092
Loudon	706	$53,004,744
Blount	434	$33,794,209

Source: http://www.oakridge.doe.gov/External/LinkClick.aspx?fileticket=BP_PIwu9sDA%3D&tabid=189&mid=746

1.3 TRANSPORTATION

The proposed EMDF site has access via Bear Creek Road to SRs 58 and 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.

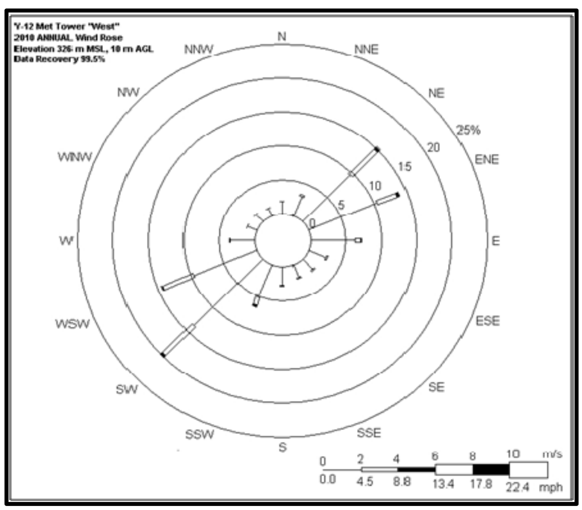
1.4.1 Climate

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[1]. snow per year. 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 C-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 mi 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 C-4. Representative Wind Rose Diagram for the Y-12 West 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

[1] Climate statistics are from http://www.ornl.gov/~das/web/ Normals/30YRNorm.pdf

as nonattainment areas for that pollutant. On March 12, 2008, the EPA promulgated the new ozone standard of 0.075 parts per million.

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. CANDIDATE SITE SCREENING

The 13 candidate sites considered for this RI/FS screening evaluation were selected utilizing previous data and information collected during a 1996 DOE site screening study (DOE 1996), the Environmental Management Waste Management Facility RI/FS (DOE 1998) and the 2008 ORR Planning document (DOE 2008a). The screening process consisted of candidate site identification, development of screening criteria to evaluate the candidate sites, and application of the criteria based on data and information gathered during the screening process. 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.

A 1996 DOE site-screening study evaluated 35 sites on the DOE ORR as potential sites for an on-site disposal facility (DOE 1996). The EMWMF RI/FS pared the original 35 candidate sites down to three sites that were carried forward as potentially suitable, including the East BCV (EBCV) (where the existing EMWMF is located), West BCV (WBCV), and White Wing Scrap Yard (WWSY) sites (DOE 1998). The 13 candidate sites considered for this RI/FS screening evaluation include some of the sites identified in the 1996 siting study as well as other possible favorable locations. The 2008 ORR planning document helped identify potential conflicts in land-use priorities between various DOE mission goals and objectives, specifically delineating long term research areas and protected land areas. Table C-4 lists the 13 candidate sites and indicates the basis for their consideration. The site locations are identified by number on Figure C-5.

Screening of the 13 candidate sites 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 C-5 identifies and briefly describes the preliminary siting criteria the candidate sites were screened against. 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. 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. The presence of surface water features, such as streams and wetlands, were a consideration. Candidate sites that presented critical construction/engineering obstacles were deferred from further consideration in the preliminary screening phase. The "discussion" column in the table identifies those candidate sites retained, identifies the option designs that are derived from an updated or modified design of another listed option, and why candidate sites were eliminated from further consideration

Table C-4. Candidate Sites Identified for the RI/FS Screening Evaluation

Candidate Site*	Basis for Consideration
(1) East BCV-Option 1	Adjacent to EMWMF, avoids tributaries
(2) East BCV-Option 2	Adjacent to EMWMF, combines Bear Creek Burial Ground (BCBG) remedy component with EMDF siting
(3) East BCV-Option 3	Adjacent to EMWMF
(4) East BCV-Option 4	Adjacent to EMWMF
(5) East BCV-Option 5	Adjacent to EMWMF
(6) East BCV-Option 6	Two separate disposal cells (6a & b), adjacent to EMWMF on west and east, avoids tributaries
(7) East BCV-Option 7	Two separate disposal cells (7a & b), avoids tributaries
(8) WBCV	Previous waste disposal facility siting study
(9) WWSY	Previous waste disposal facility siting study; Adjacent to or surrounded by contaminated area Waste Area Grouping (WAG) 11
(10) Chestnut Ridge, east of Spallation Neutron Source	Possible favorable location
(11) West-Central Chestnut Ridge	Previous waste disposal facility siting study
(12) East Chestnut Ridge	Previous waste disposal facility siting study; Fanny Knob area, hill slope, avoids tributaries
(13) Former Breeder Reactor area	Possible favorable location

*Numbers in parentheses correspond to the areas shown on Figure C-5.

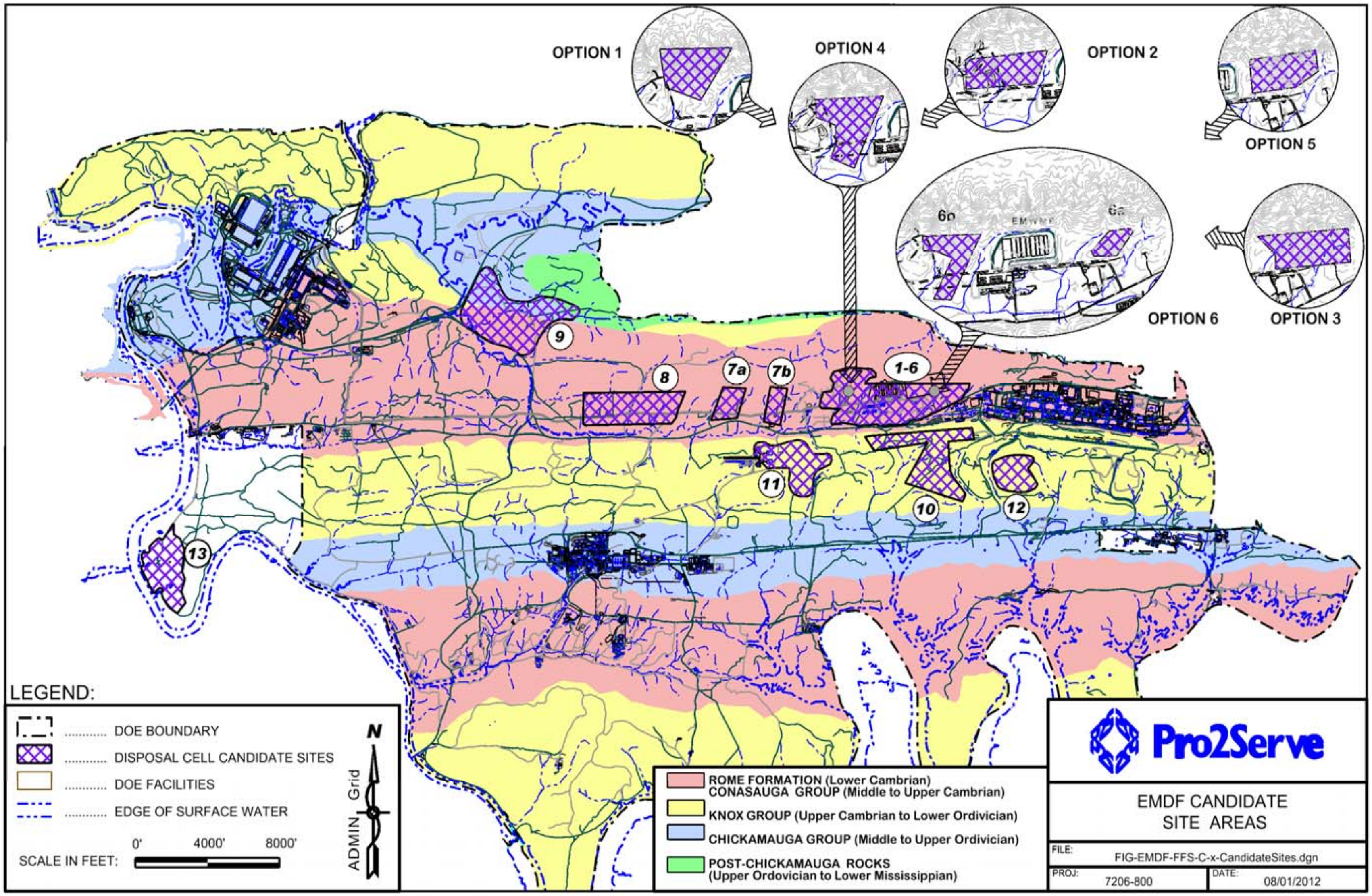


Figure C-5. EMDF Candidate Site Areas

Table C-5. Preliminary Screening of Candidate Sites

Candidate site	Preliminary Screening Criteria				Discussion
	Insufficient Area	Unfavorable Topography	Surface Water Impacts	Karst Features	
(1) East BCV-Option 1		X			Site eliminated due to unfavorable topography and excessive cut and fill.
(2) East BCV-Option 2			X		**Carried forward to secondary screening, see Table C-6**
(3) East BCV-Option 3			X		Site eliminated. Crosses headwaters of two tributaries (NT-2 and NT-3).
(4) East BCV-Option 4			X		**Carried forward to secondary screening, see Table C-6**.
(5) East BCV-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 C-6**
(6) East BCV-Option 6					A modified version of Option 4 design with an additional separate cell to the east. **Carried forward to secondary screening, see Table C-6.**
(7) East BCV-Option 7					**Carried forward to secondary screening, see Table C-6.**
(8) WBCV					**Carried forward to secondary screening, see Table C-6.**
(9) WWSY					**Carried forward to secondary screening, see Table C-6.**
(10) Chestnut Ridge		X		X	**Carried forward to secondary screening, see Table C-6.**
(11) West-Central Chestnut Ridge	X			X	Lack of suitable area for development due to proximity of Spallation Neutron Source. Karst features are present.
(12) East Chestnut Ridge	X	X			Lack of suitable area for development due to site configuration and natural and anthropogenic features.
(13) Former Breeder Reactor Area				**X**	**Carried forward to secondary screening, see Table C-6.**

The preliminary screening phase reduced the original 13 candidate sites to 9 for further evaluation. The remaining candidate sites were evaluated in a second screening phase against a set of modifying criteria. As shown in Table C-6, the modifying criteria used for the secondary screening phase were location and access, site contamination, buffer zones, land use, and disposal capacity. Modifying criteria were designed to defer 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. These criteria generally represent concerns that would need to be addressed for areas carried forward as final candidate sites, rather than a basis for elimination. The “discussion” column in Table C-6 identifies the candidate site retained and notes why other sites are eliminated from further consideration.

Geologic Buffer: Requirements for geologic buffers underlying landfills of the Tennessee Department of Environment and Conservation Waste Management System were not used as a basis to defer candidate sites from further evaluation because these buffers can be engineered if they are not naturally occurring, or "equivalent or superior protection" may be employed. The Toxic Substance Control Act of 1976 geologic buffer requirement was not used as a threshold criterion 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. Strict application of this requirement in the screening phase of the process would result in premature elimination of otherwise viable locations.

Bear Creek Burial Grounds Remedy Component: Candidate Site Option #2 shown on Figure C-5 combines a Bear Creek Burial Grounds (BCBG) remedy component with siting of the proposed landfill. Construction of a new landfill under Candidate Site Option #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 C-6) and would impact a portion of Northern Tributary (NT)-6. Excavated waste would be placed in the new landfill and/or disposed off-site. As shown in Table C-6, Candidate 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 excavation, treatment, and disposal of BCBG buried waste and high cost of implementation.

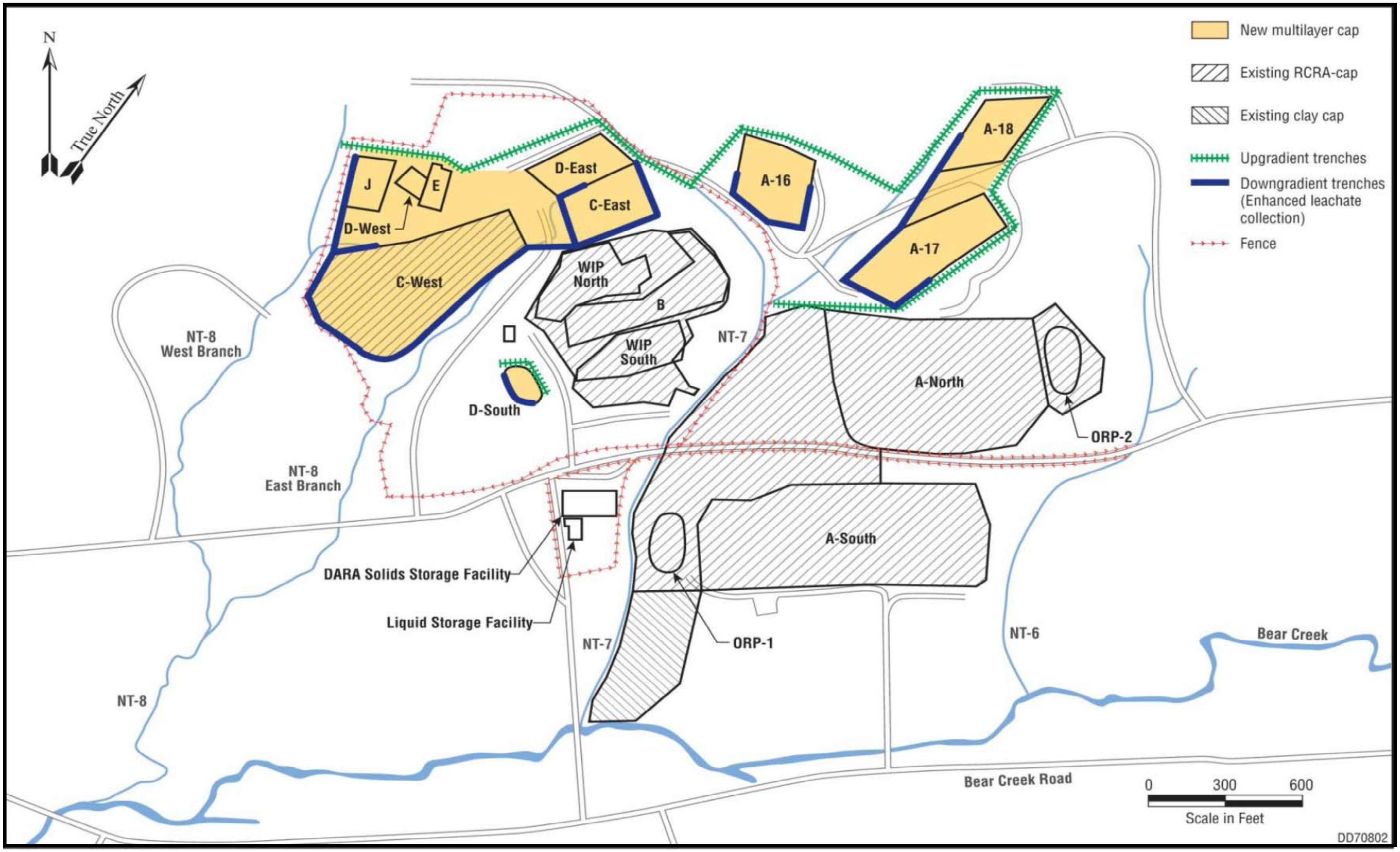


Figure C-6. Remedial Action components for the Preferred Alternative for the BCBG

Candidate Site Option #2 would be inconsistent with the preferred alternative of hydrologic isolation identified in the Proposed Plan for BCBG (DOE 2008b). The preferred alternative (see Figure C-6) includes construction of multilayer engineer caps for all previously uncapped BCBG disposal units plus one previously capped unit (BCBG C-West), construction of upgradient stormflow trenches to intercept and divert shallow groundwater 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.

The secondary screening phase reduced the remaining nine candidate sites to one final candidate site, Candidate Site Option #5, that is evaluated as the proposed site for the On-site Disposal Alternative and described in the following section.

3. PROPOSED ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY SITE DESCRIPTION

The proposed EMDF site location and setting, site geology, groundwater, surface water hydrology, conceptual flow model, ecological setting, and cultural resources are described below.

3.1 LOCATION AND SETTING

The proposed EMDF site is located in 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 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).

Table C-6. Secondary Screening of Candidate Sites

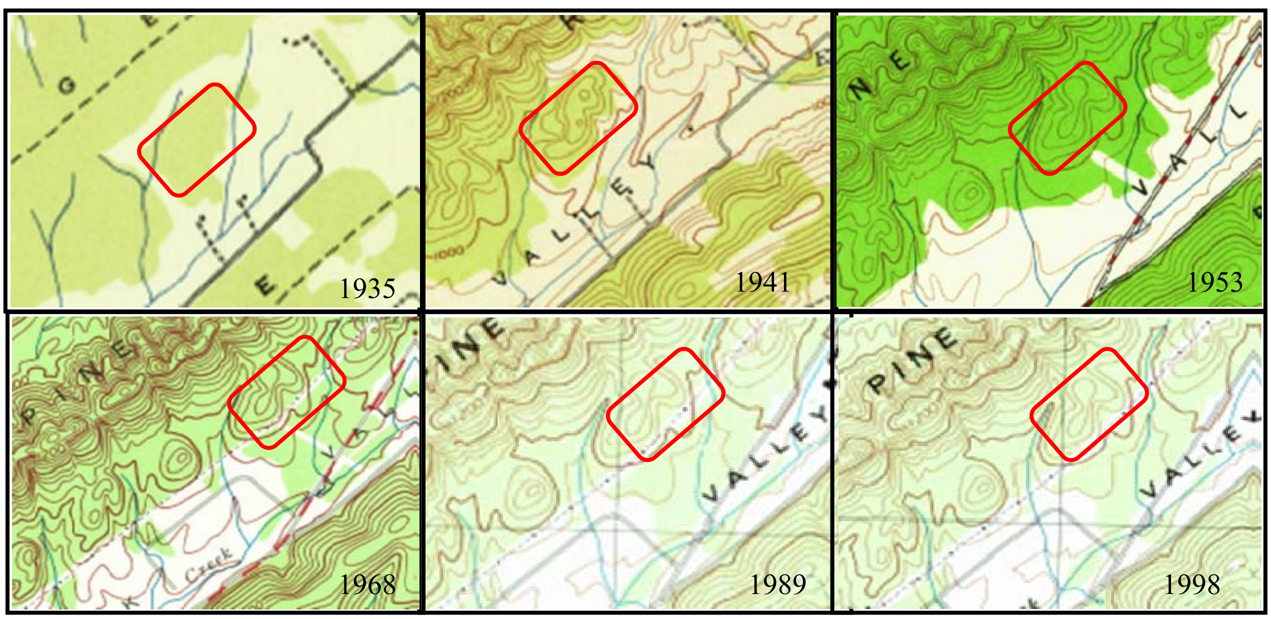
Candidate Site	Secondary Screening Criteria					Discussion
	Location and Access	Site Contamination	Buffer Zones	Land Use	Disposal Capacity	
(2) East BCV-Option 2		X	X			Site eliminated. Presence of buried waste and site contamination present significant challenges to facility construction.
(4) East BCV-Option 4			X		X	Site eliminated. Concern about adequate disposal capacity and shallow groundwater table south of the Haul Road.
(5) East BCV-Option 5						**Proposed candidate site.** Site is located in BCV Watershed Zone 3 designated for future controlled industrial use.
(6) East BCV-Option 6			X		X	Site eliminated. Concern about adequate disposal capacity. Two separate cells increase design, construction, and operations cost.
(7) East BCV-Option 7			X	X	X	Site eliminated. Adequate disposal capacity could potentially be achieved using two separate cells. Separate cells increase design, construction, and operations cost. Site is located in BCV Watershed Zone 2 designated for future recreational land use (short-term) and unrestricted land use (long-term).
(8) WBCV			X	X		Site eliminated. Site is located in BCV Watershed Zone 1 designated for future unrestricted land use.
(9) WWSY			X	X		Site eliminated. Site is located in an area designated for future unrestricted land use.
(10) Chestnut Ridge				X		Site eliminated. Located in the Walker Branch Watershed Research area, a long-term ecological research area.
(13) Former Breeder Reactor area	X		X	X		Site eliminated. Concern about proximity to the Clinch River. Site is located on karst bedrock and outside the DOE-ORR boundary.

3.1.1 Current and Former Land Use

As stated in Section 2 of this appendix, the proposed EMDF site is located in BCV Watershed Zone 3, designated for future controlled industrial use. 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. Geographic Services (USGS) 7.5-minute quadrangle maps for the Bethel Valley Quadrangle for 1935, 1941, 1953, 1968, 1989, and 1998, shown in Figure C-7, 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, the 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 C-7. Historical Map Progression for the Candidate Site

3.1.2 Local Demographics

The nearest resident is approximately 0.84 mi north of the proposed EMDF site, and a larger residential subdivision is about 1.1 mi to the northwest. Figure C-8 shows these residential locations.

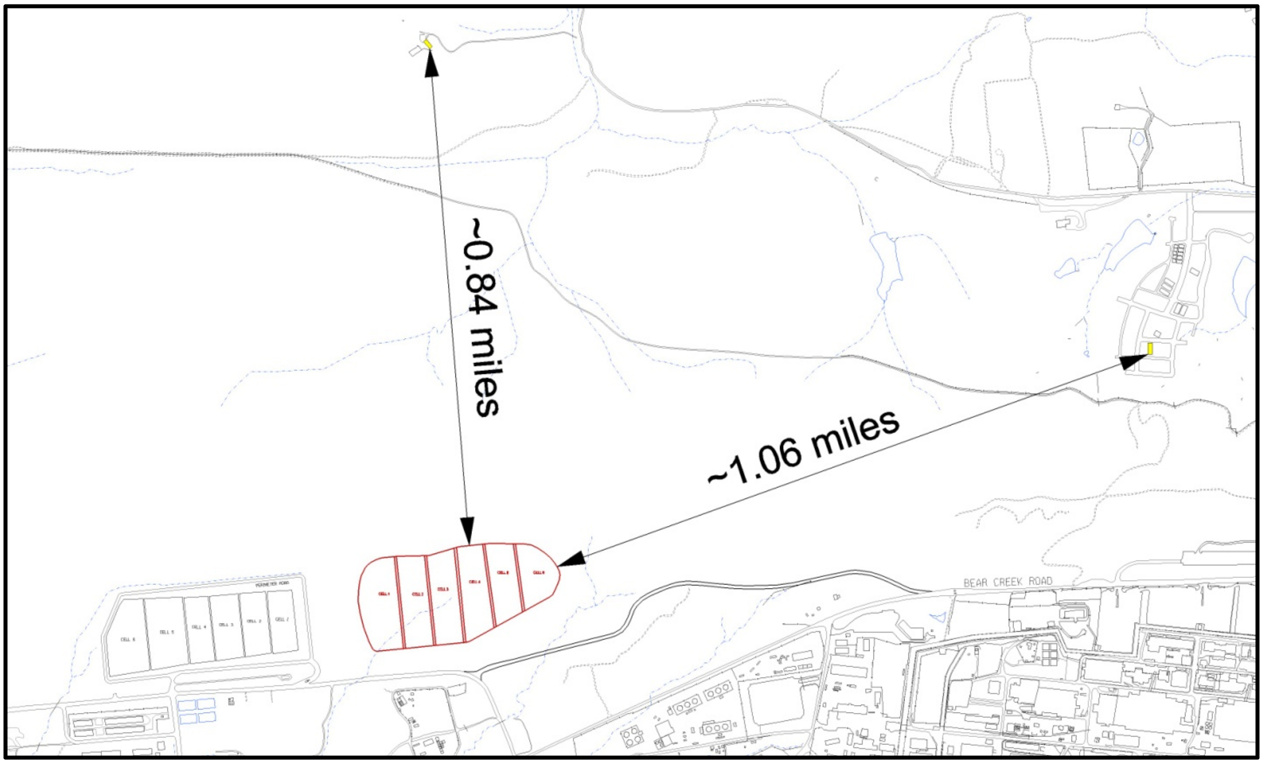


Figure C-8. Distance to Nearest Residents from the Proposed EMDF

3.2 SITE GEOLOGY

The proposed EMDF site topography and geomorphology, stratigraphy, and geologic structure are discussed below.

3.2.1 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 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 (~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 C-9. 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 groundwater flow in subsurface conduits is well documented on the Maynardville Limestone along the central axis of Bear Creek Valley, 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.

3.2.2 Stratigraphy

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 C-9 and C-10 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).

3.2.2.1 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.

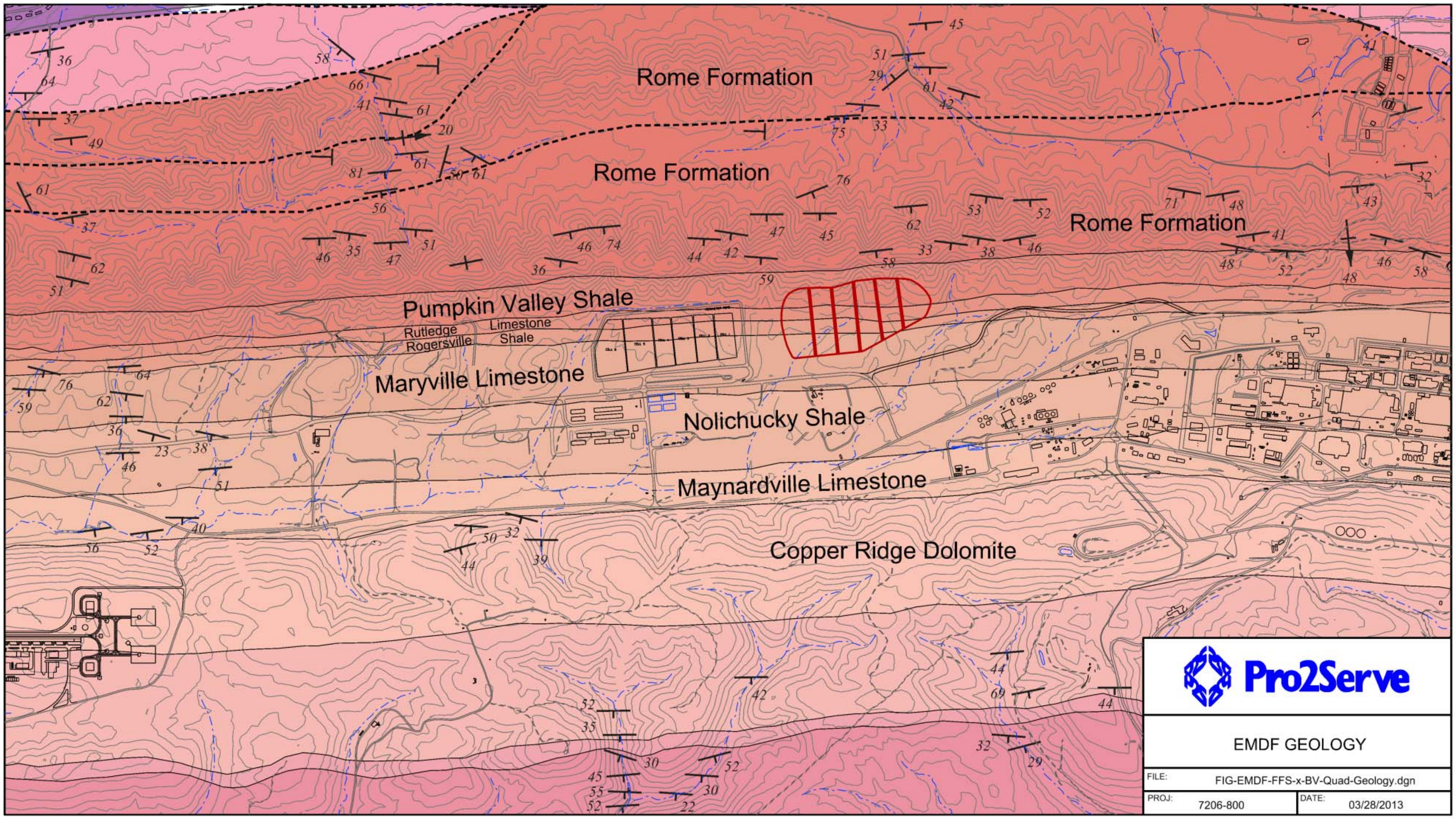


Figure C-9. Geologic Map of the EMDF Area. The EMDF conceptual footprint is shown in red.

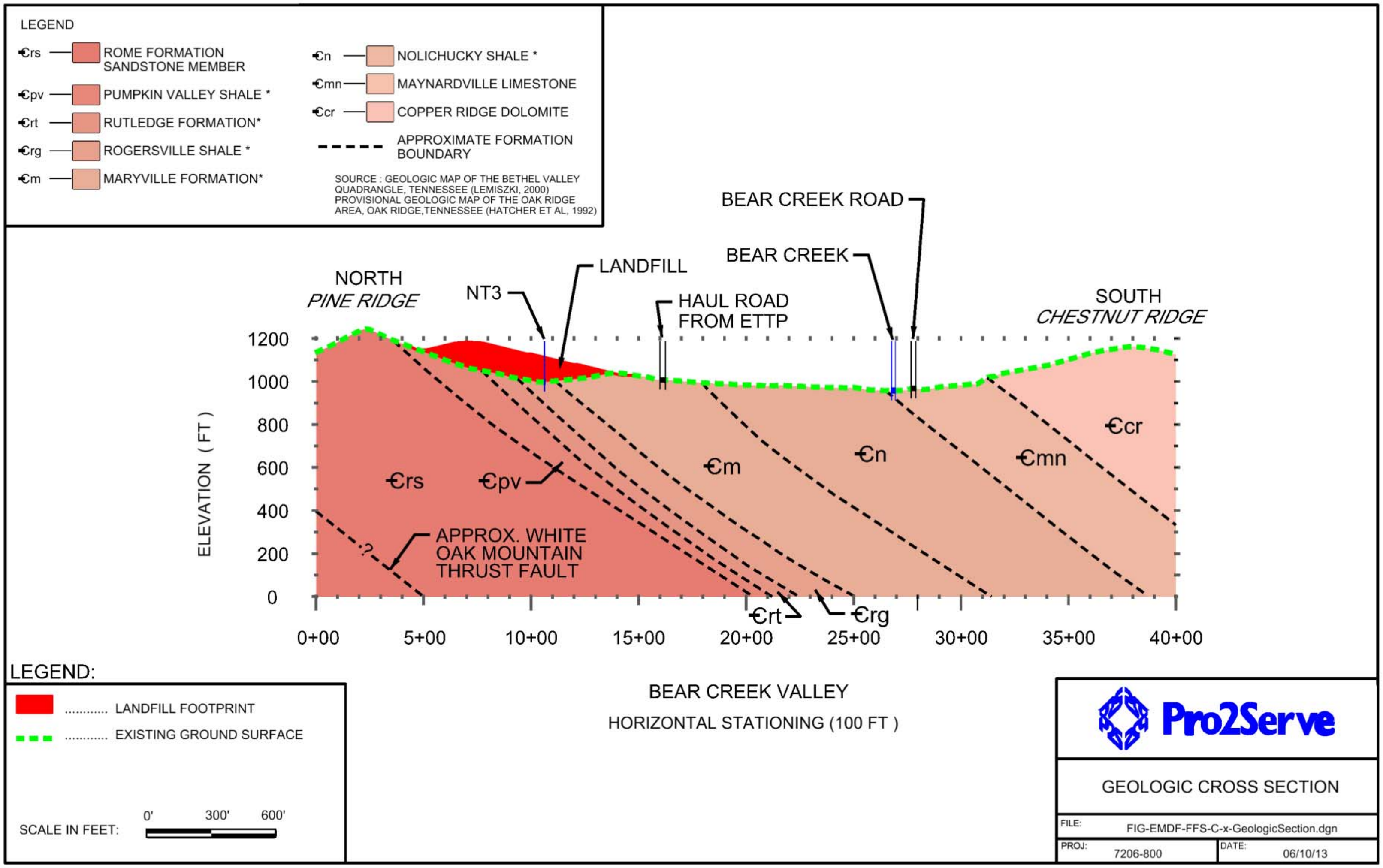


Figure C-10. Generalized Structural-Stratigraphic Cross-Section for the Proposed EMDF Site.

Adapted from Hatcher, et al. 1992

3.2.2.2 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).

3.2.2.2.1 Pumpkin Valley Shale

The Pumpkin Valley Shale is a 295 to 360 ft (90 to 109 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.

3.2.2.2.2 Rutledge Limestone

In the vicinity of the ORR, the Rutledge is a dominantly clastic with limestone interbeds varying in thickness from 70 ft to 160 ft (21 to 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 to 5 ft (0.6 to 1.5 m) thick. The upper contact with the Rogersville Shale is abrupt.

3.2.2.2.3 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 to 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 to 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 to 6 ft (1 – 2 m) thick mudstone.

3.2.2.2.4 Maryville Limestone

The Maryville Limestone on the ORR is informally subdivided into upper and lower units, and its total thickness ranges from 310 to 520 ft (95 to 158 m). Lee and Ketelle (1989) report that the Maryville Formation at the West Bear Creek Valley 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 to 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 to 40 ft (6 to 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.

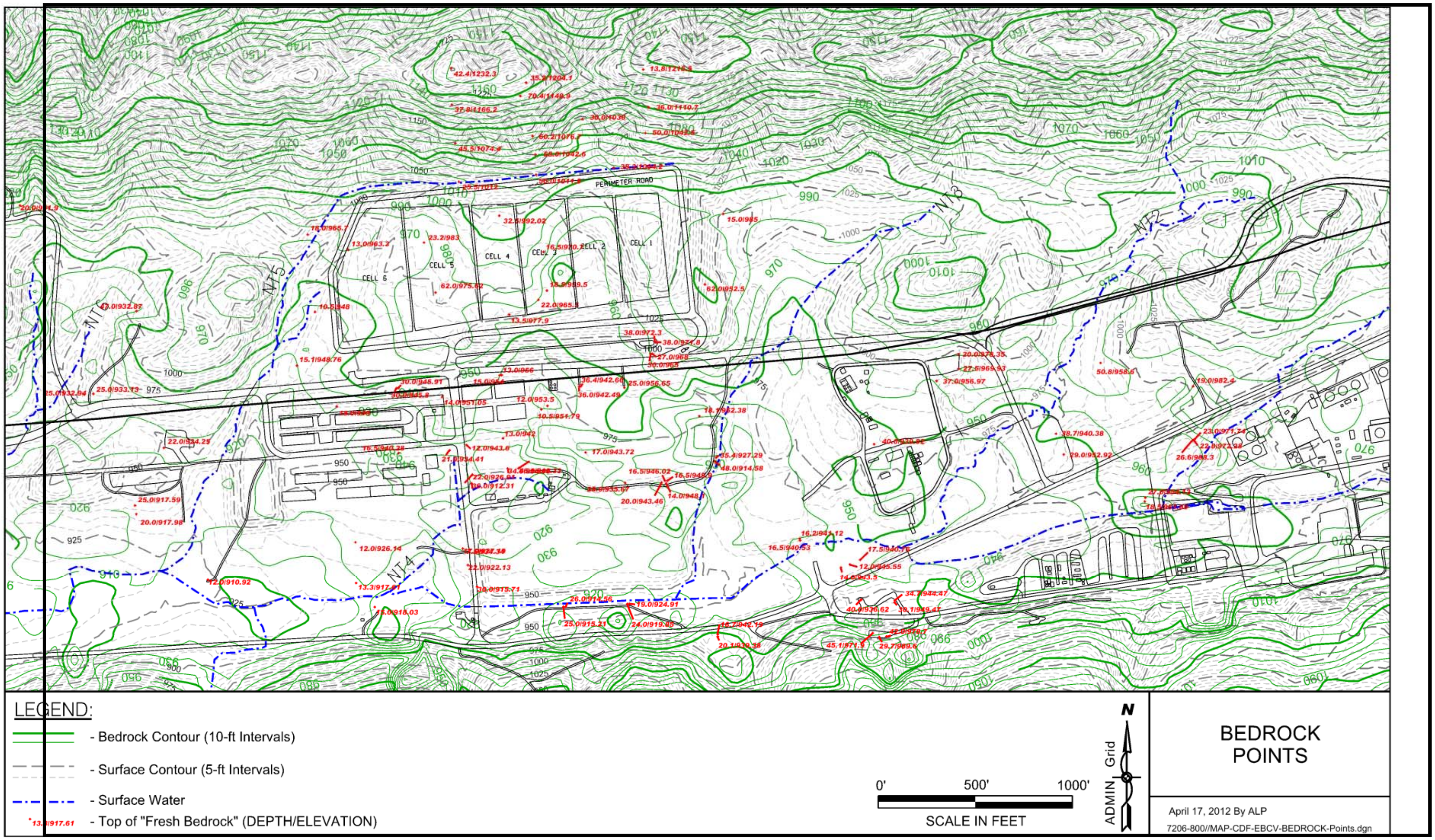
Maryville bedrock weathers to form a saprolite with translocated clay layers and iron and manganese staining. Differential weathering leads to formation of an irregular bedrock surface. Logs of borings drilled into the Maryville Formation presented in MACTEC (2003, boring H-2) and BNI (1984, wells GW-24, -25, -27, -31, -32, -33, and -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 to 32 ft range. However, the MACTEC (2003) H-2 boring log noted severe weathering in some Maryville Formation shale beds at depths of 66 to 79 ft below grade, while limestone and calcareous shale beds above and below this zone were unweathered. Figure C-11 shows bedrock topography in the EBCV area.

3.2.2.2.5 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.



Based on DOE 1997

Figure C-11. Bedrock Topography of East Bear Creek Valley

3.2.2.2.6 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.

3.2.2.3 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 to 1,100 ft (250 to 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.

3.2.3 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 C-10. The Whiteoak Mountain Thrust fault was formed during the Taconic Orogeny 245 to 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 Bear Creek Valleys, 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 Bear Creek Valley 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 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."

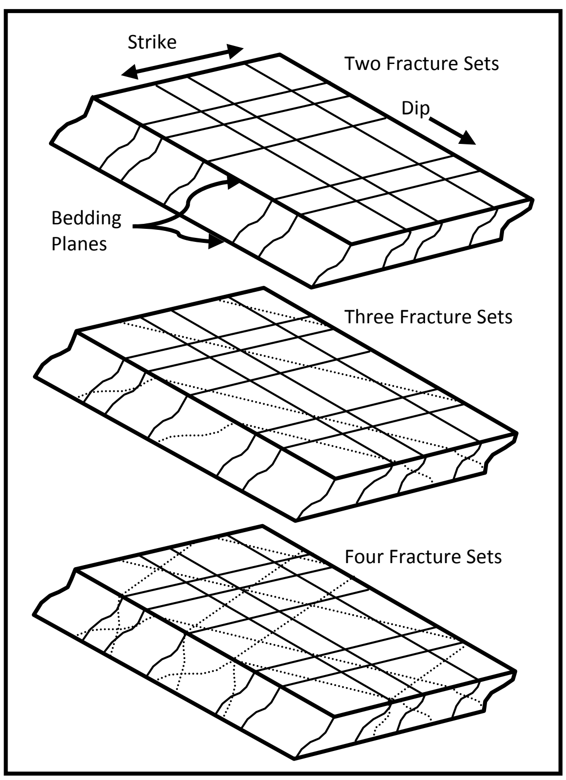


Figure C-12. Increasing Complexity Added by Multiple Fracture Sets

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 groundwater 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 (Figure C-12), 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 C-12, are common throughout the ORR.

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° to 50° to the west. Bedding planes are oriented northeast to southwest with dips ranging from 10° to ~70° to the southeast. Sledz and Huff (1981) and Rothschild, et al. (1984) also noted that fracture systems in the Conasauga Group in Bear Creek Valley 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 C-12.

Moore and Young (1992) used subsurface flow meters to determine fracture density and conductivity in Bethel and Bear Creek Valleys. 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 groundwater 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.

3.2.4 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 mi northwest 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.

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 C-7 for a description of scales referred to). Earthquakes that occurred within 30 miles of Oak Ridge in 1973 and 1989 had intensities of V to VI in Oak Ridge.

Table C-7. Earthquake Magnitude and Intensity Scales

Moment Magnitude Scale	Modified Mercalli Scale	Intensity Descriptor
< 2.0	I	Felt by instruments only
2.0 – 2.9	I - II	Weak
3.0 – 3.9	II – IV	Weak to Moderate
4.0 – 4.9	IV - VI	Moderate to Strong
5.0 – 5.9	VI - VII	Strong to Very Strong
6.0 – 6.9	VII - IX	Very Strong to Violent
7.0 and up	VIII - XII	Destructive to Catastrophic

Source: USGS, 2000. The Severity of an Earthquake

The most damaging earthquakes in Tennessee history occurred during 1811 – 1812 along the New Madrid Fault zone in Arkansas and Missouri. Five of these earthquakes had magnitudes that exceeded 8.0. It is estimated that the December 16, 1811, New Madrid earthquake was felt East Tennessee at a Modified Mercalli intensity of VII, or a moment magnitude of 6.9, producing a ground acceleration in the range of 0.07 to 0.22 g.

The USGS earthquake probability estimation program[2] estimated the probability of an earthquake of magnitude 5.0 or greater occurring within a 50 km (31 mi) radius of Oak Ridge at between 0.60 and 0.80. The probability of a magnitude 7.0 earthquake is 0.03 to 0.04 within a 1,000 year period.

3.3 GROUNDWATER

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 groundwater 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] https://geohazards.usgs.gov/ eqprob/2009/

3.3.1 Aquifer Characteristics

Groundwater 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.

3.3.1.1 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% to 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% to 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 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).

Moore and Toran (1996) note that data from the Joy-1 core hole indicates that total porosity in unweathered bedrock is unrelated to depth. Goldstrand, et al. (1995) documents matrix porosities in the Maynardville Limestone ranging from 0.1% to as high as 7% where diagenetic processes dissolved gypsum and anhydrite nodules and replaced of dolomite with calcite. Some vuggy and fenestral porosity was associated with stromatolites. Goldstrand, et al. (1995) reported that matrix porosity decreased with depth.

Worthington and Ford (2009) found that matrix porosity in selected carbonate rocks varied from ~1% to ~40%, but associated hydraulic conductivity ranged from 10^{-4} to 10^{-11} m/s ($10^{-2} – 10^{-9}$ cm/s).

3.3.1.2 Fractures

The majority of groundwater 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 to 200 fractures per meter in some Conasauga Group rocks. The mean range of fracture density in siltstones is 6 to 45 fractures per meter, and 12 to 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 in to 30 in. (2 cm to 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 mm to 0.5 mm, but in shale and siltstone saprolite the range is 0.005 mm to 1.5 mm, and in limestone saprolite the range is 0.005 mm to 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 groundwater 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.

3.3.1.3 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, because voids in EBCV rocks are encountered mainly in boreholes, and while a vertical distance can be measured, horizontal extent is much more difficult to assess. Cavities encountered in boreholes could be conduits, caverns, or vugs.

Most conduits initiate when water exploits joints, bedding planes, faults or the intersections or any combination of these to migrate. In relatively pure carbonate rocks, enlargement of fractures begins with slow dissolution of carbonate rock by acidic meteoritic water penetrating from the surface and longitudinally along fractures. Dissolution is most rapid near the point where acidic water first contacts the rock, and slows considerably, but does not entirely cease, as the water infiltrates deeper into the rock (Worthington and Ford 2009). Dissolution in shaley carbonates, such as those present in the Conasauga Group at EBCV, is much less effective in enlarging fractures or other flow paths. White and White (2001) note that karst develops best in purer end-member limestones, those with low amounts of insoluble sands and clays, and state 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.

Turbulent flow begins once openings are enlarged above some critical size (Solomon, et al. 1992; Moore 1988). Mechanical abrasion by entrained sand and silt then increases the rate of cavity enlargement and remove at least part of the resulting detritus. Any remaining detritus accumulates at the bottom of the cavity and partially protects this rock surface against further erosion. While dissolution does not stop, abrasion by particulates entrained in turbulent flow becomes the main force in developing larger cavities. Deposition of detrital materials, such as clays, may protect the cavity floor from abrasion and thus force upward extension of the opening, resulting in an oval cross-section. However, the cross-sectional area of a cavity may change considerably from one location to another as a result of local differences in rock resistance to dissolution or abrasion; the largest cavities typically occur in the purest and most massive beds (Moore 1988). Borehole logs in Conasauga Group units (mainly the Maynardville Limestone) record numerous cavities that are filled or partially filled with soft sediment. As Moore (1988) points out, a cavity may be filled at one point, but open at another. Moore (1988) reports that detected Conasauga cavities range from about 0.1 ft (0.03 m) to a maximum of 18 ft (5.9 m), with a mean of about 1.5 ft (0.51 m). At least one cavity in a bore hole in the Maynardville Limestone of EBCV exceeded 20 ft in height. Moore (1988) also estimated the vertical height of cavities as a fraction of borehole length is 0.012, which is close to the porosity values given by Worthington & Ford (2009), who found that cavities occupied <1.2% of bulk rock volume. Further, fracture porosity was reported to be in the range of 0.1% to 0.01% of bulk rock volume.

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. More than one cavity was present in 46% of wells that intercepted cavities in the Conasauga Group. However, the data set is strongly biased towards the Maynardville Limestone. A few of the Maynardville conduits have been reported to exhibit high velocity groundwater flow (Shevnell, et al. 1995). Moore (1988) and Solomon et al. (1992) suggest that a relatively small number of wells actually intersect cavities, but Shevnell, et al. (1995) stated that cavities in the Maynardville Limestone "…were intersected in numerous wells in all pickets…" and further noted that the GW-705A & B borehole encountered numerous cavities and had to be abandoned because the borehole collapsed.

As noted above, conduits form mainly in relatively pure limestones, not in shaley limestones. The proposed EMDF site overlies lower Conasauga units that are apparently not susceptible to conduit development. 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. The number of wells that intersect cavities, as well as the number of cavities per well, are highest in the Maynardville Limestone underlying the valley axis and in the Copper Ridge Dolomite underlying Chestnut Ridge. An analysis of cavities by formation for 222 wells numbered between GW-601 and GW-833, based on information provided in data summaries (BWXT 2003), found that 32% of wells drilled into the Copper Ridge encountered cavities, while 17% of Maynardville wells encountered cavities. Wells that cross the Copper Ridge-Maynardville and Maynardville-Nolichucky were even more likely to penetrate cavities (33% and 67%, respectively). Wells in the Maynardville Limestone or on its boundaries encountered multiple cavities more often than any in other stratigraphic unit in BCV. Of the 58 Nolichucky wells in the sample, only two wells encountered cavities. Wells (49) that penetrate the remaining Conasauga formations did not encounter any cavities. Within this data set, six cavities were penetrated at depths between 175 ft and 220 ft., and 61% of cavities occurred between depths of 25 ft to 75 ft. The deepest well, GW-790, extended to a depth of 1,040 ft. and penetrated the deepest cavity (219 – 220 ft) in the sample set. Many cavities were found to be mud-filled.

The vertical dimension of penetrated cavities ranged from < 1 ft to 21 ft. (GW-608 at 114-135 ft. in the Copper Ridge Dolomite). Five cavities (8%) exceeded 10 ft in height, but 72% of cavities were less than 4 ft high. All of the cavities that exceeded 10 ft. in height occurred in the Copper Ridge Dolomite or at the Copper Ridge – Maynardville boundary. It is worth noting that four of the five cavities over 10 ft in height occur between 100 and 150 ft. below grade.

While not conclusive, these data clearly indicate that the vast majority of cavities, and hence conduits, occur at relatively shallow depths 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. This conclusion is supported by a number of reports (Shevnell, et al. 1995; Solomon et al. 1992, Moore 1988) on ORR hydrogeology which note that most cavities develop at relatively shallow depths, and that the number of cavities decreases with depth. Moore (1988) statistically evaluated 170 wells containing cavities, and determined that the geometric mean depth for Conasauga Group cavities is 25 ft (8.3 m), and the maximum depth is over 215 ft (71 m). Therefore, it is possible that flow occurs in deeper conduit systems, or tiers, in the Maynardville Limestone. Pre-Watts Bar base level in the Clinch River at the west end of BCV and at Poplar Creek is approximately 710 ft above mean sea level, and the river bed is essentially on bedrock. Estimates of phreatic flow depth based on equations presented in Worthington (1991) suggest that flow, and therefore cavities/conduits, could occur to depths of over 450 ft (150 m). The known depths of cavities in the Conasauga Group are within this range. Moneymaker (1941) briefly describes exploratory drilling for Tennessee Valley Authority dams that encountered abundant, and sometimes quite large, cavities that occur below river level in carbonates. These may be the result of tier formation.

Shevnell, et al. (1995) concluded the significant conduit development occurs at shallow depths in the Maynardville Limestone, and the conduits are well interconnected. Conduits appear to have a stacked and anastomosing pattern that allows for local flow directions to change in response to changes in the water table elevation, so that underflow conduits handle baseflow, and overflow conduits fill and flow during high water periods. Conduits also are connected to surface waters. However, at the valley scale, the dominant flow direction in the Maynardville Limestone is to the west along strike. Responses in wells at different depths in several of the pickets indicate hydrologic communication in the down-dip direction, perhaps along bedding planes.

Shevnell, et al. (1995) established five "pickets" or lines of wells across (roughly perpendicular to strike) the Maynardville Limestone from the WBCV site on the west to the east end of Y-12. They then injected distilled water into one well and measured responses in the other wells in the picket. Two pickets, B and C, were located in EBCV and each picket had multiple wells that exhibited immediate response to injected water, both in water level rise (pressure) and in temperature and specific conductivity. Spring SS-4, which is on strike relative to the injection well for Picket B, also showed immediate response to injection. This indicates very rapid movement of water. Drainage in several wells was also rapid, indicating pure conduit flow, while others showed a slower drainage indicating that fracture flow may be dominant in those wells. Flow among picket wells was across the stratigraphic grain of the Maynardville Limestone; however, pickets did not extend into the Nolichucky Shale.

Conduit systems in limestone terrain may develop in tiers related to base level changes. Worthington (1991) notes that even in classical karst terrains, many caves/conduit systems do not have tiers, but where multiple tiers exist, they develop in response to decreases in water table elevation as a result of lowered base level or uplift. It is unlikely that Pleistocene glacial sea level change greatly affected areas as far inland as eastern Tennessee. If tiers and phreatic drops and lifts exist in EBCV, they are likely to discharge to springs along strike. There are eight major springs in BCV upstream of SR-95, most of which arise at the foot of Chestnut Ridge, coincident with the boundary between the Copper Ridge Dolomite and the Maynardville Limestone. Two, SS-7 and SS-8, are co-located near where Bear Creek passes under SR-95 and appear to be in line with the stratigraphic boundary between the Maynardville Limestone and the Nolichucky Shale. There are no substantial springs in BCV west of SR-95 or in Grassy Valley farther west (Robinson and Mitchell 1996), suggesting that SS-7 and SS-8 may mark the western divide of the BCV phreatic flow zone.

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 (BNI 1984). This may be evidence for soil piping.

3.3.2 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 groundwater flow rate measurement, although they require either a large number of sampling points, or knowledge of or good predictions of flow patterns.

3.3.2.1 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- and macro-scales.

Hydraulic conductivity is measured in the field using a variety of methods that involve artificially stressing the aquifer by suddenly raising or lowering the water table, by pumping, and measuring the response over time. Calculations are made on the basis of the recovery rate, and assumptions as to aquifer thickness, homogeneity and isotropy, and whether the aquifer is confined or unconfined, and other assumptions. These methods work reasonably well in aquifers characterized by homogeneous isotropic matrix porosity, but do not fare so well in fractured or karst applications. Assumptions regarding isotropy, aquifer thickness, and confinement are not reasonable in fractured or karstic systems.

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. White and White (2005) tabulate matrix hydraulic conductivities ranging from 10^{-4} cm/sec for granular limestones in the Floridan Aquifer to 10^{-8} cm/sec for dolomites in Ontario. On the ORR, hydraulic conductivities range from 10^{-9} cm/sec in deep wells to essentially infinite in large open cavities. Hydraulic conductivity varies by lithology, degree of weathering, and depth. Tables C-8 and C-9 summarize hydraulic conductivity data from several sources and compare the values to those used in preliminary waste acceptance criteria modeling described in Appendix F.

Bedrock hydraulic conductivity tends to be higher in a more pure limestone like the Maynardville Limestone, and lower in shaley units, such as the Maryville Limestone. Excluding the Maynardville Limestone, hydraulic conductivity in the Conasauga Group regolith and bedrock generally ranges between 10^{-3} to 10^{-5}cm/s. Conductivity tends to be slightly higher in the Nolichucky, Maryville, and Pumpkin Valley formations than in the Rutledge Limestone and Rogersville Shale.

Moore and Young (1992) calculated the effective porosity, specific yield, hydraulic conductivity, and transmissivity of the permeable fractures from a combination of borehole flowmeter surveys and injection and pumping tests. The geometric mean of transmissivity for permeable fractures is 9.7×10^{-5} cm^2/s, and the geometric mean of hydraulic conductivity is 1.4×10^{-4} cm/s. Average hydraulic conductivity and transmissivity are nearly the same between depths of 7 to 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 9.2×10^{-5} to 7.5×10^{-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} to 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).

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 Bear Creek Valley and Upper East Fork Poplar Creek, presented in Table C-10, 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.

Table C-8. Mean Hydraulic Conductivity by Formation Compared to Preliminary WAC Model Input

Stratigraphic Unit	Connell and Bailey (1989)				Summary Data from Preliminary WAC Model		
	Regolith		Unweathered Rock		Geometric Mean Hydraulic Conductivity (cm/s)		
	N	Hydraulic Conductivity(cm/s)	N	Hydraulic Conductivity (cm/s)	Dip direction (K_x)	Strike direction (K_y)	Vertical Direction (K_z)
Maynardville Limestone	5	2.22E-05 – 4.8E-02	13	1.09E-05 – 2.48E-02	6.71E-06	5.64E-05	6.71E-06
Nolichucky Shale	24	1.31E-05 – 1.15E-03	45	1.62E-07 – 2.80E-03	8.44E-07	7.35E-06	8.44E-07
Maryville Limestone	15	1.06E-05 – 7.34E-04	33	1.59E-07 – 7.34E-04	4.52E-07	3.94E-06	4.52E-07
Rogersville Shale & Rutledge Limestone	5	1.83E-05 – 9.88E-05	20	1.62E-07 – 1.94E-04			
Pumpkin Valley Shale	4	1.55E-05 – 4.13E-04	26	1.62E-07 – 2.96E-04	5.02E-07	4.37E-06	5.02E-07
Rome Formation	—	—	13	2.89E-06 – 2.60E-03	7.06E-07	6.14E-06	7.06E-07
Deep Bedrock, undifferentiated	—	—	5	7.06E-09 – 4.94E-08	—	—	—

Table C-9. 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

[1] Geometric mean of 40, 36, and 20 values, respectively.

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.

As noted above, use of single point hydraulic conductivity data to characterize fractures and karstic aquifers is problematic. Sara (1994, p. 6-4 – 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 determine groundwater 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 preliminary waste acceptance criteria (WAC) modeling for the EMDF presented in Appendix F.

3.3.2.2 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.

Table C-10. 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.

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 groundwater flow velocities from the second test ranged from 14 to 1,000 ft/day for the Calcofluor White dye and from 47 to 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 9.0×10^{-4} to 1.94×10^{-6} cm/s. Mean hydraulic conductivity is 4.56×10^{-5} cm/s for saprolite and 6.72×10^{-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 to 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/d (~ 1 ft/d). 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 WAGs 4 and 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 to 16.5 ft below grade, and at WAG 6, 23 to 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 to 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 groundwater 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 groundwater 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 groundwater 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.

3.3.3 Groundwater Flow

Several lines of evidence converge to indicate that groundwater flow systems on the ORR are local, not regional, and defined largely by topography and streams. The Bear Creek Valley drainage basin is confined by the relatively high local topographic relief, anisotropic groundwater 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 groundwater chemistry and depths to the brine aquiclude in Melton, Bethel, and Bear Creek valleys; 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.

Groundwater occurrence and flow under the ORR has been divided into unsaturated, saturated, and aquiclude zones (Solomon, et al. 1992; Moore and Toran 1992). Within Bear Creek Valley, 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.

3.3.3.1 Unsaturated zone

The unsaturated zone is subdivided into the storm flow zone and the vadose zone.

3.3.3.1.1 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 run-off to streams, by infiltration to groundwater, 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 run-off, 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, 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). 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 to 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.

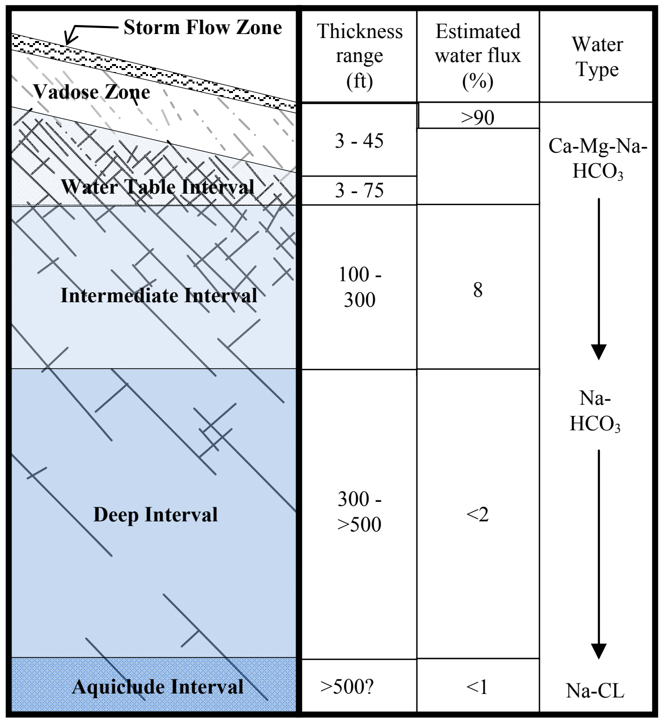
The position and drainage area of the storm-flow zone is an important consideration in landfill design, because storm-flow must be intercepted and diverted around the disposal cell in order to limit erosion of the cover and infiltration into the buried waste. This is typically accomplished through the 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.

3.3.3.1.2 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.

3.3.3.2 Saturated zone

The saturated zone includes shallow, intermediate, and deep flow zones; the majority of groundwater 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 groundwater chemical compositions. Hydrogeochemical processes involving exchange of cations on clays and other minerals result in a change from calcium bicarbonate (Ca-HCO_3) to sodium bicarbonate (Na-HCO_3) and ultimately to a sodium chloride (Na-Cl) type water at depth. These geochemical zones reflect groundwater residence times and reduction of water flux with depth. Figure C-13 illustrates this conceptual model.



Adapted from Solomon et al. (1992)

Figure C-13. Conceptual Model of Groundwater Zones in BCV

3.3.3.2.1 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 to 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 to 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 3 to 6 ft (<1-2 m) deep near perennial stream channels but may be 15 to 45 ft (5-15 m) deep beneath ridges underlain by the Rome Formation and Conasauga Group formations (Moore and Toran 1992). The depth to groundwater 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). There are no known wells or boring data within the proposed EMDF footprint; however, there are wells and groundwater data in adjacent areas south and west of the site. Seasonal high groundwater 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 estimated groundwater table map is provided in Figure C-14.

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 Bear Creek Valley 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 groundwater 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 Bear Creek Valley. 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 C-15, 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 C-16.

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 (BYBY) 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 groundwater 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 BYBY 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.

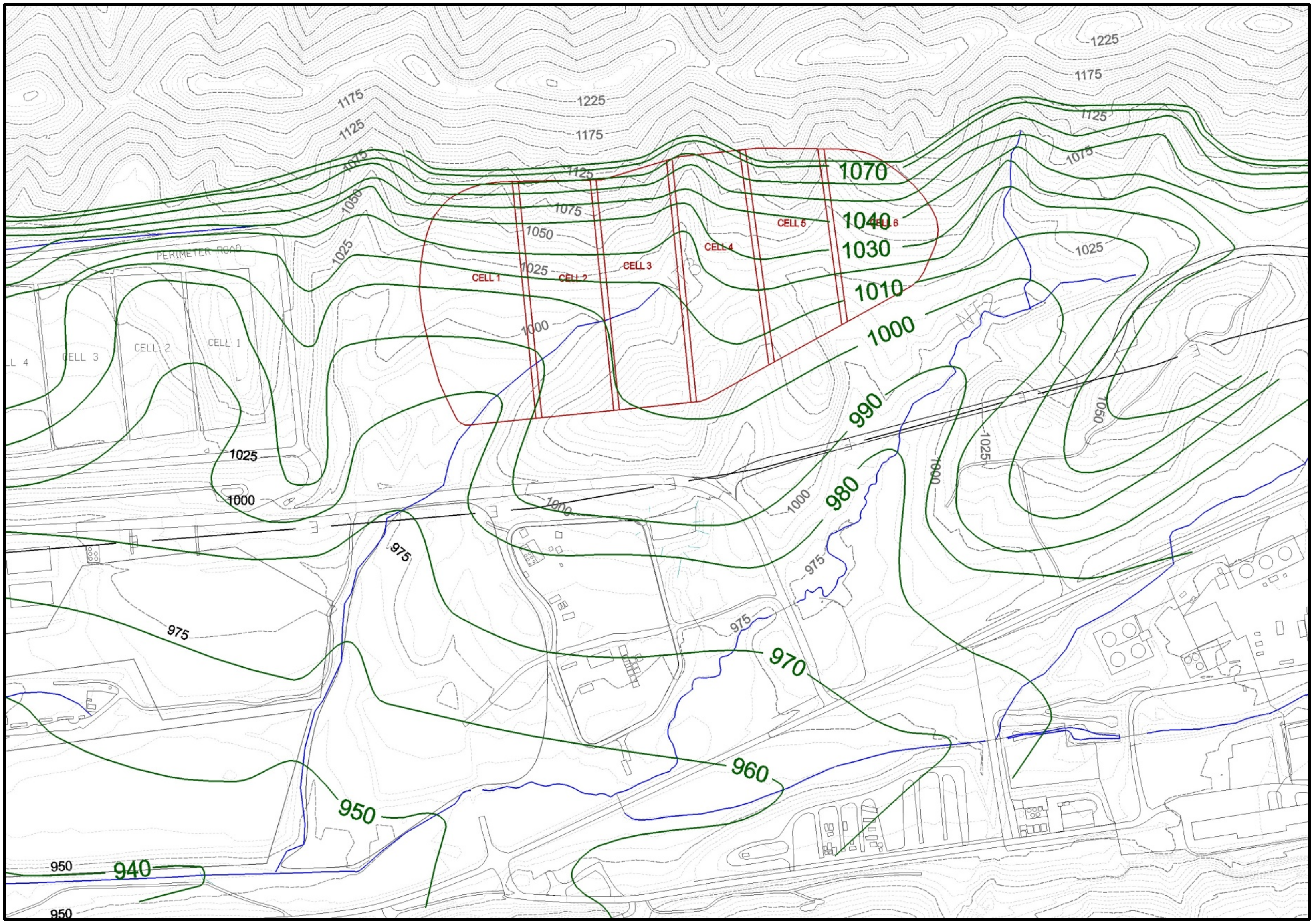
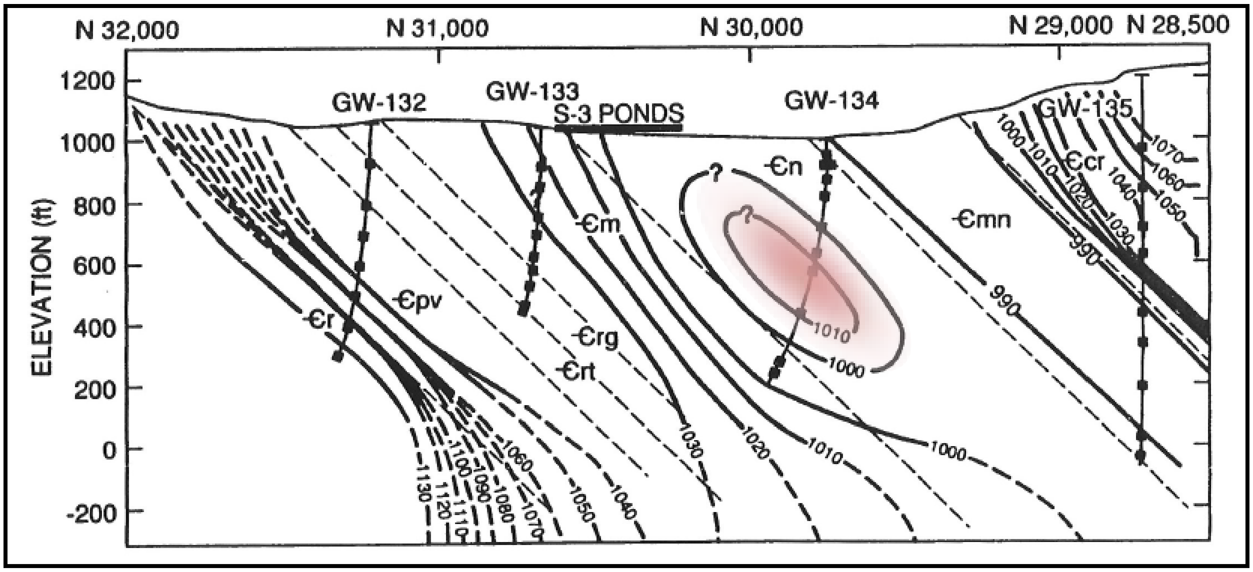
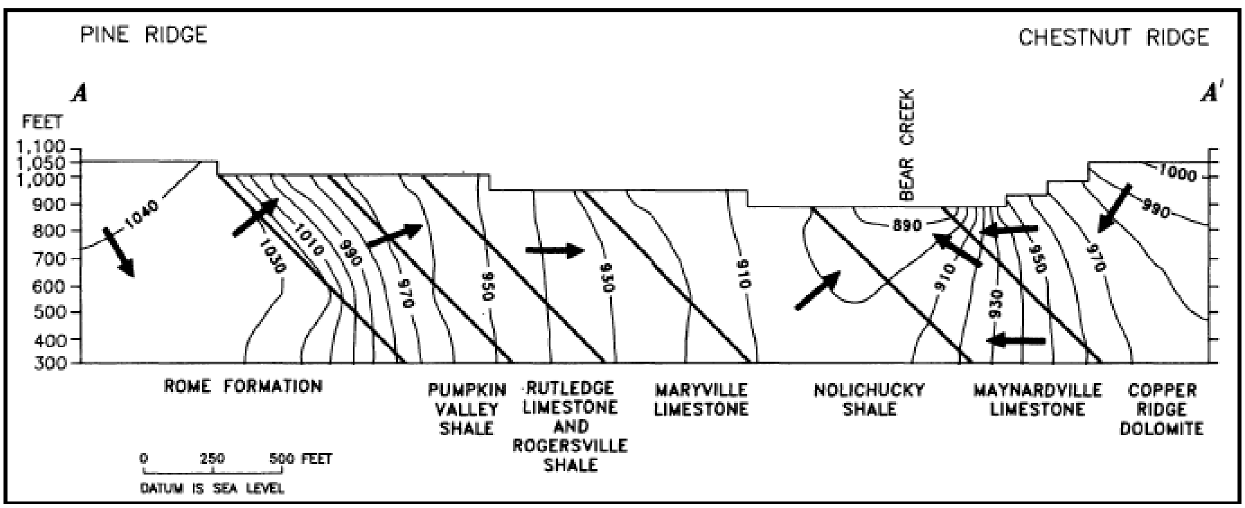


Figure C-14. Estimated High Groundwater Table Elevations for the Proposed EMDF Site



Adapted from Dreier, et al. (1993). Arrows indicate groundwater 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 C-15. 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 C-16. Cross-Sectional Representation from a Computer Model of Groundwater Hydraulic Head and Flow Patterns for EBCV

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 groundwater movement.

Most groundwater in the shallow zone is a calcium bicarbonate (Ca-Mg-Na-HCO_3) type. Haase (1991) found that this water chemistry is dominant to depths of about 75 ft, but in a few wells was found to extend to about 300 ft. The pH range for this water is 6.5 to 7.5. These waters are generally saturated with respect to calcite, but are under saturated relative to dolomite. Schreiber (1995) similarly found three water types based on dominant cations and anions in samples shallow (to 70 ft.) groundwater collected from discrete intervals. These three types were Ca-HCO_3, Na-HCO_3, and mixed Ca-NA-HCO_3. The pH ranged from 7 to 8 standard units (S.U.s) Table C-11 provides data on the geochemistry of Conasauga Group groundwater.

Shevnell (1994) indicates that shallow waters are not saturated with calcite, leading her to conclude that groundwater that is consistently under-saturated with respect to calcite indicate that these waters are influenced by recharge and have relatively short residence time. Further, temporal variations between supersaturated and under-saturated conditions in some wells can be explained by diffusion of old, saturated waters from matrix pores during low-flow periods, and flushing with under-saturated waters during high-flow or quick-flow periods.

3.3.3.2.2 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 discharge 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.

Moore and Toran (1992) postulate that flow paths in the deeper groundwater 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 groundwater zone, and that water flux decreases with depth. According to Solomon, et al. (1992), the deep zone hosts very little groundwater 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.

Table C-11. Geochemical Zones in the Conasauga Group Formations

<table>
<tr><th rowspan="2">Interval or Zone</th><th colspan="3">Bear Creek Valley (Haase 1991)</th><th colspan="2">Bear Creek Valley (Bailey and Lee 1991)</th><th colspan="3">Melton Valley (Haase, et al. 1987; Nativ, et al. 1997)</th></tr>
<tr><th>Depth (ft)</th><th>Type</th><th>pH</th><th>Depth (ft)</th><th>Type</th><th>Depth (ft)</th><th>Type</th><th>pH</th></tr>
<tr><td>Shallow</td><td>75 ft</td><td>Ca, Mg-HCO_3</td><td>NA</td><td>< 50</td><td>Ca, Mg-HCO_3 or SO_4</td><td>< 75</td><td>Ca, Mg-HCO_3 or SO_4</td><td>6.5 – 7.5</td></tr>
<tr><td>Intermediate</td><td>NA</td><td>NA</td><td>NA</td><td rowspan="2">50 – 500</td><td rowspan="2">Na-HCO_3 (with some Na-Cl and Na-SO_4</td><td>75 - 275</td><td>Na-HCO_3</td><td>6.0 – 8.5</td></tr>
<tr><td>Deep</td><td>NA</td><td>NA</td><td>NA</td><td>75 - 530</td><td>Na-HCO_3 to Na-Cl</td><td>8.0 – 10.0</td></tr>
<tr><td>Brine (aquiclude)</td><td>>530</td><td>Na-Cl</td><td>NA</td><td>NA</td><td>NA</td><td>590 (GW-121)</td><td>Ca-Na-Mg-Cl + SO_4</td><td>11.6</td></tr>
</table>

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-HCO_3) ions (Moore and Toran 1992). The transition from Ca-Mg-HCO_3 to Na-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-HCO_3 water type with distinct zones of Ca-Mg-Na-SO_4 water. These sulfate-rich water zones appear to be related to the presence of gypsum beds in the carbonate units.

This change in groundwater chemistry is interpreted to be the result of rock-water interactions and diagenesis of minerals. The rate at which the groundwater reaches chemical equilibrium with source minerals is important in the diagenetic evolution of Na-HCO_3, indicating that the groundwater is reaching equilibrium with the host rock. If clay alteration is an important control on groundwater geochemistry, then Na-HCO_3 type water may mark the transition between the actively circulating shallow zone and stagnating groundwater 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 groundwater chemistry trends from Na-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.

3.3.3.3 Aquiclude

The aquiclude is so named because the extremely high salinity of this water indicates that little or no groundwater 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 to 10.0 range, and change from $Na\text{-}HCO_3$ 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 groundwater 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 groundwater 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 groundwater 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 groundwater exchange may occur between water beneath the halocline and shallower groundwater 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 groundwater 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 groundwater. This analogous to the fresh water sea water boundary that develops in coastal aquifers.

3.3.4 Groundwater Contaminants

No contaminated groundwater or soil is known to occur on or under the proposed EMDF area. According to the BCV RI (DOE 1997), groundwater 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 groundwater plume from BYBY that underlies NT-3
- Chlorinated solvents in a plume extending down-dip in the Nolichucky from the BYBY
- Nitrate and uranium in two shallow-to-deep groundwater 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 groundwater at the Oil Landfarm and Sanitary Landfill 1

[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.

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 BYBY 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 groundwater quality. Zone 3 groundwater 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. Groundwater chemical concentrations and flux vary in direct relation to precipitation.

3.4 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.

3.4.1 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 run-off and infiltration values. Run-off 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 run-off.

Water input is usually considered to be equal to the amount of precipitation (rain and snow), but may also include surface water and groundwater inflow from other subbasins or, because groundwater 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:

ΔS = change in storage (groundwater and depression storage),

P = Precipitation,

GW_{in} = Groundwater inflow,

GW_{out} = Groundwater outflow,

ET = Evapotranspiration, and

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% to 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 45% to 50% either flows out of the region in streams, is held in reservoirs, such as Melton Lake, or recharges the groundwater system. Evapotranspiration is greatest during the growing season when plants are transpiring and when warm weather increases direct evaporation rates.

Groundwater inflow is often assumed to be absent or negligible because surface water drainage divides are usually more or less coincident with groundwater 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 C-12. Preliminary WAC model recharge rates range from 7 in./yr to 8.75 in./yr.

Table C-12. 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
Groundwater Recharge	3.1 in (78.6 mm)	6.7	9.55 in (242.6 mm)	22.1
Groundwater Storage	0.59 in (15 mm)	1.3		

The BCV RI (DOE 1997) and results of groundwater 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 groundwater divide. Thus, there is a possibility of extra-basin groundwater inflow to the Bear Creek watershed.

Groundwater outflow is not directly measurable, and therefore must be estimated using flow nets or computer models. Groundwater 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}, ΔS are not discriminated.

Change in groundwater 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 groundwater 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 groundwater storage range between 8% and 22% of total precipitation. As noted above, change in groundwater 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.

3.4.2 North Tributaries of Bear Creek

Two small streams, tributaries of Bear Creek, are near the candidate site, as shown in Figure C-17. These are North Tributary (NT)-2 and NT-3. Both are southwest flowing second-order streams to their junctions with 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.

NT-3 receives flow from valleys fed by precipitation and by springs and seeps at its headwaters on the east and west side.

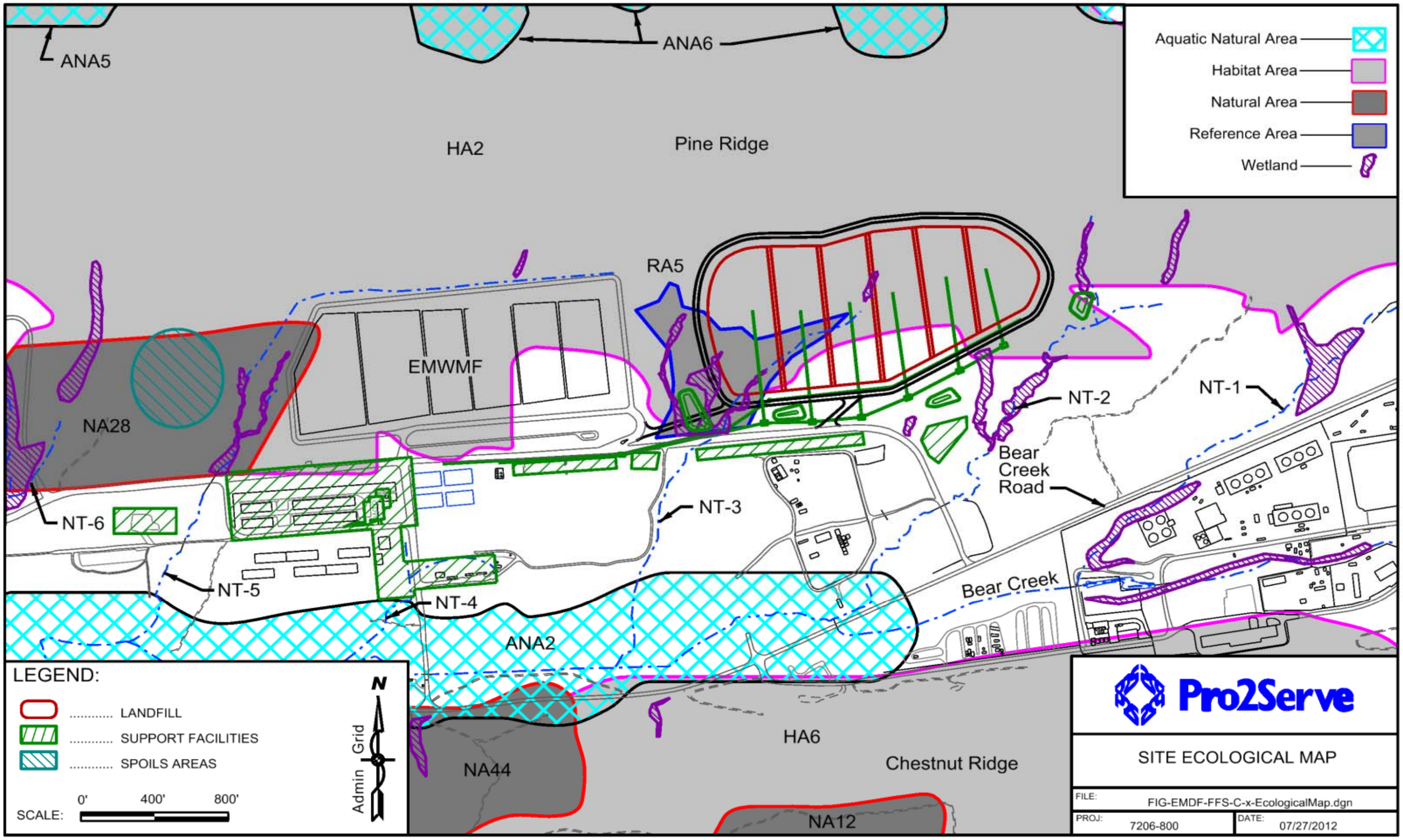


Figure C-17. Streams, Wetlands and Reference Areas in the Vicinity of the Proposed EMDF

Both NT-2 and NT-3 have small wetlands along portions of their main channels. The hydrology of wetlands near the Haul Road have been affected by the construction of the Haul Road. The NT-3 wetlands on the north side of the Haul Road (Temporary Quillwort Pond) have expanded since the lower reaches were restored as a result of a flow-limiting plate that was welded across the culvert that was installed as part of NT-3 stream. This allowed water to accumulate on the north side of the Haul Road, and may have unintentionally contributed to wetlands enlargement.

3.4.2.1 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 groundwater 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 through 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 through April). Portions of Bear Creek are also largely dry during the fall dry season above NT-8, about 1.3 mi 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.

Both streams are expected to flow during the dry season, and experience flow increases during the wet season, for a short period after heavy or prolonged rainfall events. However, flow will rapidly recede as surface flow and storm flow ceases.

3.4.2.2 Gaining and losing reaches

Both NT-2 and NT-3 exhibit gaining and losing reaches during high base flow conditions. 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.

3.4.2.3 Tributary chemistry indicators

Ranges of values for four stream chemistry indicator parameters are provided in Table C-13. 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- 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.

Table C-13. Summarized Water Chemistry Parameters for NT-2 and NT-3

Stream	Measurement period	Type	pH	Specific Conductivity (µS/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

3.4.2.4 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 BYBY, 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. 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/yr 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 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/yr. 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.

3.4.3 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 groundwater and surface water flow.

3.4.3.1 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.

3.4.3.2 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 BYBY 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.

3.4.3.3 Bear Creek water chemistry

Table C-14 provides a summary of Bear Creek water chemistry indicators. The pH of water in the upper reaches of Bear Creek averages close to 8 S.U.s, 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 C-14. Summary of Bear Creek Water Chemistry Indicators

Station*	N	Period	pH (S.U.)	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

3.4.3.4 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/yr at the integration point (BCK 9.2) and ≤27.2 kg/yr 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 groundwater plumes in EBCV, and some of this contaminated groundwater 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.

3.5 CONCEPTUAL FLOW MODEL

The conceptual model developed here is based on a three-porosity system in Conasauga Group units at the EMDF site. This system is composed of:

- Matrix pores in clastic saprolite

- Fractures in saprolite, unweathered clastics, and unweathered carbonates
- Cavity systems in carbonate

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. The high density of fractures in Conasauga rocks and saprolite defines 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 groundwater flow. The majority of flow from ridge flanks is directed towards the valley axis by the north tributaries and vertically upward from deeper groundwater 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 groundwater 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 C-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 and White (2005, 2003), who note that groundwater 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 and 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 2003, 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.

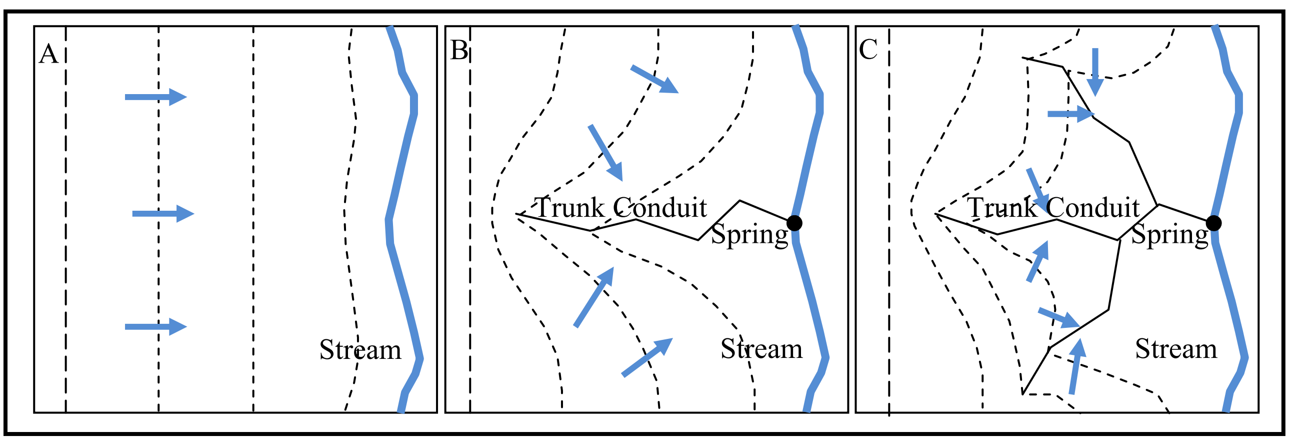


Figure C-18. Conceptualization of Development of Self-Organized Permeability in Carbonate Aquifer

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 groundwater 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. The strong anisotropy of saprolite and bedrock hydraulic conductivity will result in a more rectilinear groundwater 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 C-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 by the fact large segments of the stream go dry in summer, but flow continuously during the winter wet season. The shape of the shallow BYBY alpha plume in groundwater, as reported in (DOE 1997), and modeling conducted as part of this RI/FS (see Appendix F) support this concept.

3.6 ECOLOGICAL SETTING

The proposed EMDF site is characterized by upland deciduous hardwood forests, intermittent streams, springs, and seeps, and small upland wetlands. A number of areas on the ORR have been identified as Natural Areas, Aquatic Natural Areas (ANAs), Reference Areas (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 be or could be impacted by construction and operation of the proposed EMDF. Figure C-17 shows these features.

A severe down burst or microburst occurred over the crest of Pine Ridge at aa 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 Forest Service (Mori, pers. comm., June 5, 2013) were directed down both flanks of Pine Ridge causing numerous trees to fall or be snapped off. Destruction was particularly heavy and widespread along the east branch of NT-3 and over into the valley of NT-2.

3.6.1 Wetlands

Two wetlands, one near NT-2 and one near NT-3, are within the conceptual landfill footprint and will be impacted by landfill construction.

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. One wetland area on the north side of the Haul Road covering approximately 1 acre has been identified along the main channel of NT-2, as well as along a valley that enters from the north (Rosensteel and Trettin 1993). It is likely that this northern valley and associated wetland would be affected by EMDF construction. No status species have been reported in this wetland area (Parr 2012; Rosensteel and Trettin, 1993; Cunningham and Pounds 1991), although Pounds (1998) suggested that orchids of an indeterminate species may exist along NT-2.

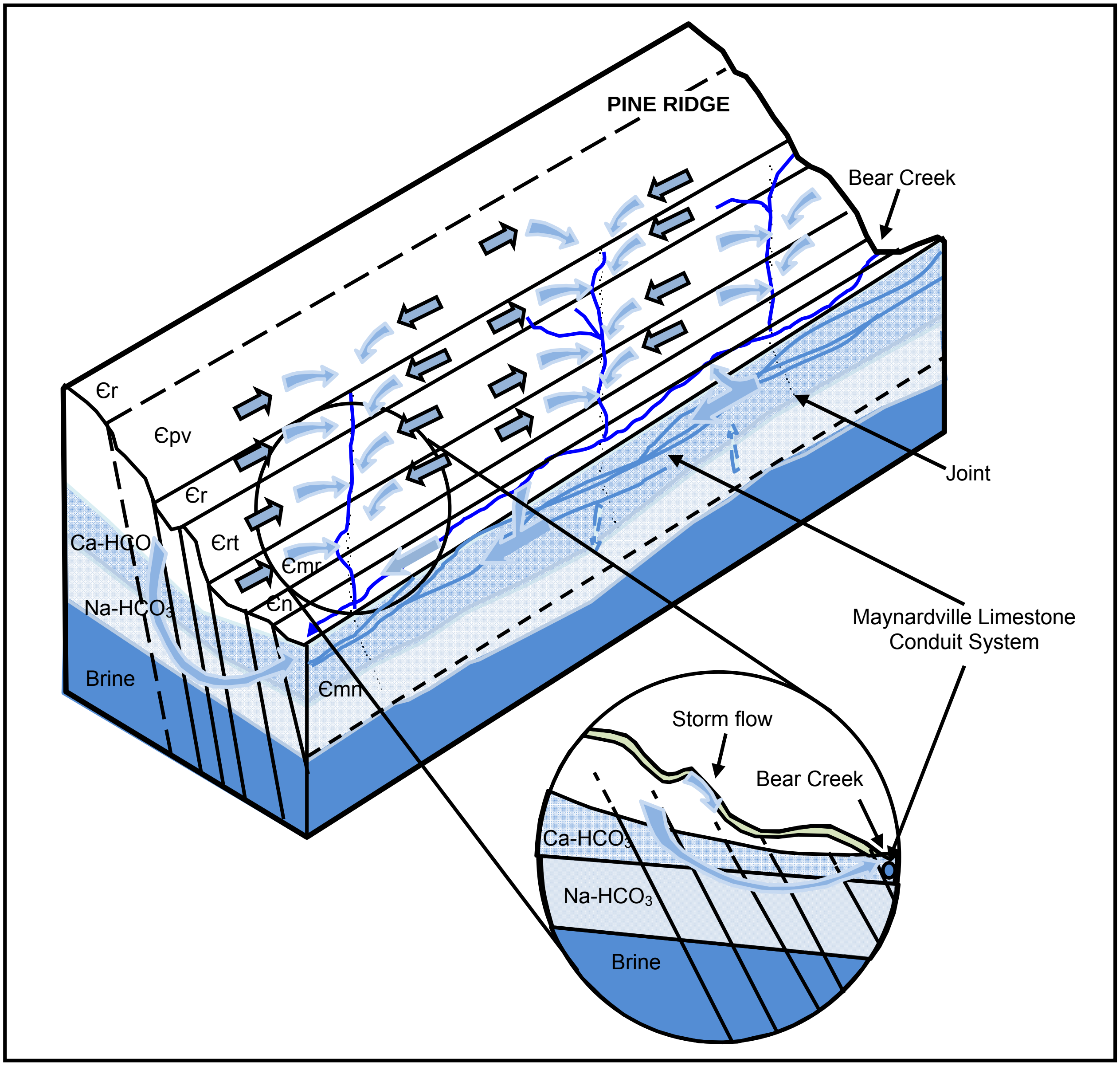


Figure C-19. Block Diagram Illustrating Conceptual Groundwater Flow Model for the Proposed EMDF Site

RA-5 encompasses the Quillwort Temporary Pond wetland on NT-3 where two valleys join the main stream channel immediately north of the Haul Road. This wetland appears to have been formed, in part, by a partial restrictor plate installed over the culvert before it passes under the Haul Road. This wetland has an estimated gross area of approximately 1 acre (Rosensteel and Trettin 1993). The two small valleys are classed as forested wetlands in tributary bottoms with dense understory, while the center channel wetland is classed as 'forested wetland in depression at tributary head' (Rosensteel and Trettin 1993). RA-5 is known to contain clammy hedge hyssop (*Gratiola neglecta* Torr.) and Carolina quillwort (*Isoetes caroliniana* [A.A. Eaton] Luebke; this name is considered by the Interagency Taxonomic Information System to be synonymous with *Isoetes valida* (Engelmann) Clute, strong quillwort). None of these is a federal- or state-listed threatened or endangered species, nor are they sensitive species in Tennessee (TDEC 2008). RA-5 may be an important amphibian breeding ground (Parr, pers. comm., 2012).

However, Baranski (2009) ranked the ORR natural areas and reference areas on several factors, and found that RA-5 ranked among the lowest priority sites.

NT-3 also has a small (0.1 acre) wetland in its headwaters, which is 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.

3.6.2 Aquatic Resource Monitoring in Bear Creek

Bear Creek is designated as Oak Ridge Research Park 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 representatives of 11 orders of insects, including springtails, mayflies, dragon flies and damselflies, stoneflies, crickets and grasshoppers, alderflies and fishflies, 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 Highway 95.

Biological monitoring of stream sites in Bear Creek Valley 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 Bear Creek Valley 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 Burn Yard/Bone Yard 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* Rafinesque 1871) 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* Linnaeus 1758) 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 FY 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 to 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 groundwater.

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 groundwater discharges in the Bear Creek (DOE 2012). Most contaminant levels also decrease in the downstream direction.

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).

3.6.3 Stream Resources Associated with NT-3

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 to 88.6%, over the same period. The mean number of plant species per transect also declined, from 15.8 to 13.6. This is apparently due to an invasive plant species (*Lespedeza cuneata* (de Courset) G.Don) that out-competes native species.

NT-3 water quality measures (pH, dissolved oxygen, 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* Agassiz 1854) has been routinely observed in NT-3. Largescale stonerollers (*Campostoma oligolepis* Hubbs and Greene 1935), 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 depth of the stream under normal conditions, poor substrate conditions, and the tendency of the stream for go dry in late summer.

3.6.4 Other Status Species

No 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 ST-2 and Walker Branch. The yellow bellied sapsucker (*Sphyrapicus varius* L. 1766), 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* Wilson 1810) 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 (*Accipter striatus* Vieillot 1807), 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* Bonaparte 1828) 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 (*Circus cyaneus* L. 1766); 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.

3.6.5 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.

3.7 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 C-20. 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.

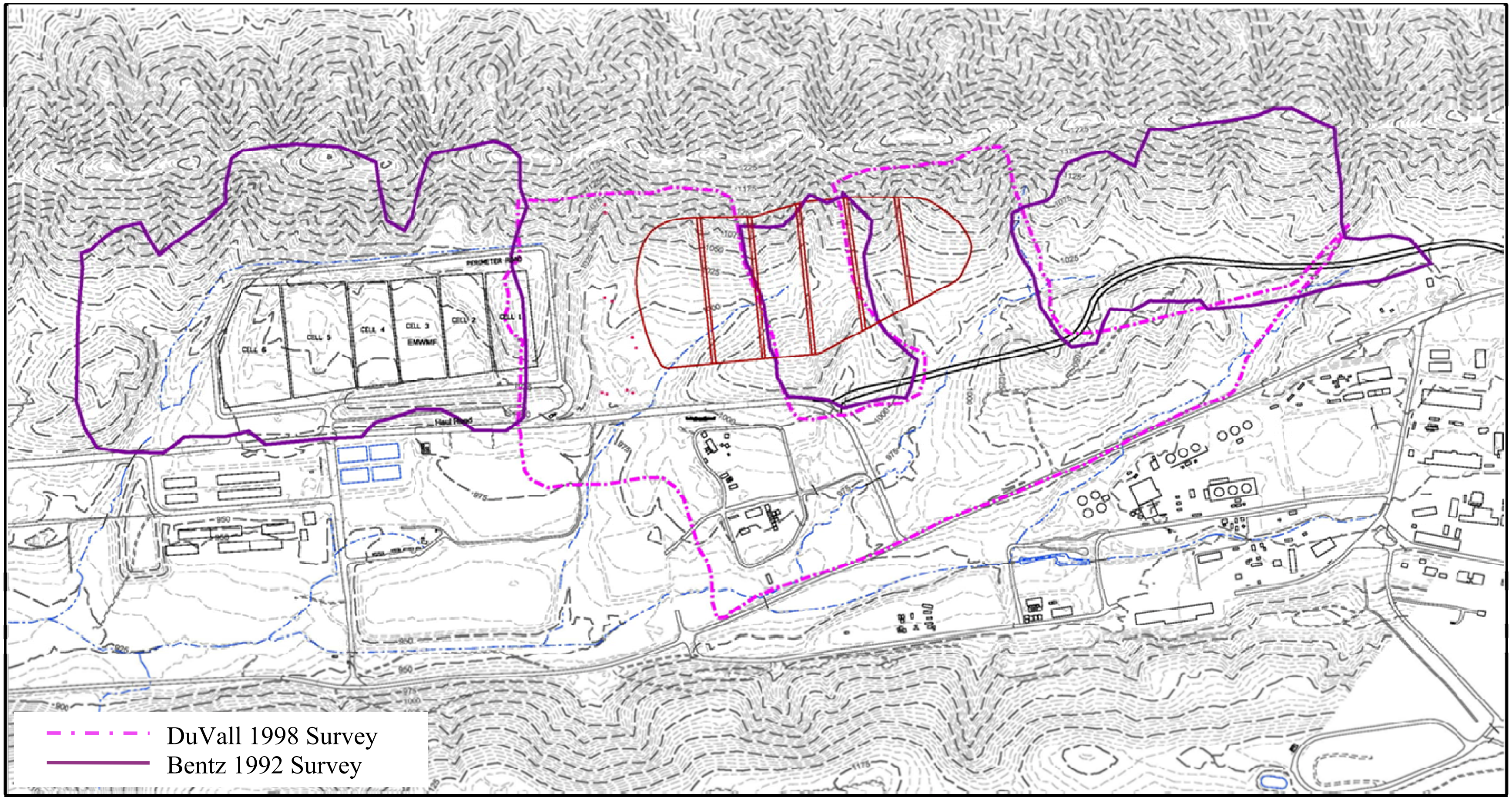


Figure C-20. Area Covered by Archaeological Reconnaissance Report in DuVall (1998)

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APPENDIX D:

ALTERNATIVES RISK ASSESSMENT AND FUGITIVE EMISSION MODELING

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CONTENTS

FIGURES

TABLES

ACRONYMS

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
ETTP	East Tennessee Technology Park
FEMA	Federal Emergency Management Agency
ILCR	Incremental Lifetime Cancer Risk
LLW	low-level waste
MEI	maximally exposed individual
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
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
WAC	Waste Acceptance Criteria
Y-12	Y-12 National Security Complex

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.

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, NV. 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, UT 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, AZ 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, UT (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 D-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.

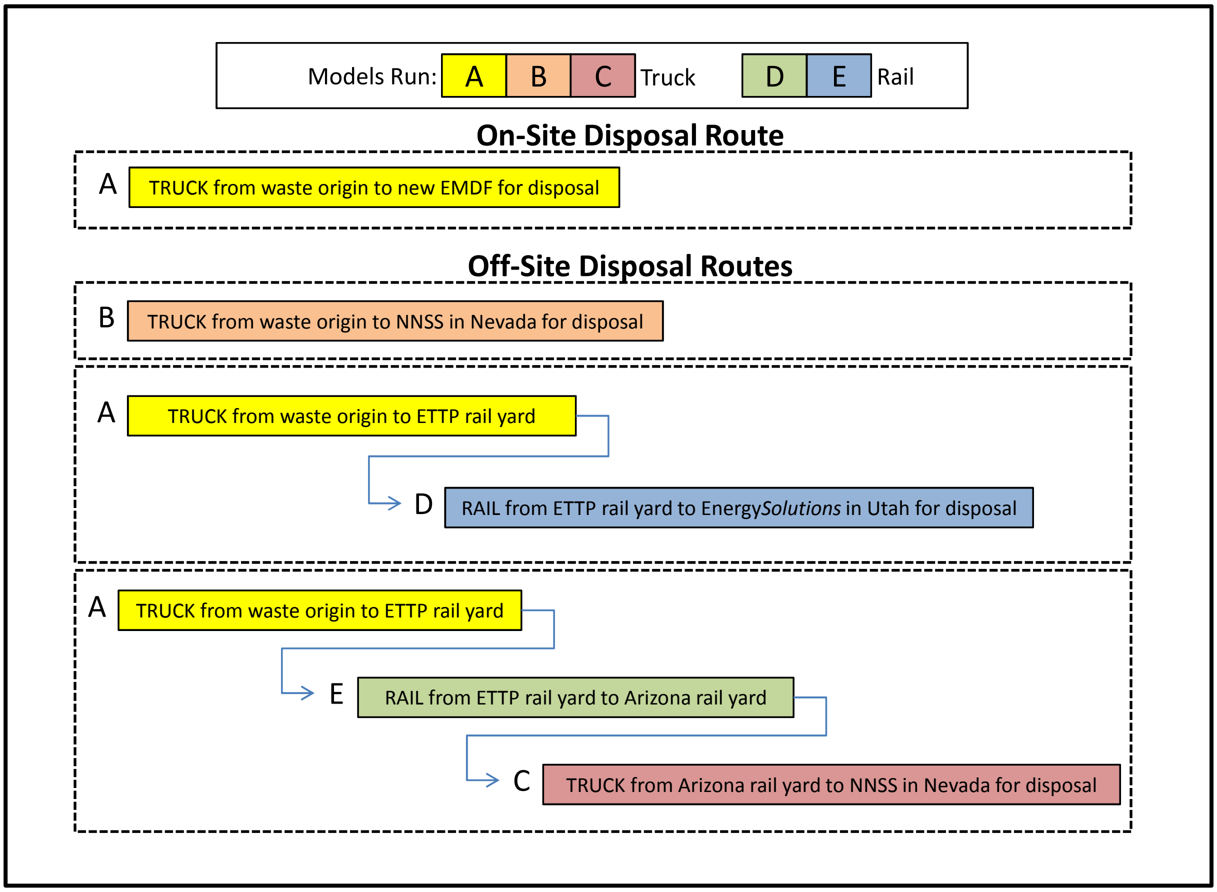

Figure D-1. Transportation Routes Assessed in On-site and Off-site Disposal Alternatives

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 D-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.

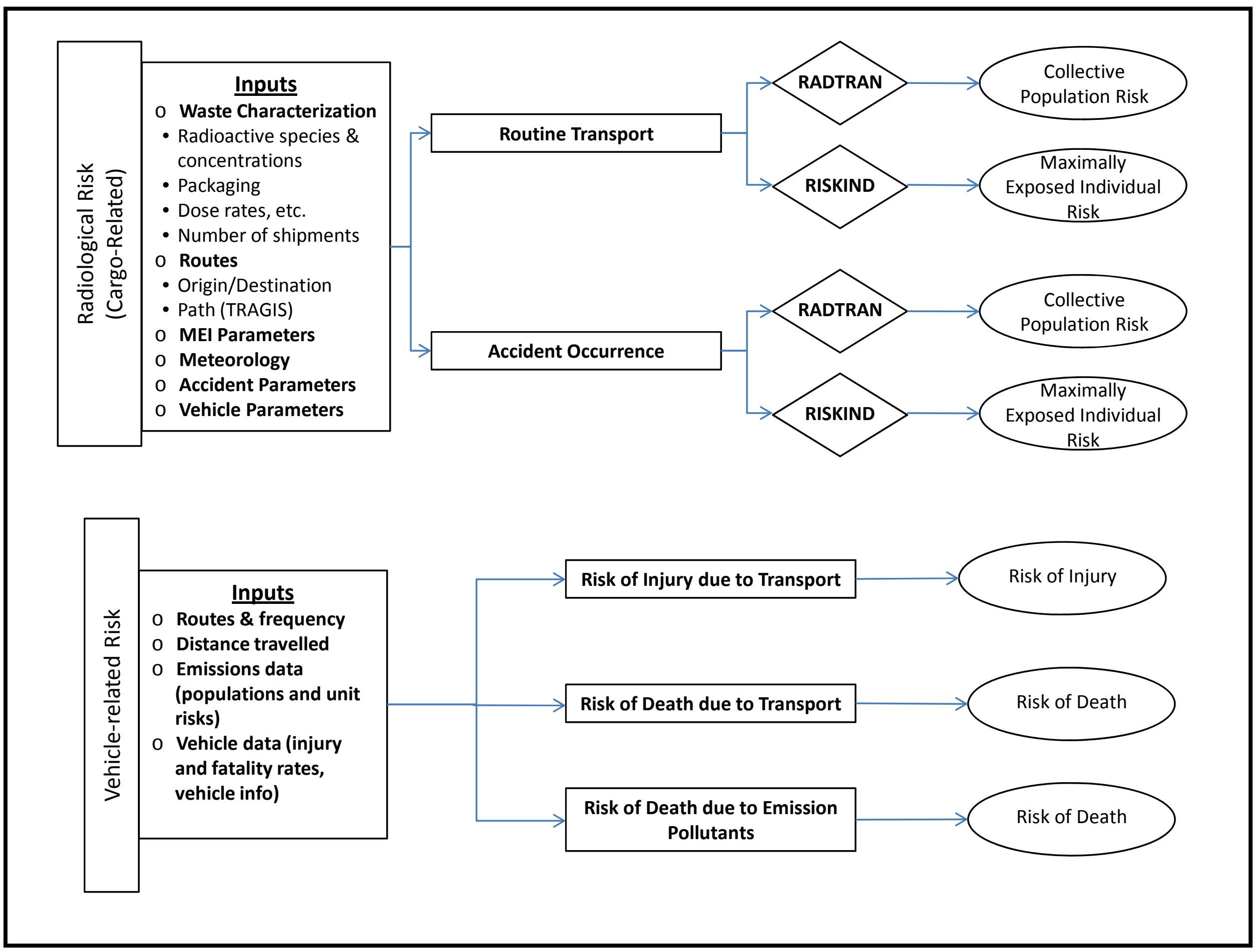

Figure D-2. Approach to Determining Transportation Risk

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 D-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 Section 2.1 and 2.3 and Figure D-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 D-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, AZ to NNSS (drivers, person in traffic, resident along route, truck inspector, and person at service station)
- Rail travel from ETTP rail to either Clive, UT or Kingman, AZ (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 D-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 173,454 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 x 8 ft x20 ft. The shipping container is assumed to hold 11 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 D-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 D-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 9200 m^3/year is assumed. This is the average breathing rate based on the default breathing rate of 8000 m^3/year (2.9×10^{-4} m^3/sec) for RISKIND and the 3.3×10^{-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 D-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 D-1.
- Mixed waste (LLW/RCRA) is transferred to Energy*Solutions* in Clive, UT for disposal.
- LLW and LLW/TSCA waste is transferred to NNSS for disposal.
- Classified waste is trucked to NNSS for disposal.
- 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, AZ): 167,130
  - On-site transport (intermodals) to ETTP rail yard (and further transporting to Clive, UT): 6,190
  - Off-site transport (truckloads: some trucks carry two intermodals [debris], some trucks carry one intermodal [soil], due to weight limitations) from Kingman, AZ to NNSS: 99,834
  - Off-site transport of classified waste from ETTP to NNSS: 67
- 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 (six intermodals per rail car based on carrying soil or eight intermodals per rail car based on carrying debris) from ETTP rail yard to Clive, UT: 817
  - Off-site rail transport (six intermodals per rail car based on carrying soil or eight intermodals per rail car based on carrying debris) from ETTP rail yard to Kingman, AZ: 22,247
- A rail car is assumed to hold six intermodals, stacked two high. This makes the rail car dimension 12 ft x 8 ft x 60 ft long. Shipping car holds 66 yd^3 of waste. Waste is assumed to have a density of 1.5 g/cm^3, approximately that of soil. (For radionuclide exposure modeling, six intermodals of soil were assumed for assumed for all rail shipments. The weight of six intermodals of soil is approximately equivalent to eight intermodals of debris.)
- 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 D-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 to 2010 was calculated to escalate the population densities input to the RADTRAN model.

- Numbers of persons during stops were assumed as: 10 (5 to 20 m) at rest/refuel stops, 10 (5 to 100 m) in traffic jams, and 1 (1 to 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 2.9×10^{-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. Handlers are assumed to be under dose-tracking/limit program and not analyzed.
- 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 D-2.
- Routine and accident scenarios are evaluated for MEIs and collective populations.

Table D-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 D-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 41 Suburban	64.4 Rural 40.2 Suburban 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 hr Long-term 50 yr	Short-term 2 hr Long-term 50 yr
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 6×10^{-4} fatal cancers/TEDE and 8×10^{-4} cancer illnesses/TEDE to convert to mortality and morbidity rates, respectively, for both collective populations and MEIs (DOE 2003). Table D-3 and D–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 D-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 D-4). As expected, on-site transport of waste carries a significantly lower risk of cancer illnesses and fatalities than off-site transport of waste.

Table D-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.

Table D-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 D-4. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Multiple (All) Shipments

Receptor/Scenario	On-site Disposal Alternative		Off-site Disposal Alternative (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 = 173,454		Number of shipments = 67		Number of shipments = 167,130 (to ETTP rail) 22,247 (rail to Kingman) 99,834 (Kingman to NNSS)		Number of shipments = 6,190 (to ETTP rail) 817 (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)	8.65E-03	1.15E-02	6.03E-04	8.04E-04	4.80E-02	6.39E-02	3.12E-04	4.15E-04	4.89E-02	6.52E-02
Resident Along Route	4.16E-03	5.55E-03	1.61E-06	2.14E-06	6.94E-03	9.26E-03	1.68E-04	2.24E-04	7.11E-03	9.48E-03
Accidents										
Driver (Truck) or Crew Member (Rail)	1.33E-03	1.78E-03	5.15E-07	6.86E-07	2.19E-03	2.92E-03	5.27E-05	7.03E-05	2.25E-03	2.99E-03
Resident Along Route	5.31E-04	7.08E-04	2.05E-07	2.73E-07	9.65E-04	1.29E-03	2.44E-05	3.25E-05	9.90E-04	1.32E-03
Collective Population										
Routine Travel										
Crew	7.37E-03	9.82E-03	1.28E-03	1.70E-03	1.72E-02	2.29E-02	2.63E-04	3.51E-04	1.87E-02	2.49E-02
On-Link	a	a	7.12E-04	9.49E-04	6.36E-02	8.48E-02	3.84E-04	5.11E-04	6.47E-02	8.63E-02
Off-Link	6.79E-05	9.05E-05	5.19E-05	6.91E-05	1.09E-01	1.46E-01	2.95E-03	3.93E-03	1.12E-01	1.50E-01
Handlers	1.02E-01	1.37E-01	3.96E-05	5.27E-05	2.05E-01	2.73E-01	5.38E-03	7.18E-03	2.10E-01	2.80E-01
Accidents										
Societal Accident Exposure	2.77E-08	3.69E-08	1.36E-07	1.82E-07	1.43E-04	1.90E-04	9.08E-07	1.21E-06	1.44E-04	1.92E-04

[a] No on-link analysis for on-site; all travel is on non-public road.

Table D-5. Transportation Risk Assessment, Injury and Fatality Risk Due to Vehicle-related Incidents

Scenario	Emissions	Vehicle Travel	
	Fatal	Fatal	Non-Fatal
On-site Disposal Alternative			
Truck to EMDF	1.09E-02	2.45E-02	8.48E-01
Off-site Disposal Alternative			
Truck to NNSS	1.64E-02	4.52E-03	7.84E-02
Truck to ETTP; Rail to Clive, UT	7.19E-02	3.43E-02	1.11E-01
Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	7.42E+00	1.41E+00	1.35E+01
Off-site Total	**7.50E+00**	**1.45E+00**	**1.37E+01**

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, AZ, 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 D–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 D-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 D-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)	1.50E+00	2.01E+00	4.80E-02	6.39E-02
Resident Along Route	4.01E-03	5.35E-03	6.94E-03	9.26E-03
Accident				
Driver (Truck) or Crew Member (Rail)	1.28E-03	1.71E-03	2.19E-03	2.92E-03
Resident Along Route	5.11E-04	6.82E-04	9.65E-04	1.29E-03
Collective Population				
Routine Travel				
Crew	3.19E+00	4.25E+00	1.72E-02	2.29E-02
On-Link	1.77E+00	2.37E+00	6.36E-02	8.48E-02
Off-Link	1.29E-01	1.72E-01	1.09E-01	1.46E-01
Handlers	9.87E-02	1.32E-01	2.05E-01	2.73E-01
Accident				
Societal Accident Exposure	3.40E-04	4.53E-04	1.43E-04	1.90E-04

Table D-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	4.10E+01	1.13E+01	1.96E+02
Truck and Rail Transport			
Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	7.42E+00	1.41E+00	1.35E+01

3. NATURAL PHENOMENA

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 4.26×10^{-5}/yr (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 and; therefore, only the radioactive portion of the waste is considered in the assessment.

3.1 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 ~ 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 D-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.

3.2 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 4.26×10^{-5} was estimated based on these two reference sources.

3.3 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 groundwater and surface water.

The ILCR as calculated by RESRAD from radiation exposure resulting from tornado-dispersed contamination is 2.90×10^{-4} at the peak risk (immediately following dispersion). Applying the probability of tornado occurrence (4.26×10^{-5}) and a 30-year operating window (which is somewhat higher than the current assumed lifecycle of 23 years) for the disposal facility results in a maximum total aggregate risk of 3.71×10^{-7}.

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 1350 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 Highway 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 D-8. Methods used for calculating emission rates were those presented in AP-42 (EPA 1995).

Table D-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 • 250 work days per year • Wind speed 4.1 mi/hr • Mean vehicle speed of 7.1 mi/hr (applicable only to grading operations) • Silt content of the gravel haul roads of 6%
Assumptions:
• Only one of the four main activities will occur at one time. • 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. • 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). • Salt is used on roads for ice control, not sand/gravel and; therefore, are removed from calculations. • Unpaved roads travelled are considered as industrial (not public). • The different materials handled during the various activities would have varying moisture and silt contents. • 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 D–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 D-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-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

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APPENDIX E:

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

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CONTENTS

TABLES

ACRONYMS

ALARA	as low as reasonably achievable
ARAP	Aquatic Resource Alteration Permit
ARAR	applicable or relevant and appropriate requirement
AWQC	Ambient Water Quality Criteria
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	Department of Energy
DOT	U.S. Department of Transportation
EDE	effective dose equivalent
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EO	Executive Order
EPA	Environmental Protection Agency
FR	Federal Register
FML	flexible membrane liner
GCL	geosynthetic clay liner
LLW	low-level waste
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NT	North Tributary (to Bear Creek)
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OSWER	Office of Solid Waste and Emergency Response
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PPE	personal protective equipment
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
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

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), 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 United States (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 the 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, neither the regulations promulgated by OSHA nor DOE Orders related to occupational safety are 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 to obtain federal, state, or local permits (CERCLA Section 121[e]). To ensure that CERCLA response actions proceed as rapidly as possible, EPA has 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 (DOE 1992) participants have agreed that the DOE Oak Ridge Reservation 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 E-1 lists the chemical-specific ARARs/TBCs; Table E-2 lists the location-specific ARARs/TBCs; and Table E-3 lists the action-specific ARARs/TBCs.

Table E-4 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 three 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 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 of "equivalent protectiveness" under 40 CFR 300.430 (f)(ii)(C)(4).

2. The Tennessee Department of Environment and Conservation (TDEC) hydrological conditions requirement for land disposal of radioactive waste that the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site (TDEC 0400-20-11-.17[1][h]). A waiver for this requirement will be requested on the basis of "equivalent protectiveness" under 40 CFR 300.430 (f)(ii)(C)(4).

3. The TDEC Ambient Water Quality Criteria (AWQC) applicable to discharges into Bear Creek are those for recreation contained in TDEC 1200-04-03-.03(4). A waiver for this requirement is requested that will allow applicable discharges into Bear Creek to meet the TDEC AWQC for Fish and Aquatic Life contained in TDEC 1200-04-03-.03(3). This waiver is requested for an interim time period, the duration of operation of the On-site Disposal facility, plus the time period following closure that is required to dewater the capped landfill area. A waiver for this

requirement will be requested on the basis of "interim measure" under 40 CFR 300.430 (f)(ii)(C)(1).

The waiver 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 Section 3 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).

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. WAIVER 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 three requirements will be requested. These requirements include:

- 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.
- A TDEC hydrologic conditions requirement for land disposal of radioactive waste specifies the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site (TDEC 0400-20-11-.17[1][h]). Construction of a disposal facility at the EMDF site evaluated under the On-site Disposal Alternative would not meet this TDEC requirement.
- TDEC AWQC applicable to discharges to surface waters of Bear Creek, at the location of EMWMF and the proposed EMDF, are those for Recreation contained in TDEC 1200-04-03-.03(4). Meeting the Recreation AWQC would disallow the discharge of significant volumes of contact water and leachate, requiring transfer and treatment for millions of gallons of contact water and leachate that would otherwise meet Fish and Aquatic Life AWQC contained in 1200-04-03-.03(3), thus allowing direct discharge of these volumes.

If on-site disposal is the selected remedy, waivers from the TSCA and TDEC hydrologic conditions requirements would be requested on the basis of 40 CFR 300.430(f)(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."

A waiver to meet TDEC Fish and Aquatic Life AWQC rather than Recreational AWQC would be requested, if on-site disposal is the selected remedy, on the basis of 40 CFR 300.430(f)(ii)(C)(1),"interim measure". The discharge of contact water and leachate to surface water per Fish and Aquatic Life AWQC would be closely monitored and only carried out for the duration of operation of the landfill and the post-closure dewatering period following capping of the landfill, after which any discharges would be required to meet TDEC Recreation AWQC contained in 1200-04-03-.03(4).

TSCA requirement 40 *CFR* 761.75(b)(3): An "equivalent protectiveness" waiver of the TSCA 50-ft groundwater buffer requirement would be requested as allowed by 40 CFR 300.430 (f)(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 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 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 hr (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 clay. The range of hydraulic conductivities for these materials range from <1×10^{-7} cm/sec for low permeability clay; 5×10^{-9} cm/sec for GCLs; and between 1×10^{-11} and 1×10^{-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 groundwater table. This design is highly effective at preventing and retarding contaminant movement.

There is precedence for waiver of the TSCA 50 ft groundwater buffer requirement. It is commonly waived in the southeast because of high groundwater tables; EPA-Region 4 has waived this requirement in the past, including granting a waiver for the EMWMF.

TDEC requirement TDEC 0400-20-11-.17(1)(h): As discussed in Chapter 6 of this RI/FS, the EMDF would be constructed over part of North Tributary (NT)-3. This tributary to Bear Creek is fed by springs and seeps that are hydraulically connected to the site and discharge groundwater to the surface within the disposal site. A waiver is requested from this ARAR on the basis of equivalent protectiveness, as allowed by 40 CFR 300.430 (f)(ii)(C)(4). Equivalent protectiveness is demonstrated by the conceptual design that includes an extensive underdrain system, shallow upgradient French drain, upgradient geomembrane-lined diversion ditch, and a landfill liner composed of multiple impermeable layers, which are designed to mitigate the hydrologic conditions at the site and provide "equivalent protectiveness." Upgradient storm water would be diverted around the landfill in a geomembrane-lined ditch. The shallow upgradient French drain would intercept and divert shallow perched groundwater flowing within the stormflow zone away from the buried waste. The landfill would be constructed over a portion of NT-3 and flow would be rerouted west of the new facility and rejoin the existing NT-3 channel south of the Haul Road. In addition, construction of the landfill would eliminate percolation of surface water into the ground within the footprint of the landfill. Collectively, these design features would lower the groundwater table beneath the landfill and would reduce groundwater fluctuations. The underdrain system would provide a pathway for upgradient and/or upwelling seeps and springs to flow beneath the landfill, while maintaining at least a 10 ft thick geologic buffer below the liner system.[1] The underdrain system would provide a "preferred pathway" for groundwater and could be used as a tertiary leak detection and removal system for the landfill.

TDEC Recreation AWQC 1200-04-03-.03(4): Request for a waiver to meet Fish and Aquatic Life AWQC, rather than recreation AWQC, for discharges of contact water and leachate would be made for an interim period of time, including the period of operation of the on-site disposal facility plus the time required to dewater the capped and closed facility during post-closure. Under the scenario analyzed in this RI/FS, this equates to 22 years of operation, plus a conservatively assumed 10-year period of time for dewatering.

AWQC for Fish and Aquatic Life are protective. There is no prospect of recreational use in Bear Creek in the near-term. As a practical matter, the low and intermittent flow in Bear Creek precludes fishing for consumptive purposes. The reach of stream at issue is proximate to the Y-12 National Security Complex facility, patrolled, surrounded by legacy burial grounds, and for decades will be part of the Bear Creek Valley cleanup effort. Application of Fish and Aquatic Life AWQC would be appropriate while an on-site remedial action and the Bear Creek Valley remedial action are ongoing.

[1] The EMWMF design complies with the TDEC solid waste requirement for a 10 ft geologic buffer (TDEC 0400-11-01-.04[4][a][2](i) at TDEC's request. Consistent with this agreement, the conceptual design for the proposed EMDF includes a 10 ft geologic buffer.

4. 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, groundwater, 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 E-1) that are discussed below.

4.1 RADIATION PROTECTION

The radiation dose to members of the public must not exceed 100-mrem/yr total effective dose equivalent (EDE) 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.

The TDEC performance standard specifies that concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not exceed annual dose limits. The release of radioactivity in effluents to the general environment must also be maintained at ALARA levels.

EPA guidance Office of Solid Waste and Emergency Response (OSWER) 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)].

4.2 PROTECTION FROM HAZARDOUS CONSTITUENTS

Detection and, if necessary, compliance monitoring for groundwater will be conducted during landfill operation, closure, and post-closure. Monitoring wells will be installed at appropriate locations and depths to sample the groundwater 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.

5. LOCATION-SPECIFIC ARARs/TBCs

Location-specific requirements (see Table E-2) establish restrictions on permissible concentrations of hazardous substances 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.

5.1 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 C 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, the extent of wetlands impact would be determined based on wetlands survey and other detailed design considerations. 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- or 500-year floodplain of Bear Creek. Regulations regarding potential impacts on floodplains would be applicable if construction could impact the floodplain. Construction activities at the EMDF site would involve some disturbance of wetlands and aquatic resources; mitigation activities are therefore assumed in the on-site cost estimate.

5.2 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 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.

5.3 ENDANGERED, THREATENED, OR RARE SPECIES

As described in Appendix C, the EMDF site is not known to contain plants that are threatened or endangered, in need of management, or species of concern (Baranski 2009). For the On-site Disposal Alternative, a biologic and wetlands survey would be conducted, and any rare plants within the area would be protected and preserved per the Tennessee Rare Plant Protection and Conservation Act of 1985. In addition, the Tennessee dace (*Phoxinus tennesseensis*), which is listed as a "species in need of management" by the state of Tennessee, has been found throughout Bear Creek and several of its tributaries. 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.

Tennessee lists state-specific threatened, endangered, and in-need-of-management animal species in Tennessee Wildlife Resource Conservation Proclamations (TWRCP) 00-14 and 00-15, which supersede TWCRP 94-16 and 94-17. The TDEC Division of Natural Areas Natural Heritage Program Rare Animal List (2009) may also be 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) may also be consulted for threatened and special status species.

5.4 CULTURAL RESOURCES

There are no known significant historical or archaeological resources within the EMDF footprint, support facilities, or roadways (see Appendix C). 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.

6. 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 ORR. This facility would be designed to manage low-level waste (LLW), RCRA 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), including a minimal volume of disposal facility operations waste, would be shipped to an off-site commercial facility for disposal. ARARs for off-site shipment are addressed in Chapter 7 of this Appendix.

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- 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 Table E-3) address:

- General construction standards – site preparation, excavation activities, etc.
- Waste management
- Disposal site suitability requirements
- Wastewater collection and discharge
- Design, construction, and operation of a mixed (RCRA hazardous, TSCA chemical and LLW landfill
- Closure
- Post closure care

- Off-site Transportation and Disposal (for the small portion of CERCLA waste that will not meet the on-site disposal facility WAC)

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, subsequent management will be in accordance with the on-site disposal facility's WAC attainment plan, a post-ROD primary document. Facility operations could also be shut down temporarily, necessitating waste accumulation. Storage, accumulation, and transportation requirements have been included as ARARs for the on-site disposal facility as appropriate to address these contingencies.

6.1 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 E-3, 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.

6.2 WASTE MANAGEMENT

Table E-3 lists ARARs and TBC guidance for characterization and management of different types of waste streams.

6.2.1 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 [PPE], 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 Order/Manual 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.

6.2.2 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.

6.2.3 Waste Segregation

TSCA waste must be segregated from incompatible wastes during management and storage. LLW should be segregated from mixed waste.

6.2.4 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.

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).

Per DOE TBC guidance, 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.

6.3 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, areas subject to seismic activity, geologic processes, or hydrogeology that adversely affect the facility's stability or ability to meet performance standards. These site conditions, if present, must not preclude design and construction of the facility so that the performance standards will be met. Performance standards for the facility include the requirement to achieve long-term stability of the disposal. TDEC requires that the facility site must be capable of being characterized, modeled, analyzed, and monitored and specifies a pre-operational monitoring program be conducted.

As noted in Chapter 3 of this Appendix, a waiver of two hydrologic condition requirements would be requested on the basis of equivalent protectiveness of landfill design (40 CFR 300.430 [f][ii][C][4]). TDEC Rule 0400-20-11-.17(1)(h) requires that "the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site", e.g., that there be no streams, springs, or seeps at the site. The proposed EMDF would be built over the upper reaches of Bear Creek tributary NT-3, which is fed by springs and seeps during the wet season.

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.

With the exception of these requirements, implementation of the On-site Disposal Alternative would meet all CERCLA ARARs. In addition, the risk assessment and preliminary WAC analyses (see Appendix D and Appendix F, 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.

6.4 WASTEWATER COLLECTION AND DISCHARGE

Non-contact storm water generated during construction, operations, closure and post-closure will be collected in sedimentation basins to allow for solids to settle out, and then released to surface streams.

Wastewater (leachate and contact water) collected during EMDF operations and post-operational dewatering activities would be routed through new piping to the existing storage tanks and retention ponds now used at the EMWMF. Wastewater would be sampled and analyzed to determine if it complies with applicable TDEC water quality standards. Wastewater that does not meet the standards will be transported by tanker truck to an existing wastewater treatment plant on the ORR for treatment and subsequent discharge via a permitted outfall. Wastewater that meets the applicable release standards will be released to surface streams.

6.5 DESIGN, CONSTRUCTION, AND OPERATION OF A MIXED (RCRA HAZARDOUS, TSCA CHEMICAL AND LOW-LEVEL RADIOACTIVE) WASTE LANDFILL

Table E-3 lists RCRA, TSCA, TDEC Radiation Protection, and DOE 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 groundwater 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 E-3.

RCRA regulations require that the landfill design must prevent leachate generation and release of hazardous constituents to groundwater. 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.

Landfill leachate and contact water (i.e., stormwater that has contacted the waste but not entered the leachate collection system) will be contained in above-ground tanks and surface impoundments and tested for the presence of contaminants at levels above discharge limits. If the contained wastewater is found to meet discharge criteria, it will be released to surface streams. In the event the wastewater is found to be contaminated at levels exceeding release criteria, it will be trucked to the Oak Ridge National Laboratory (ORNL) Process Waste Treatment Complex or other suitable ORR wastewater treatment facility for treatment and discharge through a National Pollutant Discharge Elimination System-permitted outfall. Leachate and contact water ARARs include Tennessee Rule 1200-04-03-.05(6) and Rule 1200-04-03-.03(4). A waiver will be requested to follow TDEC 1200-04-03-.03(3) AWQC for Fish and Aquatic Life rather than TDEC 1200-04-03-.03(4), see Chapter 3 of this Appendix. DOE Order 458.1 is TBC guidance for wastewater handling and discharge.

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 will be determined after discussions with regulators. Specific ARARs relating to monitoring are provided in a subsection of Table E-3. Corrective action plans for releases must be in place prior to accepting wastes.

DOE Order 435.1 (including subordinate manuals and standards) performance objectives, requirement for a Disposal Authorization Statement, landfill design requirements, and landfill operational requirements are TBC requirements and guidance for the EMDF.

TDEC Radiation Protection requirements that are relevant and appropriate include that the facility design must consider long-term isolation, compliance with performance objectives, and avoidance of site degradation through erosion. Low-level waste must be placed to maintain package integrity and prevent void spaces, and a buffer zone of land must be maintained beneath the disposal unit and between the unit and disposal boundary. Closure and stabilization measures must be carried out as each disposal unit is filled and covered. A monitoring system to detect releases of radioactivity before they leave the site boundary must be employed throughout operations.

DOE provides TBC guidance that the facility be designed, constructed, and operated with consideration for the effects of natural phenomena and hazards in order to ensure facility performance. The facility should have control and stabilization features for long-term management of uranium, thorium and their decay products.

6.6 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.

TDEC provides similar requirements for closure of an LLW disposal facility. Groundwater detection monitoring will continue through closure. 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 chemical-waste landfill should parallel closure requirements under RCRA.

6.7 POSTCLOSURE 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. Per RCRA, post-closure care must begin after closure and must continue for 30 years. 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 maintenance, maintenance and operation of the leachate collection system as long as leachate is being generated, and environmental monitoring, including groundwater detection monitoring.

6.8 ENVIRONMENTAL MONITORING DURING OPERATION, CLOSURE, AND POST-CLOSURE CARE

RCRA and TSCA provide requirements for construction of groundwater monitoring wells. RCRA specifies groundwater monitoring program requirements, sample collection, and detection monitoring.

The owner of a RCRA landfill must conduct monitoring of leachate, surface water, and groundwater during landfill operations, closure, and the post-closure care period. Groundwater detection monitoring is designed to detect a release from the landfill. In the event of a release, remedial actions would be planned and implemented under CERCLA, as applied by the FFA, and not RCRA. Therefore, RCRA compliance monitoring and corrective action requirements are not applicable.

RCRA and TSCA provide requirements for locating and constructing groundwater monitoring wells. RCRA specifies groundwater monitoring program requirements, sample collection, and analyses to be conducted. Analyses to be conducted on groundwater during detection monitoring once per year are to include the analytes list 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 prior to waste receipt.

The TDEC Radiation Protection regulations contain relevant and appropriate requirements for a monitoring system. Additionally, DOE Order 435.1 has TBC requirements for monitoring. The disposal facility must have plans for corrective actions that would be taken if monitoring detects migration of radionuclides. Institutional controls include, at a minimum, administrative restrictions for sale and use of property and securing the area to prevent human contact with hazardous substances.

6.9 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 E-4 and discussed below in Chapter 7.

7. OFF-SITE DISPOSAL ALTERNATIVE ARARs/TBCs

Table E-4 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 E-3 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. Per DOE Manual 435.1-1(I)(2)(F)(4), 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 E-1. Chemical-specific ARARs and TBC Guidance for the On-site Disposal Alternative

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
Releases of radionuclides in the environment	Exposure to individual members of the public from radiation shall not exceed a total EDE of 0.1 rem/year (100 mrem/year), exclusive of the dose contributions from background radiation, any medical administration the individual has received, or voluntary participation in medical/research programs.	Activities causing direct exposure to radiation or the release of radionuclides into the environment – **relevant and appropriate**	10 CFR 20.1301(a)(1) TDEC 0400-20-05-.60(1)(a)
	Shall use, to the extent practicable, procedures and engineering controls based on sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.		10 CFR 20.1101(b)
	Concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ. Reasonable effort shall be made to maintain releases of radioactivity in effluents to the general environment ALARA.		TDEC 0400-20-11-.16(2)

Table E-2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
Floodplains/Wetlands			
Presence of floodplain as defined in 10 *CFR* 1022.4(i) or within "lowland and relatively flat areas adjoining inland and coastal waters and other flood-prone areas such as offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in a given year" (Executive Order [EO] 11988, Sect. 6[c], and TDEC 1200-1-7).	Action shall be taken to reduce the risk of flood loss; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values of floodplains. Measures to mitigate adverse effects of actions in a floodplain include, but are not limited to: minimum grading requirements, runoff controls, design and construction constraints, and protection of ecology-sensitive areas as provided in 10 *CFR* 1022.12(a)(3). The potential effects of actions in floodplains shall be evaluated and consideration of flood hazards and floodplain management ensured. If action is taken in floodplains, alternatives that avoid adverse effects and incompatible development and minimize potential harms shall be considered.	Federal actions potentially impacting or taking place within floodplains that involve: • Acquiring, managing, and disposing of lands and facilities; • Providing federally undertaken, financed, or assisted construction and improvements; and • Conducting federal activities and programs affecting land use - **TBC**	EO 11988 (May 24, 1977);
Presence of wetlands as defined 10 CFR 1022.4(v), and TDEC 1200-01-07.01	Avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. Measures to mitigate adverse effects of actions in a wetland include, but are not limited to: minimum grading requirements, runoff controls, design and construction constraints, and protection of ecology-sensitive areas as provided in 10 CFR 1022.13(a)(3). New construction in wetlands areas should be particularly avoided unless there are no practicable alternatives. Wetlands protection considerations shall be incorporated into planning, regulating, and decision-making processes.	Federal actions potentially impacting or taking place within wetlands that involve: • Acquiring, managing, and disposing of lands and facilities; • Providing federally undertaken, financed, or assisted construction and improvements; and • Conducting federal activities and programs affecting land use **– applicable**	10 CFR 1022.3(a); TDEC 1200-04-07-.01(3)

Table E-2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
	Potential effects of any new construction in wetlands that are not in a floodplain shall be evaluated. Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse impacts on wetlands.		10 CFR 1022.3(c); 10 CFR 1022.3(d)
Presence of jurisdictional wetlands as defined in 40 *CFR* 230.3(t) and 33 *CFR* 328.3(b)	Action to avoid degradation or destruction of wetlands must be taken to the extent possible. Discharges for which there is a practicable alternative with less adverse impacts or those which would cause or contribute to significant degradation are prohibited. If adverse impacts are unavoidable, action must be taken to enhance, restore or create alternative wetlands.	Action involving discharge of dredge or fill material into wetlands **– applicable**	40 CFR 230.10(d)
Aquatic Resources			
Action potentially altering the properties of any "Waters of the State"	Erosion and sediment control requirements include, but are not limited to the following. • Limit clearing, grubbing, and other disturbances in areas in or immediately adjacent to Waters of the State to the minimum necessary to accomplish the proposed activity. • Unnecessary vegetation removal is prohibited and all disturbed areas must be properly stabilized and re-vegetated as soon as practicable. • Limit excavation, dredging, bank reshaping, or grading to the minimum necessary to install authorized structures, accommodate stabilization, or prepare banks for re-vegetation. • Maintain the erosion and sedimentation control measures throughout the construction period. • Upon achievement of final grade, stabilize and re-vegetate, within 30 days, all disturbed areas by sodding, seeding, or mulching, or using appropriate native riparian species.	Action potentially altering the properties of any "waters of the State" – **applicable**	TDEC Aquatic Resource Alteration General Permit Program Requirements

Table E-2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
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 United States Code [USC] 661 et seq.)
Location encompassing aquatic ecosystem with dependent fish, wildlife, other aquatic life, or habitat or as defined in 40 *CFR* 230.3(c)	Except as provided under Section 404(b)2 of the Clean Water Act of 1972 (CWA), no discharge of dredged or fill material into an aquatic ecosystem is permitted if there is a practicable alternative that would have less adverse impact. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps per 40 *CFR* 230.70 et seq. are taken to 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) 40 CFR 230.10(d)
Endangered, Threatened, or Rare Species			
Presence of Tennessee state-listed endangered or threatened animal species as created and amended pursuant to TCA 70-8-105	No person may take, harass, or destroy wildlife listed as threatened or endangered or otherwise violate the terms of TCA 70-8-105(c) or destroy knowingly the habitat of such species without due consideration of alternatives for the welfare of state-listed or federally-listed endangered species.	Action impacting such species – **applicable**	TWRCP 00-14 and 00-15 Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act (TCA 70-8-104C)-. See also Tennessee Natural Heritage Program Rare Animal List (2009)
Presence of Tennessee-listed endangered or rare plant species as listed in TDEC 0400-6-2-.04	Protected species may not be uprooted, dug, taken, removed, damaged or destroyed, possessed, or otherwise disturbed for any purpose.	Action impacting plant species determined by the Commissioner (of TDEC) to be in jeopardy, including, but not limited to, "endangered species" pursuant to the federal Endangered Species Act – **relevant and appropriate**	16 USC 1531 et seq. TDEC 0400-06-02-.04 and Tennessee Natural Heritage Program Rare Plant List (2012)
Presence of Tennessee state-listed wildlife species "in need of management" as listed in TWRCP 00-14 & 00-15	No person may knowingly destroy the habitat of such species. Certain exceptions may be allowed for reasons such as education, science, etc., or where necessary to alleviate property damage or protect human health or safety.	Action impacting such species – **applicable**	TCA 70-8-104(b); TWRCP 00-14 and 00-15

Table E-2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
Presence of Tennessee nongame species (Tennessee dace) as defined in TCA 70-8-103	May not take (i.e., harass, hunt, capture, kill or attempt to kill), possess, transport, export, or process nongame wildlife species. May not knowingly destroy the habitat of such wildlife species. Upon good cause shown and where necessary to protect human health or safety, endangered or threatened species may be removed, captured, or destroyed.	Action impacting Tennessee nongame species, including wildlife species which are "in need of management" (as listed in TWRCP 00-14 and 00-15) – **applicable**	TCA 70-8-104(c) TWRCP 00-15, Section II TWRCP 00-14(II) and TWRCP 00-15 TCA 70-8-106(e) TWRCP 00-14(II)(1)(c)
Presence of federally endangered or threatened species, as listed 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 take.	Action impacting such species – **applicable**	16 U.S.C. §1536(a)(2)–Section 7(a)(2)
Cultural Resources			
Presence of archaeological resources on public land	Section 106 of the National Historic Preservation Act requires Federal agencies to take into account the effects of their undertakings on historic properties and afford the Council a reasonable opportunity to comment on such undertakings. It is the statutory obligation of the Federal agency to fulfill the requirements of section 106 and to ensure that an agency official with jurisdiction over an undertaking takes legal and financial responsibility for section 106 compliance in accordance with subpart B of this part.	Action that would impact any resource discovered during remedial activities – **applicable**	36 CFR 800.1 36 CFR 800.2(a) 43 CFR 7.4(a)
Presence of archaeological or historic resources	A survey of affected areas for resources and data must be conducted and steps taken to recover, protect, and preserve data or request DOI do so. The state archaeologist and secretary of interior must be advised of the presence of the data.	Action involving alteration of terrain that might cause irreparable loss or destruction of any discovered significant scientific, prehistoric, historic, or archaeological resources – **applicable**	36 CFR 800.4(b) 43 CFR 10.3(c)

Table E-2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
Presence of archaeological resources	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**	43 CFR 7.4(a)
Presence of human remains, funerary objects, sacred objects, or objects of cultural patrimony for Native Americans	If an inadvertent discovery is made in connection with an on-going activity, activity must stop in the area of the discovery and reasonable effort be made to secure and protect the objects discovered. Disposition of all inadvertently discovered items must be carried out in prescribed procedures.	Objects that are in federal possession or control or that are excavated intentionally or discovered inadvertently on federal lands or under federal control – **applicable**	43 CFR 10.4(c)
	Must consult with Indian tribe likely to be affiliated with the objects to determine further disposition.		43 CFR 10.4(d)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation(s)
General Construction Standards–Site Preparation, Excavation Activities, etc.			
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., demolition of existing buildings or structures, construction operations, grading of roads, or clearing of land) – **applicable**	TDEC 1200-03-08-.01(1)
	• Use, where possible, of water or chemicals for control of dust from construction operation, grading of roads, or the clearing of land; and		TDEC 1200-03-08-.01(1)(a)
	• Application of asphalt, oil, water, or suitable chemicals on dirt roads, materials stockpiles, and other surfaces that can create airborne dusts.		TDEC 1200-03-08-.01(1)(b)
	Shall not cause or allow fugitive dust to be emitted in such a manner as to exceed 5 min/h or 20 min/d beyond property boundary lines on which emission originates.		TDEC 1200-03-08-.01(2)
Activities causing radionuclide emissions	Exposures to the public from all radiation sources released into atmosphere from DOE facility shall not cause EDE > 10 mrem (0.1 mSv) per year.	Radionuclide emissions from point sources, as well as diffuse or fugitive emissions, at a DOE facility – **applicable**	40 CFR 61.92; TDEC 1200-3-11-.08(6)
Activities causing storm water runoff	Implement good construction management techniques (including sediment and erosion controls, vegetative controls, and structural controls) in accordance with the substantive requirements of *General Permit No. TNR10-0000, Appendix F* to ensure water discharge:	Storm water runoff discharges from land disturbed by construction activity– disturbance of $\geq$1 acre total **– relevant and appropriate**	TCA 69-3-108(l) TDEC 1200-4-10-.03(2)(a)
	• Does not violate water quality criteria as stated in TDEC 1200-4-3, including but not limited to prevention of discharges that cause a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of water of the state for any of the uses designated for that water body by TDEC 1200-4-4; and		*Tennessee General Permit No. TNR100000* Section 4.3.2(a)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• Does not violate other conditions detailed in *General Permit No. TNR10-0000.*		
	• Does not contain distinctly visible floating scum, oil, or other matter.		*Tennessee General Permit No. TNR100000* Section 4.3.2(b)
	• Does not cause an objectionable color contrast in the receiving stream.		*Tennessee General Permit No. TNR100000* Section 4.3.2(c)
	• Muddy water to be pumped from excavation and work areas must be held in settling basins or filtered or chemically treated prior to its discharge into surface waters. Water must be discharged through a pipe, well-grassed or lined channel or other equivalent means so that the discharge does not cause erosion and sedimentation.		*Tennessee General Permit No. TNR100000* Section 3.5.3.3
	• Shall develop and maintain a site-specific storm water pollution prevention plan (SWPPP) or equivalent document which includes a description of all potential sources of pollution, describe practices to be used to reduce pollutants in storm water discharges and assure compliance with substantive requirements of General Permit No. TNR10-0000.		*Tennessee General Permit No. TNR100000* Section 1.4.2 Tennessee Erosion and Sediment Control Handbook (guidance)
	• 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.		*Tennessee General Permit No. TNR100000* Section 4.3.2(d)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The following conditions apply to all land disturbance work:		
	• Sediment should be removed from sediment traps, silt fences, sedimentation ponds, and other sediment controls as necessary, and must be removed when design capacity has been reduced by 50%.		*Tennessee General Permit No. TNR100000* Section 3.5.3.1(e)
	• Clearing and grubbing must be held to the minimum necessary for grading and equipment operation.		*Tennessee General Permit No. TNR100000* Section 3.5.3.1(i)
	• Construction must be sequenced to minimize the exposure time of graded or denuded areas.		*Tennessee General Permit No. TNR100000* Section 3.5.3.1(j)
	• Construction must be phased for projects in which over 50 acres of soil will be disturbed. Areas of the completed phase must be stabilized within 15 days (in accordance with Section 3.5.3.2 *Tennessee General Permit No. TNR10-0000*). No more than 50 acres of active soil disturbance is allowed at any time during the construction project.		*Tennessee General Permit No. TNR100000* Section 3.5.3.1(k)
	• Erosion prevention and sediment control measures must be in place and functional before earth moving operations begin, and must be constructed and maintained throughout the construction period.		*Tennessee General Permit No. TNR100000* Section 3.5.3.1(l)
	• Pre-construction vegetative ground cover shall not be destroyed, removed or disturbed more than 10 days prior to grading or earth moving unless the area is seeded and/or mulched or other temporary cover is installed.		*Tennessee General Permit No. TNR100000* Section 3.5.3.1(h)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• Permanent stabilization with perennial vegetation (using native herbaceous and woody plants where practicable) or other permanently stable, non eroding surface shall replace any temporary measures as soon as practicable.		*Tennessee General Permit No. TNR100000* Section 3.5.3.2
	• Runoff from any undisturbed acreage should be diverted around the disturbed area and the sediment basin.		*Tennessee General Permit No. TNR100000* Section 3.5.3.3
	• Erosion prevention and sediment control measures shall be designed according to the size and slope of disturbed drainage areas with the goal of detaining runoff and trapping sediment.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.3
	• Discharges from sediment basins and traps must be through a pipe, well-grassed or lined channel or other equivalent means so that the discharge does not cause erosion and sedimentation.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.3
Waste Management			
Characterization of solid waste (all primary and secondary wastes)	Must determine if that waste is hazardous waste or if waste is excluded under 40 *CFR* 261.4(b); and Must determine if waste is listed under 40 *CFR* Part 261, or Must characterize waste by using prescribed testing methods or applying generator knowledge based on information regarding material or processes used. If waste is determined to be hazardous, it must be managed in accordance with pertinent provisions of 40 *CFR* 261-268.	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(l)(b)(l) 40 CFR 262.11(b) TDEC 0400-12-01-.03(1)(b)(2) 40 CFR 262.11(c) and (d) TDEC 0400-12-11- .03(l)(b)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Title 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous – **applicable**	40 CFR 262.11(d); TDEC 0400-12-01-.03(1)(b)(4)
Characterization of hazardous waste (all primary and secondary wastes)	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 pertinent sections of 40 *CFR* 264 to 268.	Generation of RCRA hazardous waste (including RCRA characteristic hazardous waste that is not D001 non-wastewater treated by CMBST, RORGS, or POLYM of Section 268.42, Table 1) for storage, treatment or disposal – **applicable**	40 *CFR* 264.13(a)(1) TDEC 0400-12-01-.06(2)(d)(1)
	Must determine the underlying hazardous constituents (as defined in 40 *CFR* 268.2[i]) in the waste.		40 *CFR* 268.9(a); TDEC 0400-12-01-.10(1)(i)(1)
	Must determine if the waste is restricted from land disposal under 40 *CFR* 268 et seq. by testing in accordance with prescribed methods or use of generator knowledge of waste.		40 *CFR* 268.7 TDEC 0400-12-01-.10(1)(g)(1)(i)
	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)
Characterization of LLW (e.g., contaminated PPE, equipment, wastewater)	Shall be characterized using direct or indirect methods and the characterization documented in sufficient detail to ensure safe management and compliance with the WAC of the receiving facility.	Generation of LLW for storage or disposal at a DOE facility – **TBC**	DOE M 435.1-1 (IV)(I)
	Characterization data shall, at a minimum, include the following information relevant to the management of the waste:		DOE M 435.1-1(IV)(I)(2)
	• Physical and chemical characteristics;		DOE M 435.1-1(IV)(I)(2)(a)
	• Volume, including the waste and any stabilization or absorbent media;		DOE M 435.1-1(IV)(I)(2)(b)
	• Weight of the container and contents;		DOE M 435.1-1(IV)(I)(2)(c)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• Identities, activities, and concentrations of major radionuclides; • Characterization date; • Generating source; and Other information that might be needed to prepare and maintain the disposal facility performance assessment or demonstrate compliance with performance objectives		DOE M 435.1-1(IV)(I)(2)(d) DOE M 435.1-1(IV)(I)(2)(e) DOE M 435.1-1(IV)(I)(2)(f) DOE M 435.1-1(IV)(I)(2)(g)
Temporary storage of hazardous waste in containers (e.g., PPE, rags, etc.)	A generator may accumulate hazardous waste at the facility provided that: • Waste is placed in containers that comply with 40 *CFR* 265.171-173 (Subpart 1); and • The date upon which accumulation begins is clearly marked and visible for inspection on each container; • Container is marked with the words "hazardous waste," and	Accumulation of RCRA hazardous waste on site as defined in 40 *CFR* 260.10 – **applicable**	40 CFR 262.34(a)(1)(i) TDEC 0400-12-01-.03(4)(e)(2)(i)(I) 40 CFR 262.34(a)(2) TDEC 0400-12-01-.03(4)(e)(2)(ii) 40 CFR 262.34(a)(3) TDEC 0400-12-01-.03(4)(e)(2)(iv)
	• Container may be marked with other words that identify the contents.	Accumulation of 55 gal or less the contents of RCRA hazardous waste at or near any point of generation – **applicable**	40 CFR 262.34(c)(1) TDEC 0400-12-01-.03(4)(e)(5)
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 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 TDEC 0400-12-01-.05(9)(c)
	Keep containers closed during storage, except to add/remove waste;		40 CFR 264.173(a) TDEC 0400-12-01-.05(9)(d)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Open, handle and store containers in a manner that will not cause containers to rupture or leak.		40 CFR 264.173(b) TDEC 0400-12-01-.05(9)(d)(2)
Design and operation of a RCRA container storage area	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or 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) TDEC 0400-12-01-.06(9)(f)(3)
	Area must have a containment system designed and operated as follows:	Storage of RCRA hazardous waste with free liquids or F020, F02l, F022, F023, F026 and F027 in containers – **applicable**	40 CFR 264.175(a); TDEC 0400-12-01-.06(9)(f)
	• 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;		40 CFR 264.175(b)(1) TDEC 0400-12-01-.06(9)(f)(2)(i)
	• 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;		40 CFR 264.175(b)(2) TDEC 0400-12-01-.06(9)(f)(2)(ii)
	• Bust have sufficient capacity to contain 10% of the volume of containers or the volume of the largest container, whichever is greater;		40 CFR 264.175(b)(3) TDEC 0400-12-01-.06(9)(f)(2)(iii)
	• Run-on into the system must be prevented unless the collection system has sufficient capacity to contain along with volume required for containers; and		40 CFR 264.175(b)(4) TDEC 0400-12-01-.06(9)(f)(2)(iv)
	• 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.		40 CFR 264.17(5)(b)(5) TDEC 0400-12-01-.06(9)(f)(2)(v)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Temporary storage of LLW (e.g., contaminated PPE, scrap metal, soil)	Ensure that radioactive waste is stored in a manner that protects the public, workers, and the environment and that the integrity of waste storage is maintained for the expected time of storage.	Management of LLW at a DOE Facility – **TBC**	DOE M 435.1-1 (IV)(N)(1)
	LLW shall not be readily capable of detonation, explosive decomposition, reaction at anticipated pressures and temperatures, or explosive reaction with water.		DOE M 435.1-1 (IV)(N)(1)
	LLW shall be stored in a location and manner that protects the integrity of waste for the expected time of storage.	Management of LLW at a DOE Facility – **TBC**	DOE M 435.1-1 (IV)(N)(3)
	LLW shall be managed to identify and segregate LLW from mixed waste.		DOE M 435.1-1 (IV)(N)(6)
	LLW shall be packaged in a manner that provides containment and protection for the duration of the anticipated storage period and until disposal is achieved or until the waste has been removed from the container.	Storage of LLW in containers at a DOE facility – **TBC**	DOE M 435.1-1 (IV)(L)(1)(a)
	Vents or other measures shall be provided if the potential exists for pressurizing or generating flammable or explosive concentrations of gases within the waste container.		DOE M 435.1-1 (IV)(L)(1)(b)
	Containers shall be marked such that their contents can be identified.		DOE M 435.1-1 (IV)(L)(1)(c)
Temporary storage of PCB waste (e.g., PPE, rags) in a container(s)	Container(s) shall be marked as illustrated in 40 *CFR* 761.45(a).	Storage of PCBs and PCB Items at concentrations ≥50 ppm for disposal – **applicable**	40 CFR 761.40(a)(1)
	Storage area must be properly marked as required by 40 *CFR* 761.40(a)(10).		40 CFR 761.65(c)(3)
	Any leaking PCB Items and their contents shall be transferred immediately to a properly marked non-leaking container(s).		40 CFR 761.65(c)(5)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Container(s) shall be in accordance with requirements set forth in DOT HMR at 49 *CFR* 171-180.		40 CFR 761.65(c)(6)
Storage of PCB waste and/or PCB/radioactive waste in a RCRA-regulated container storage area	PCB storage does not have to meet storage unit requirements in 40 *CFR* 761.65(b)(1) provided that the unit: • Is permitted by EPA under RCRA §3004, or	Storage of PCBs and PCB items designated for disposal – **applicable**	40 CFR 761.65(b)(2)(i)
	• Qualifies for interim status under RCRA §3005; or		40 CFR 761.65(b)(2)(ii)
	• Is permitted by an authorized state under RCRA §3006 and,		40 CFR 761.65(b)(2)(iii)
	• PCB spills cleaned up in accordance with subpart G of 40 *CFR* 761		40 CFR 761.65(c)(1)(iv)
Storage of PCB/radioactive waste in containers	For liquid wastes, containers must be non-leaking	Storage of PCB/radioactive waste in containers other than those meeting Department of Transportation Hazardous Materials Regulations performance standards - **applicable**	40 CFR 761.65(c)(6)(i)(A)
	For non-liquid wastes, containers must be designed to prevent buildup of liquids if such containers are stored in a area meeting the containment requirements of 40 CFR 761.65(b)(1)(ii); and		40 CFR 761.65(c)(6)(i)(B)
	For both liquid and non-liquid wastes, containers must meet all regulations and requirements pertaining to nuclear criticality safety.		40 CFR 761.65(c)(6)(i)(C)
Management of PCB waste (e.g., contaminated PPE, scrap metal, soil, debris, 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 PCBs are found.	Generation of PCB remediation waste as defined in 40 *CFR* 761.3 – **applicable**	40 CFR 761.61

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Management of PCB/radioactive waste (e.g., contaminated PPE, scrap metal, soil, debris)	Any person storing such waste must do so taking into account both its PCB concentration and radioactive properties, except as provided in 40 *CFR* 761.65(a)(1), (b)(1)(ii) and (c)(6)(i).	Generation for disposal of PCB/ radioactive waste with ≥ 50 ppm PCBs – **applicable**	40 CFR 761.50(b)(7)(i)
Management of TSCA PCB wastes	Other wastes that are not compatible with PCBs shall be segregated from the PCBs throughout the handling and disposal process.	Management, storage of PCBs or PCB Items – **applicable**	40 CFR 761.75(b)(8)(i)
Treatment/Disposal			
Packaging of LLW for disposal (e.g., contaminated PPE, scrap metal, debris, rags)	LLW must not be packaged for disposal in cardboard or fiberboard boxes.	Generation of LLW for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(1)
	LLW must be solidified or packaged in sufficient absorbent material to absorb twice the volume of liquid.	Generation of liquid LLW for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(2)
	LLW shall contain as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume.	Generation of solid LLW containing liquid for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(3)
	LLW must not be capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures or of explosive reaction with water.	Generation of LLW for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(4)
	LLW must not contain, or be capable of generating, quantities of toxic gases, vapor, or fumes.		TDEC 0400-20-11-.17(7)(a)(5)
	LLW must not be pyrophoric.		TDEC 0400-20-11-.17(7)(a)(6)
	LLW must have structural stability either by processing the waste or placing the waste in a container or structure that provides stability after disposal.		TDEC 0400-20-11-.17(7)(b)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	LLW must be converted into a form that contains as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1 percent of the volume of the waste when the waste is in a disposal container designed to ensure stability, or 0.5% of the volume of the waste for waste processed to a stable form.	Generation of liquid LLW or LLW containing liquids for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(7)(b)(2)
	Void spaces within the waste and between the waste and its package must be reduced to the extent practicable.	Generation of LLW for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(7)(b)(3)
Treatment of LLW	Treatment to provide more stable waste forms and to improve the long-term performance of a LLW disposal facility shall be implemented as necessary to meet the performance objectives of the disposal facility.	Generation of LLW for disposal at a DOE facility – **TBC**	DOE M 435.1-1(IV)(O)
Treatment of uranium and thorium bearing LLW	Potentially biodegradable uranium and thorium bearing LLW shall be properly conditioned so that the generation and escape of biogenic gases will not cause the emission or dose limits in DOE O 458.1 paragraph 4.h.(1) to be exceeded and that bio-degradation within the facility will not result in premature structural failure.	Placement of potentially biodegradable contaminated wastes in a long-term management facility – **TBC**	DOE O 458.1(4)(h)(1)(d)(3)
Disposal of LLW (e.g., debris, scrap metal, soil)	LLW shall be certified as meeting waste acceptance requirements before it is transferred to the receiving facility.	Generation of LLW for disposal – **TBC**	DOE M 435.1-1(IV)(J)(2)
Exposure to any member of the public from the disposal of LLW	Not cause a total effective dose exceeding 100 mrem (1mSv) in a year, an equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year, or an equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose.		DOE O 435.1 Chap. 4(b)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Exposure from the disposal of LLW	Not cause radon-222 flux rates to exceed 20 pCi (0.7 Bq) m-2 sec-1 averaged over the surface area overlaying waste, including the covering or other confinement structures, wherever radium-226 wastes are accepted for storage or disposal		DOE O 458.1(4)(f)(2)
Disposal of RCRA hazardous waste in a land-based unit	RCRA-restricted waste may be land disposed only if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 *CFR* 268.40 before land disposal.	Land disposal, as defined in 40 *CFR* 268.2, of RCRA restricted waste – **applicable**	40 CFR 268.40(a) TDEC 0400-12-01-.10(3)(a)
	Hazardous waste must be treated in accordance with the alternative treatment standards of 40 *CFR* 268.49(c), or according to the Universal Treatment Standards specified in 40 *CFR* 268.48 applicable to the listed and/or characteristic waste contaminating the soil, prior to land disposal.		40 CFR 268.49(b) TDEC 0400-12-01-.10(3)(j)(2)
	Hazardous waste may be land disposed if it meets the requirements in the table "Alternative Treatment Standards for Hazardous Debris" at 40 *CFR* 268.45 before land disposal or the debris is treated to the waste-specific treatment standard provided in 40 *CFR* 268.40 for the waste contaminating the debris.		40 CFR 268.45(a) TDEC 0400-12-01-.06(10)(3)(f)(1)
	Disposal of hazardous waste is not prohibited if the wastes no longer exhibit a characteristic at the point of land disposal, unless the wastes are subject to a specified method of treatment other than DEACT in 40 *CFR* 268.40 or are D003 reactive cyanide.	Land disposal, as defined in 40 *CFR* 268.2, or restricted RCRA characteristically hazardous waste – **applicable**	40 CFR 268.1(c)(4)(iv) TDEC 0400-12-01-.06(10)(1)(3)(iv)(IV)
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 The resulting waste, mixture or dissolution of material no longer is reactive or ignitable; and	Disposal of ignitable or reactive RCRA waste – **applicable**	40 CFR 264.312(a) TDEC 0400-12-01-.06(14)(m)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	40 *CFR* 264.17(b) is complied with (see below) Ignitable or reactive RCRA waste may be landfilled without meeting 40 *CFR* 264.312(a), provided wastes are disposed of in such a way that they are protected from any materials or conditions which may cause them to ignite; Must be disposed of in non-leaking containers which are carefully handled and placed so as to avoid heat, sparks, rupture, or any other condition that might cause ignition of the wastes; Must be covered daily with soil or other non-combustible material to minimize the potential of ignition; Must not be disposed of in cells that contain or will contain other wastes which may generate heat sufficient to cause ignition of the waste.	Disposal of ignitable or reactive RCRA waste (except for prohibited wastes which remain subject to treatment standards in 40 *CFR* 268.40 *et seq.*) – **applicable**	40 CFR 264.312(b) TDEC 0400-12-01-.06(14)(m)(2)
	Incompatible wastes must not be placed into a RCRA landfill cell unless 40 *CFR* 264.17(b) is compiled with (see below).	Disposal of incompatible wastes in a RCRA landfill – **applicable**	40 CFR 264.313 TDEC 0400-12-01-.06(14)(n)
Treatment and Disposal of ignitable, reactive, or incompatible RCRA wastes	Must take precautions to prevent reactions which: • Generate extreme heat, pressure, fire or explosion, or produce uncontrolled fumes or gases which pose a risk of fire or explosion; • Produce uncontrolled toxic fumes or gases which threaten human health or the environment; • Damage the structural integrity of the device or facility.	Operation of a RCRA facility that treats, stores, or disposes of ignitable, reactive, or incompatible wastes – **applicable**	40 CFR 264.17(b) TDEC 0400-12-01-.06(2)(h)(2)
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(b) TDEC 0400-12-01-.06(14)(o)(4)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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. Sorbents used to treat free liquids to be disposed of in landfills must be non-biodegradable as described in 264.315(e)(1). 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.	Placement of containers containing RCRA hazardous waste in a landfill – **applicable**	40 CFR 264.314(d) TDEC 0400-12-01-.06(14)(o)(4) 40 CFR 264.314(e) TDEC 0400-12-01-.06(14)(o)(5) 40 CFR 264.315 TDEC 0400-12-01-.06(14)(p)
Disposal of PCB/radioactive waste	Any person disposing of such waste must do so taking into account both its PCB concentration and its radioactive properties. If, after taking into account only the PCB properties in the waste, it meets requirements for disposal in a facility permitted, licensed, or registered by a state as a municipal or non-municipal nonhazardous waste landfill, the person may dispose of such waste without regard to the PCBs, based on its radioactive properties alone, in accordance with applicable requirements.	Disposal of PCB/ radioactive waste (e.g., contaminated PPE, scrap metal, soil, debris) with ≥ 50 ppm PCBs – **applicable**	40 CFR 761.50(b)(7)(ii)
Disposal of bulk PCB remediation waste	Bulk PCB remediation waste shall be disposed of: • In a hazardous waste landfill permitted by EPA under §3004 of RCRA, • In a hazardous waste landfill permitted by a State authorized under §3006 of RCRA, or • In a PCB disposal facility approved under 40 *CFR* 761.60.	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 E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Performance-based disposal of PCB remediation waste	May dispose of non-liquid PCB remediation waste by one of the following methods: • In a high-temperature incinerator approved under Section 761.70(b), • By an alternate disposal method approved under Section 761.60(e), • In a chemical waste landfill approved under Section 761.75, • In a facility with a coordinated approval issued under Section 761.77, or • Through decontamination in accordance with Section 761.79.	Disposal of non-liquid PCB remediation waste as defined in 40 *CFR* 761.3 – **applicable**	40 CFR 761.61(b)(2) 40 CFR 761.61(b)(2)(i) 40 *CFR* 761.61(b)(2)(ii)
Disposal of PCB cleanup wastes (PPE, rags, non-liquid cleaning materials)	Non-liquid PCB cleanup waste shall be disposed of either: • In a facility permitted, licensed or registered by a State to manage municipal solid waste under 40 *CFR* 258 or non-municipal, nonhazardous waste subject to 40 *CFR* 257.5 thru 257.30; or • In a RCRA Subtitle C landfill permitted by a State to accept PCB waste, or • In an approved PCB disposal facility, or • Through decontamination under 40 *CFR* 761.79(b) or (c).	Generation of non-liquid PCBs at any concentration during and from the cleanup of PCB remediation waste – **applicable**	40 CFR 761.6 1(a)(5)(v)(A)
Disposal of PCB cleaning solvents abrasives, and equipment	PCB cleaning solvents abrasives and equipment may be reused after decontamination in accordance with 40 *CFR* 761.79.	Generation of PCB wastes from the cleanup of PCB remediation waste – **applicable**	40 CFR 761.6 1(a)(5)(v)(B)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Disposal of PCB bulk product waste *(e.g., debris or scrap metal with PCB painted surfaces)*	May dispose of PCB bulk product waste by one of the following methods:	Disposal of PCB bulk product waste as defined in 40 *CFR* 761.3 – **applicable**	40 CFR 761.62(a)
	• In an incinerator approved under Section 761.70;		40 CFR 761.62(a)(1)
	• In a chemical waste landfill approved under Section 761.75;		40 CFR 761.62(a)(2)
	• In a hazardous waste landfill permitted by EPA under 3004 of RCRA or by authorized state under 3006 of RCRA;		40 CFR 761.62(a)(3)
	• Under alternate disposal approved under section 761.60(e);		40 CFR 761.62(a)(4)
	• In accordance with decontamination provisions of 761.79;		40 CFR 761.62(a)(5)
	• In accordance with thermal decontamination provisions of 761.79(e)(6) for metal surfaces in contact with PCBs.		40 CFR 761.62(a)(6)
Disposal of TSCA PCB wastes	PCBs and PCB items shall be placed in a manner that will prevent damage to containers or articles. Other wastes that are not compatible with PCBs shall be segregated from the PCBs throughout the handling and disposal process.	Disposal of PCBs or PCB Items in chemical waste landfill – **applicable**	40 CFR 761.75(b)(8)(i)
Disposal of PCB liquids (*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.	Disposal of PCB container with liquid PCB between 50 ppm and 500 ppm – **applicable**	40 CFR 761.75(b)(8)(ii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	May be disposed of if container is surrounded by an amount of inert sorbent material capable of absorbing all of the liquid contents of the container.		
Disposal Site Suitability Requirements			
Siting of a RCRA landfill	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 can demonstrated that procedures are in effect which will cause the waste to be removed safely, before flood waters can reach the facility. 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(b)(1) TDEC 0400-12-01-.06(2)(i) 40 CFR 264.18(a)(1)
	Underlying the liners shall be a geologic buffer which shall have: • A maximum hydraulic conductivity of 1.0 x 10-5 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 • Have a maximum hydraulic conductivity of 1.0 x 10^{-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 • Other equivalent or superior protection as defined in subpart (ii) of this part.	Construction of a solid waste landfill – **relevant and appropriate**	0400-11-01-.04(a)(2)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Siting of a TSCA landfill	The bottom of the landfill shall be above the historical high groundwater table as provided below. Floodplains, shorelands, and groundwater 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** **Waiver Requested**	40 CFR 761.75(b)(3)
	There shall be no hydraulic connection between the site and standing or flowing surface water	Construction of a TSCA chemical waste landfill – **applicable**	
	Floodplains, shore lands and groundwater recharge areas shall be avoided.		
	A TSCA landfill shall provide diversion structures capable of diverting all surface water runoff from a 24-hr, 25-year storm.	Construction of a TSCA chemical waste landfill (above the 100-year floodwater elevation) – **applicable**	40 CFR 761.75(b)(4)(ii)
	The landfill site shall be located in an area of low to moderate relief to minimize erosion and to help prevent landslides or slumping.	Construction of a TSCA chemical waste landfill – **applicable**	40 CFR 761.75(b)(5)
Siting of a LLW disposal facility	LLW disposal sites shall be capable of being characterized, modeled, analyzed, and monitored.	Land disposal of LLW – **relevant and appropriate**	TDEC 0400-20-11-.17(1)(b)
	LLW disposal sites should be selected so that projected population growth and future developments are not likely to affect the ability of the disposal facility to meet performance objectives.		TDEC 0400-20-11-.17(1)(c)
	Areas must be avoided having known natural resources which, if exploited, would result in failure of the cell to meet performance objectives.		TDEC 0400-20-11-.17(1)(d)
	Disposal site must be generally well drained and free of areas of flooding and frequent ponding.		TDEC 0400-20-11-.17(1)(e)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Waste disposal shall not take place in a 100-year floodplain or wetland.		
	Upstream drainage areas must be minimized to decrease the amount of runoff which could erode or inundate the disposal unit.		TDEC 0400-20-11-.17(1)(f)
	The disposal site must provide sufficient depth to the water table that groundwater intrusion, perennial or otherwise, into the waste will not occur.		TDEC 0400-20-11-.17(1)(g)
Siting of a LLW disposal facility	If it can be conclusively shown that disposal site characteristics will result in molecular diffusion being the predominant means of radionuclide movement and the rate of movement will result in the performance objectives of Rules of the TDEC 1200-2-11-.16 being met, wastes may disposed of below the water table. In no case will waste disposal be permitted in the zone of fluctuation of the water table.	Land disposal of LLW – **relevant and appropriate**	TDEC 0400-20-11-.17(1)(g)
	The hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site.	Waiver is requested	TDEC 0400-20-11-.17(1)(h)
	Areas must be avoided where tectonic processes such as faulting, folding, seismic activity may occur with such frequency to affect the ability of the site to meet the performance objectives.		TDEC 0400-20-11.17(1)(i)
	Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landslides, or weathering may occur with such frequency and extent to affect the ability of the disposal site to meet performance objectives or preclude defensible modeling and prediction of long-term impacts.		TDEC 0400-20-11-.17(1)(j)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The disposal site must not be located where nearby activities or facilities could impact the site's ability to meet performance objectives or mask environmental monitoring.		TDEC 0400-20-11-.17(1)(k)
	A preoperational monitoring program must be conducted to provide basic environmental data on the disposal site characteristics.		TDEC 0400-20-11-.17(4)(a)
Wastewater Discharge			
Operation of RCRA an above-grade 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) TDEC 0400-12-01-.10(e)(1)
	Must use appropriate controls and practices to prevent spills an overflows from the tank or containment system. These include at a minimum:		40 CFR 264.194(b) TDEC 0400-12-01-.10(e)(2)
	• Spill prevention controls (e.g., check valves, dry disconnect couplings);		40 CFR 264.194(b)(1) TDEC 0400-12-01-.10(e)(2)(i)
	• Maintenance of sufficient freeboard in uncovered tanks to prevent overtopping by wave or wind action or by precipitation.		40 CFR 264.194(b)(3) TDEC 0400-12-01-.10(e)(2)(iii)
	Must comply with the requirements of 40 CFR 264.196 if a leak or a spill occurs in the tank system.		40 CFR 264.194(c) TDEC 0400-12-01-.10(e)(3)
Inspection of RCRA above-grade tank system	Must develop and follow a schedule for inspecting overfill controls.	Storage of RCRA hazardous waste in a new tank system — **relevant and appropriate**	40 CFR 264.195(a) TDEC 0400-12-01-10(f)(1)
	Must inspect at least once each operating day: • Aboveground portions of the tank system, if any, to detect corrosion or releases of waste;		40 CFR 264.195(b)(1) TDEC 0400-12-01-10(f)(2)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Inspection of RCRA above-grade tank system	• Data gathered from monitoring and leak detection equipment (e.g., pressure or temperature gauges monitoring wells) to ensure that the tank system is being operated according to its design; and		40 CFR 264.195(b)(2) TDEC 0400-12-01-10(f)(2)(ii)
	• The construction materials and the area immediately surrounding the externally accessible portion of the tank system, including the secondary containment system (e.g., dikes) to detect erosion or signs of releases of hazardous waste (e.g. wet spots, dead vegetation).		40 CFR 264.195(b)(3) TDEC 0400-12-01-10(f)(2)(iii)
	Must not be placed in tank system unless: • Waste is treated, rendered, or mixed before or immediately after placement in the tank system so that the resulting waste, mixture or dissolved material is no longer ignitable or reactive and 40 CFR 264.17(b) is complied with; or	Storage of RCRA ignitable or reactive hazardous waste in a new tank system — **applicable**	40 CFR 264.198(a)(1) TDEC 0400-12-01-.10(i)(1)(i)
	• Waste is stored or treated in such a way that it is protected from any material or conditions that may cause the waste to ignite or react; or		40 CFR 264.198(a)(2) TDEC 0400-12-01-.10(i)(1)(ii)
	• The tank system is used solely for emergencies.		40 CFR 264.198(a)(3) TDEC 0400-12-01-.10(i)(1)(iii)
	Must not be placed in the same tank system, unless 40 CFR 264.17(b) is complied with.	Storage of incompatible RCRA hazardous waste in a new tank system **— applicable**	40 CFR 264.199(a) TDEC 0400-12-01-.10(j)(1)
	Hazardous waste must not be placed in a tank system that has not been decontaminated and that previously held an incompatible waste or material unless 40 CFR 264.17(b) is complied with.		40 CFR 264.199(b) TDEC 0400-12-01-.10(j)(2)
Control of emissions from an above-grade RCRA tank system	Shall manage all hazardous waste placed in a tank in accordance with the applicable air emission requirements of subparts AA, BB, CC of 40 CFR Part 264.	Storage of RCRA hazardous waste in a new tank system — **relevant and appropriate**	40 CFR 264.200 TDEC 0400-12-01-.10(k)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	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 the result of implementing remedial activities required under CERCLA authorities.		40 CFR 264.1080(b)(5) TDEC 0400-12-01-.32(a)(2)(v)
Run-on, Run-off, and Erosion Control at Disposal Facilities	The operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the active portion of the facility for all flow up to and including peak discharge from a 24-hour, 25-year storm. The operator must design, construct, operate, and maintain a run-off management system to collect and control at least the peak flow volume resulting from a 24-hour, 25-year storm. Holding facilities (e.g., sediment basins) associated with run-on and run-off control systems must be designed to detain at least the water volume resulting from a 24 hour, 25 year storm and to divert through emergency spillways at least the peak flow resulting from a 24-hour, 100-year storm. Collection and holding facilities associated with run-on and run-off control systems must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system. Run-on and run-off must be managed separately from leachate unless otherwise approved by the Commissioner. The operator must take other erosion control measures (e.g., temporary mulching or seeding, silt barriers) as necessary to control erosion of the site.	Operation of surface impoundments – **relevant and appropriate**	TDEC 0400-11-01-.04(2)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Transport to wastewater treatment facility	All tank systems, conveyance systems, and ancillary equipment used to store or transport waste to an on-site NPDES-permitted wastewater treatment facility are exempt from the requirements of RCRA Subtitle C standards.	On-site wastewater treatment units that are subject to regulation under Section 402 or Section 307(b) of CWA (NPDES-permitted) – **applicable**	40 CFR 270.1(c)(2)(v); TDEC 0400-12-01-.07(1)(b)(4)(iv)
Discharge of contaminated storm water	Shall receive the degree of treatment or effluent reduction necessary to comply with water quality standards and, where appropriate, will comply with the "Standard of performance" as required by TN Water Quality Control Act of 1977 at TSCA 69-3-103(30).	Point Source discharge(s) of pollutants into surface water – **applicable**	TDEC 1200-04-03-.05(6)
Discharge of liquid wastes containing radioactive materials	Absorbed dose to native animal aquatic organism must not exceed 1 rad/day Operators of DOE facilities discharging or releasing liquids containing radionuclides from DOE activities must: • Characterize planned and unplanned releases of liquids containing radionuclides from DOE activities, consistent with the potential for on and off-site impacts, and provide an assessment of radiological consequences as necessary to demonstrate compliance with the requirements of this Order. • Conduct activities to ensure that liquid releases containing radionuclides from DOE activities are managed in a manner that protects ground water resources now and in the future, based on use and value considerations. • Conduct activities to ensure that liquid discharges containing radionuclides from DOE activities do not exceed an annual average (at the point of discharge) of either of the following:	Discharge of radioactive materials in liquid waste to surface water at a DOE facility – **TBC**	DOE Order 458.1(4)(g)(1) O 458.1(4)(g)(3) O 458.1(4)(g)(4) O 458.1(4)(g)(11)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	(a) 5 pCi (0.2 Bq) per gram above background of settleable solids for alpha-emitting radionuclides. (b) 50 pCi (2 Bq) per gram above background of settleable solids for beta-gamma-emitting radionuclides. Ensure that storm water runoff containing radionuclides from DOE activities is considered, as appropriate, as a pathway of exposure that has the potential for on- and off-site impacts. Using a graded approach, the receiving ecosystem including, but not limited to, wetlands, floodplains, streams, ponds, basins and lakes must be monitored to evaluate human or ecological impacts when warranted based on site specific risk.		
	Radiological activities that have the potential to impact the environment must be conducted in a manner that protects populations of aquatic animals, terrestrial plants, and terrestrial animals in local ecosystems from adverse effects due to radiation and radioactive material released from DOE operations.	Discharge of radioactive materials in liquid waste to surface water at a DOE facility – **TBC**	DOE Order 458.1(4)(j)(1)
In-stream general water quality criteria – recreational use	There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive odors	Discharge to surface water – **applicable, waiver requested**	TDEC 1200-04-03-.03(4)(a)
	The pH value shall lie within the range of 6.0 to 9.0 and not fluctuate more than 1.0 unit over a period of 24 hours		TDEC 1200-04-03-.03(4)(b)
	There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to fish and aquatic life.		TDEC 1200-04-03-.03(4)(c)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	There shall be no suspended solids, turbidity, or color in such amounts or of such character that will result in any objectionable appearance of the water, considering the nature and location of the water.		TDEC 1200-04-03-.03(4)(d)
	The maximum water temperature shall not exceed 3 degrees C relative to an upstream control point. The temperature of the water shall not exceed 30.5 degrees C and the maximum rate of change shall be 2 degrees C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.		TDEC 1200-04-03-.03(4)(e)
	The concentration of the E. coli group shall not exceed 126 colony forming units per 100 ml, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml.		TDEC 1200-04-03-.03(4)(f)
	The waters shall not contain substances that will result in objectionable taste or odor		TDEC 1200-04-03-.03(4)(g)
	The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that the public's recreational uses of the waterbody or other downstream waters are detrimentally affected. Unless demonstrated otherwise, the nutrient criteria found in 1200-04-03-.03(3)(k) will be considered adequately protective of this use.		TDEC 1200-04-03-.03(4)(h)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The waters shall not contain toxic substances, whether alone or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish, or will propose toxic conditions that will adversely affect man, animal, aquatic life, or wildlife. Human health criteria have been derived to protect the consumer from consumption of contaminated fish and water. The water and organisms criteria should only be applied to those waters classified for both recreation and domestic water supply. The criteria for recreation are as follows:		TDEC 1200-04-03-.03(4)(j)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements			Prerequisite	Citation(s)
In-Stream general water quality criteria – recreational use	**Compound**	**Water & Organisms Criteria* (ug/L)**	**Organisms Only Criteria (ug/L)**		
	INORGANICS				
	Antimony	5.6	640		
	Arsenic (c)	10.0	10.0		
	Mercury	0.05	0.051		
	Nickel	610	4600		
	Thallium	0.24	0.47		
	Cyanide	140	140		
	Dioxin**	0.000001	0.000001		
	VOLATILES				
	Acrolein	190	290		
	Acrylonitrile (c)	0.51	2.5		
	Benzene (c)	22	510		
	Bromoform (c)	43	1400		
	Carbon tetrachloride (c)	2.3	16		
	Chlorobenzene	130	1600		
	Chlorodibromomethane (c)	4	130		
	Chloroform (c)	57	4700		
	Dichlorobromomethane (c)	5.5	170		
	1,2-Dichloroethane (c)	3.8	370		
	1,1-Dichloroethylene	330	7100		
	1,2-Dichloropropane (c)	5	150		
	1,3-Dichloropropene (c)	3.4	210		
	Ethylbenzene	530	2100		
	Methyl bromide	47	1500		
	Methylene chloride (c)	46	5900		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements		Prerequisite	Citation(s)
	1,1,2,2-Tetrachloroethane (c)	1.7	40	
	Tetrachloroethylene (c)	6.9	33	
	Toluene	1300	15000	
	1,2-Trans-Dichloroethylene	140	10000	
	1,1,2-Trichloroethane (c)	5.9	160	
	Trichloroethylene (c)	25	300	
	Vinyl chloride (c)	0.25	24	
	2-Chlorophenol	81	150	
	2,4-Dichlorophenol	77	290	
	2,4-Dimethylphenol	380	850	
	2-Methyl-4,6-dinitrophenol	13	280	
	2,4-Dinitrophenol	69	5300	
	Pentachlorophenol (c) (pH)	2.7	30	
	Phenol	21000	1700000	
	2,4,6-Trichlorophenol (c)	14	24	
	BASE NEUTRALS			
	Acenaphthene	670	990	
	Anthracene	8300	40000	
	Benzidine (c)	0.00086	0.002	
	Benzo(a)anthracene (c)	0.038	0.18	
	Benzo(a)pyrene (c)	0.038	0.18	
	Benzo(b)fluoranthene (c)	0.038	0.18	
	Benzo(k)fluoranthene (c)	0.038	0.18	
	Bis(2-Chlorethyl)ether (c)	0.3	5.3	
	Bis(2-Chloro-isopropyl)ether	1400	65000	
	Bis(2-Ethylhexyl)phthalate (c)	12	22	
	Butylbenzyl Phthalate	1500	1900	
	2-Chloronaphthalene	1000	1600	
	Chrysene (c)	0.038	0.18	

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements		Prerequisite	Citation(s)
	Dibenz(a,h)Anthracene (c)	0.038	0.18	
	1,2-Dichlorobenzene	420	1300	
	1,3-Dichlorobenzene	320	960	
	1,4-Dichlorobenzene	63	190	
	3,3-Dichlorobenzidine (c)	0.21	0.28	
	Diethyl phthalate	17000	44000	
	Dimethyl phthalate	270000	1100000	
	Di-n-butyl phthalate	2000	4500	
	2,4-Dinitrotoluene (c)	1.1	34	
	1,2-Diphenylhydrazine (c)	0.36	2	
	Fluoranthene	130	140	
	Fluorene	1100	5300	
	Hexachlorobenzene (c)	0.0028	0.0029	
	Hexachlorobutadiene (c)	4.4	180	
	Hexachlorocyclopentadiene	40	1100	
	Hexachloroethane (c)	14	33	
	Ideno(1,2,3-cd)Pyrene (c)	0.038	0.18	
	Isophorone (c)	350	9600	
	Nitrobenzene	17	690	
	N-Nitrosodimethylamine (c)	0.0069	30	
	N-Nitrosodi-n-Propylamine (c)	0.05	5.1	
	N-Nitrosodiphenylamine (c)	33	60	
	Pyrene	830	4000	
	1,2,4-Trichlorobenzene	35	70	
	PESTICIDES			
	Aldrin (c)	0.00049	0.0005	
	a-BHC (c)	0.026	0.049	
	b-BHC (c)	0.091	0.17	
	g-BHC - Lindane	0.98	1.8	

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements		Prerequisite	Citation(s)
	Chlordane (c)	0.008	0.0081	
	4-4'-DDT (c)	0.0022	0.0022	
	4,4'-DDE (c)	0.0022	0.0022	
	4,4'-DDD (c)	0.0031	0.0031	
	Dieldrin (c)	0.00052	0.00054	
	a-Endosulfan	62	89	
	b-Endosulfan	62	89	
	Endosulfan Sulfate	62	89	
	Endrin	0.059	0.06	
	Endrin Aldehyde	0.29	0.3	
	Heptachlor (c)	0.00079	0.00079	
	Heptachlor epoxide (c)	0.00039	0.00039	
	PCB, total (c)	0.00064	0.00064	
	Toxaphene (c)	0.0028	0.0028	
	(c) 10^{-5} risk level is used for all carcinogenic pollutants.			
	* These criteria are for protection of public health due to consumption of water and organisms and should only be applied to these waters designated for both recreation and domestic water supply.			
	** Total dioxin is the sum of the concentrations of all dioxin and dibenzofuran isomers after multiplication by Toxic Equivalent Factors (TEFs). Following are the TEFs currently recommended by EPA (subject to revision):			
	DIOXIN ISOMERS	**TEF**		
	Mono- Di- & TriCDDs	0		
	2,3,7,8-TCDD	1		
	Other TCDDs	0		
	2,3,7,8-PeCDD	0.5		
	Other PeCDDs	0		
	Other PeCDFs	0		
	2,3,7,8-HxCDD	0.1		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Other HxCDDs 0 Other HxCDFs 0 2,3,7,8-HpCDD 0.01 Other HpCDDs 0 OCDD 0.001 **FURAN ISOMERS TEF** Mono- Di- & TriCDFs 0 2,3,7,8-TCDF 0.1 Other TCDFs 0 1,2,3,7,8-PeCDF 0.05 2,3,4,7,8-PeCDF 0.5 Other PeCDFs 0 2,3,7,8-HxCDF 0.1 2,3,7,8-HpCDF 0.01 Other HpCDFs 0 OCDF 0.001		
	The waters shall not contain other pollutants in quantities which may have a detrimental effect on recreation. A public fishing advisory will be considered when the calculated risk of additional cancers exceeds 10^{-4} for typical consumers or 10^{-5} for atypical consumers (See definition). A "do not consume" advisory will be issued for the protection of typical consumers and a "precautionary advisory" will be issued for the protection of atypical consumers. The following formula will be used to calculate the risk of additional cancers : $R = qE$, where: R= Plausible-upper-limit risk of cancer associated with a chemical in a fisheries species for a human subpopulation. q = Carcinogenic Potency Factor for the chemical		TDEC 1200-04-03-.03(4)(k) TDEC 1200-04-03-.03(4)(l)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	(mg kg-1 day-1)-1 estimated as the upper 95 percent confidence limit of the slope of a linear dose-response curve. Scientifically defensible Potency Factors will be used. E = Exposure dose of the chemical (mg kg-1 day-1) from the fish species for the human subpopulation in the area. E is calculated by the following formula: $E = \frac{C\ I\ X}{W}$ where: C = Concentration of the chemical (mg/kg) in the edible portion of the species in the area. The average levels from multiple fillet samples of the same species will be used. Catfish will be analyzed skin-off with the belly flap included in the sample. Game fish and carp will be analyzed skin-on with the belly flap included in the sample. Sizes of fish collected for analysis will represent the ranges of sizes likely to be collected and consumed by the public. References on this subject include, but are not limited to: EPA's Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories. I = Mean daily consumption rate (g/day averaged over 70 year lifetime) of the fish species by the human subpopulation in the area. 6.5 g/day will be used unless better site-specific information is available. X = Relative absorption coefficient, or the ratio of human absorption efficiency to test animal absorption efficiency of the chemical. Assumed to be 1.0 unless better information is available. W = Average human mass (kg). 75 kg will be used. For substances for which the public health concern is based on toxicity, a "do not consume" advisory will be considered warranted when average levels		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	of the substance in the edible portion of fish exceed U.S. Food and Drug Administration (FDA) Action Levels or EPA national criteria. Based on the rationale used by FDA or EPA for their levels, the Commissioner may issue precautionary advisories at levels appropriate to protect sensitive populations.		
Design, Construction, and Operation of a Mixed (RCRA hazardous, TSCA chemical and low-level radioactive) Waste Landfill			
Security System	Operators 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(5)(b) and (c).	Operation of a RCRA landfill – **applicable**	40 CFR 264.14 TDEC 0400-12-01.06(2)(e)
Security System	Unless a natural barrier adequately deters access by the general public, either warning signs and fencing must be installed and maintained or requirements of 40 *CFR* 61.154(c)(1) and (2) must be met.	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)
	Warning signs must be displayed at all entrances and at intervals of 330 ft or less along the property line of the site.		40 CFR 61.154(b)(1)
	The warning signs must:		
	• Be posted in a manner and location that a person can easily ready the legend;		40 CFR 61.154(b)(1)(i)
	• Conform to the requirements of (20 in. × 14 in.) upright format signs in 29 *CFR* 1901.145(d)(4); and		40 CFR 61.154(b)(1)(ii)
	• Display the legend in the lower panel with letter sizes and styles of a visibility at least equal to those specified in 40 *CFR* 61.154(b)(1)(iii).		40 CFR 61.154(b)(1)(iii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The perimeter of the disposal site must be fenced in a manner adequate to deter access by the general public.		40 CFR 61.154(b)(2)
	A 6-ft woven mesh fence, wall or similar device shall be placed around the site to prevent unauthorized access. 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. 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)(i) 40 CFR 761.75(b)(9)(ii) 40 CFR 761.75(b)(9)(iii)
General Inspections	Operators must inspect facility for malfunctions and deterioration, operator errors, and discharges, often enough to identify and correct any problems. 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.	Operation of a RCRA landfill – **applicable**	40 CFR 264.15(a) TDEC 0400-12-01-.06(2)(f)(1) 40 CFR 264.15(c) TDEC 0400-12-01-.06(2)(f)(3)
Personnel training	Operators must ensure personnel are adequately trained in hazardous waste, emergency response, monitoring equipment maintenance, alarm systems procedures, etc.	Operation of a RCRA landfill – **applicable**	40 CFR 264.16 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.	Operation of a RCRA landfill – **applicable**	40 CFR 264.19 TDEC 0400-12-01-.06(2)(j)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Contingency plan	Operators must have 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.	Operation of a RCRA landfill – **applicable**	40 CFR 264.51 TDEC 0400-12-01-.06(4)(b)
	Operators must have at least one emergency coordinator on the facility premises or on call responsible for coordinating emergency response measures in accordance with 40 *CFR* 264.56.		40 CFR 264.55 TDEC 0400-12-01-.06(4)(f)
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; TDEC 0400-12-01-.06(3)
Inventory requirements	The location, dimensions, contents, and location of each cell must be recorded in reference to permanently surveyed benchmarks.	Operation of a RCRA landfill – **applicable**	40 CFR 264.309 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)
Inventory requirements	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 0400-20-11-.17(3)(g)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Surface water monitoring	The groundwater 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)
	Any surface watercourse designated by EPA shall be sampled at least monthly when the landfill is being used for disposal operations, and for a time period specified by the EPA on a frequency of no less than once every six months after final closure of the disposal area.	Operation of a TSCA chemical waste landfill – **applicable**	40 CFR 761.75(b)(6)(i)(B) & (C)
	As a minimum, all samples shall be analyzed for the following parameters: • PCBs • pH • Specific conductance • Chlorinated organics Sampling methods and analytical procedures for these parameters shall comply with those specified in 40 *CFR* Part 136, as amended in 41 Federal Register 52779 on December 1, 1976.		40 *CFR* 761.75 (b)(6)(iii)
Liner and leachate collection system design for a RCRA landfill	The owner must install two or more liners and a leachate collection and removal system above and between such liners.	Construction of a RCRA landfill – **applicable**	40 CFR 264.301(c) TDEC 0400-12-01-.06(14)(b)(3)(i)(I)
	The liner system must include: • 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 postclosure period; and		40 CFR 264.301(c)(1)(i)(A); TDEC 0400-12-01-.06(14)(b)(3)(i)(I)I

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• A composite bottom liner consisting of at least two components: – Upper component must be designed and constructed of materials to prevent migration of hazardous constituents into this component during the active life and postclosure period; and – Lower component designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the upper component were to occur; – Constructed of at least 3 ft of compacted soil material with a hydraulic conductivity of no more than 1×10^{-7} cm/second		40 CFR 264.301(c)(1)(i)(B); TDEC 1200-1-11-.06(14)(3)(i)(I)II
	– Liners must comply with paragraphs (a)(1)(i), (ii), and (iii) of TDEC 0400-12-01-.06(14)(b)(3)(i) (I)III		40 CFR 264.301(c)(1)(ii); TDEC 0400-12-01-.06(14)(b)(3)(i) (I)III
	The liner must be:		40 CFR 264.301(a)(1) TDEC 0400-12-01-.06(14))(b)(1)(i)(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 are exposed, climatic conditions, or stress from installation or daily operation;		40 CFR 264.301(a)(1)(i)
	• 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		40 CFR 264.301(a)(1)(ii) TDEC 0400-12-01-.06(14)(b)(1)(i)(II)
	• Installed to cover all areas likely to be in contact with the waste or leachate		40 CFR 264.301(a)(1)(iii) TDEC 0400-12-01-.06(14)(b)(1)(i) (III)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Top leachate collection and removal system	The top leachate collection and removal system of a RCRA landfill 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; and Leachate collection system must be constructed of materials that are: • Chemically resistant to waste managed in landfill and leachate generated; and • Sufficient strength and thickness to prevent collapse under pressures exerted by overlying wastes, waste cover materials, and by any equipment used.	Construction of a RCRA landfill – **applicable**	40 CFR 264.301(c)(2) TDEC 0400-12-01-.06(14)(b)(1) (ii) 40 CFR 264.301(c)(3); TDEC 0400-12-01-.06(14)(b)(1) (ii)(I) 40 CFR 264.301(c)(3)(iii); TDEC 0400-12-01-.06(14)(b)(1) (ii)(I)I 40 CFR 264.301(c)(2); TDEC 0400-12-01-.06(14)(b)(1) (ii)(I)II
Bottom leachate collection and removal system/leak detection system	Leachate collection and removal system must be capable of detecting, collecting, and removing leachate from all areas of the landfill during active life and the post-closure care period. Requirements for a leak detection system are satisfied by installation of a system that is: • Constructed with a bottom slope of 1% or more; • Constructed of granular drainage materials with a hydraulic conductivity of 1×10^{-2} cm/second and a thickness of 12 in. or more or synthetic or geonet drainage materials with a transmissivity of 3×10^{-5} m^2/sec; • Constructed of materials that are chemically resistant to waste managed and expected leachate to be generated, and structurally sufficient to resist pressures exerted by waste, cover, and equipment used at the landfill;	Construction of a RCRA landfill – **applicable**	40 CFR 264.301(c)(3) TDEC 0400-12-01-.06(14)(b)(3) (iii) 40 CFR 264.301(c)(3)(i) TDEC 0400-12-01-.06(14)(b)(3)(iii)(I) 40 CFR 264.301(c)(3)(ii) TDEC 0400-12-01-.06(14))(b)(3)(iii)(II) 40 CFR 264.301(c)(3)(iii) TDEC 0400-12-01-.06(14)(b)(3) (iii)(III)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• Designed and operated to minimize clogging during the active life of the facility and post-closure care period; and • Constructed with sumps and liquid removal methods (e.g., pumps) adequate to prevent the backup of liquids into the drainage layer and capable of measuring and recording the volume of liquids present in the sump and liquids present in the sump and of liquids removed.		40 CFR 264.301(c)(3)(iv) TDEC 0400-12-01-.06(14)(b)(3) (iii)(IV) 40 CFR 264.301(c)(3)(v) TDEC 0400-12-01-.06(14)(b)(3) (iii)(V)
	Operators must collect and remove liquids in the leak detection system sumps to minimize the head on the bottom liner. If the leak detection system is located below the seasonal high water table, a demonstration must be made that the system will not be adversely affected by groundwater	Operation of a RCRA landfill – **applicable** Construction of a RCRA landfill – **applicable**	40 CFR 264.301 (c)(4) TDEC 0400-12-01-06(14)(b)(3)(iv) 40 CFR 264.301(c)(5) TDEC 0400-12-01-.06(14)(b)(3)(v)
Leak Detection System	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 1 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	Action leakage rate – **applicable**	40 CFR 264.302(a)
Leachate collection monitoring system for TSCA landfill	A leachate collection monitoring system shall be installed above the chemical waste landfill. Acceptable system includes compound leachate collection.	Construction of a TSCA chemical waste landfill – **applicable**	40 CFR 761.75(b)(7)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Compound leachate collection system consists of a gravity flow drain field installed above the waste disposal facility liner and above a secondary installed liner.		40 CFR 761.75 (b)(7)(ii)
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.	Construction of a RCRA landfill – **applicable**	40 CFR 264.301(g) 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-hr, 25-year storm event.		40 CFR 264.301(h) TDEC 0400-12-01-.06(14)(b)(8)
	Collection and holding facilities must be emptied or otherwise expeditiously managed after storm events to maintain design capacity of the system.	Operation of a RCRA landfill – **applicable**	40 CFR 264.301(i) 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.	Operation of a RCRA landfill – **applicable**	40 CFR 264.301(j) TDEC 0400-12-01-.06(14)(b)(10)
	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)
	At the end of each operating day, or at least every 24-hr period while the site is in continuous operation, cover the asbestos containing waste with:		40 CFR 61.154(c)
	• At least 6 in. of compacted non asbestos-containing material, or		40 CFR 61.154(c)(1)
	• A resinous or petroleum based dust suppression agent that effectively binds dust and controls wind erosion in the manner and frequency specified by the manufacturer.		40 CFR 61.154(c)(2)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	RCRA landfill operators must inspect landfill weekly and after storm events to ensure proper functioning of: • Run-on and runoff control systems, • Wind dispersal control systems, and • Leachate collection and removal systems.	Operation of a RCRA landfill – **applicable**	40 CFR 264.303(b)(1)-(3) TDEC 0400-12-01-.06(14)(d)(2)(i)-(iii)
	RCRA landfill operators must record the amount of liquids removed from the leak detection system sumps at least weekly during the active life and closure period.	Operation of a RCRA landfill – **applicable**	40 CFR 264.303(c)(1) TDEC 0400-12-01-.06(14)(d)(3)(ii)
Monitoring and inspection of liners, leak detection, run-on/ run-off systems during the active life of the facility	During construction or installation, liners and cover systems must be inspected for uniformity, damage and imperfections (e.g., holes, cracks, thin spots, etc.).	Construction of a RCRA landfill – **applicable**	40 CFR 264.303(a) TDEC 0400-12-01-.06(14)(d)
Post-construction inspection	Immediately after construction or installations: • synthetic liners and covers must be inspected to ensure; tight seams and joints and the absence of tears, punctures or blisters; • soil based and mixed liners and covers must be inspected for imperfections including lenses, cracks, channels or other structural non-uniformities	Construction of a RCRA landfill – **applicable**	40 CFR 264.303(a)(1) TDEC 0400-12-01-.06(14)(d)(1)(i) 40 CFR 264.303(a)(2) TDEC 0400-12-01-.06(14)(d)(1)(ii)
	RCRA landfill operators must inspect landfill weekly and after storm events to ensure proper functioning of: • Run-on and runoff control systems, • Wind dispersal control systems, and • Leachate collection and removal systems.	Operation of a RCRA landfill – **applicable**	40 CFR 264.303(b); TDEC 0400-12-01-.06(14)(d)(2)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	RCRA landfill operators must record the amount of liquids removed from the leak detection system sumps at least weekly during the active life and closure period.	Operation of a RCRA landfill – **applicable**	40 CFR 264.303(c)(1) TDEC 0400-12-01-.06(14)(d)(3) (ii)
Response actions for leak detection system	RCRA landfill operators 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) TDEC 0400-12-01-.06(14)(e)(1)
	RCRA landfill operators 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) 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 or closure; and		40 CFR 264.304(b)(4) 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) TDEC 0400-12-01-.06(14)(e)(2) (v)
	RCRA landfill operators must assess the source and amounts of the liquids by source;	Leak and/or remediation determinations required – **applicable**	40 CFR 264.304(c)(1) TDEC 0400-12-01-.06(14)(c)(3) (i)
	Conduct analysis of the liquids to identify sources and possible location of the leaks; and	Leak and/or remediation determinations required – **applicable**	40 CFR 264.304(c)(1)(ii) TDEC 0400-12-01-.06(14)(e)(3) (i)(II)
	Assess seriousness of leaks in terms of potential for escaping into the environment; or		40 CFR 264.304(c)(2))(iii) TDEC 0400-12-01-.06(14)(e)(3)(i)(III)
	Document why such assessments are not needed.		40 CFR 264.304(c)(2) TDEC 0400-12-01-.06(14)(e)(3) (ii)
Liner design requirements for a TSCA landfill	TSCA chemical waste landfills 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:	Construction of a TSCA chemical waste landfill – **applicable**	40 CFR 761.75(b)(1)
	• In place soil thickness, 4-ft or compacted soil liner thickness, 3-ft;		40 CFR 761.75(b)(1)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• Permeability (cm sec), equal to or less than 1×10^{-7}; • percent soil passing No. 200 sieve > 30; • Liquid limit, > 30; and • Plasticity Index > 15; or 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. 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.		40 CFR 761.75(b)(1)(ii) 40 CFR 761.75(b)(1)(iii) 40 CFR 761.75(b)(1)(iv) 40 CFR 761.75(b)(1)(v) 40 CFR 761.75(b)(2)
Performance objectives for LLW disposal facility	A land disposal facility must be sited, designed, operated, closed and controlled after closure so that reasonable assurance exists that exposures to humans are within limits established in the performance objectives in 1200-2-11-.16(2) and (5).	Operation and Closure of LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.16(l)
LLW disposal site stability	The disposal facility must be sited, designed, used, operated and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.	Operation and Closure of LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.16(5)
LLW disposal facility design	Land disposal site design features must be directed toward long-term isolation and avoidance of the need for continuing active maintenance after site closure.	Land disposal of LLW – **relevant and appropriate**	TDEC 0400-20-11-.17(2)(a)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The disposal site design and operation must be compatible with the disposal site closure and stabilization plan and lead to disposal site closure that assures compliance with the performance objectives.		TDEC 0400-20-11-.17(2)(b)
	The disposal site design must compliment and improve, where appropriate, the ability of the disposal site's natural characteristics to assure that the performance objectives are met.		TDEC 0400-20-11-.17(2)(c)
	Surface features must direct surface water drainage away from disposal units at velocities and gradients which will not result in erosion that will require on-going active maintenance in the future.	Construction of LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(2)(e)
LLW disposal operations	Wastes must be emplaced in a manner that maintains the package integrity during emplacement, and minimizes the void spaces to be filled.	Operation of LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(3) (d)
	A buffer zone of land must be maintained between the disposal unit and disposal boundary and beneath the disposed waste.		TDEC 0400-20-11-.17(3) (h)
	The buffer zone shall be of adequate dimensions to carry out environmental monitoring activities.		TDEC 0400-20-11-.17(3)(h)
	Void spaces between waste packages must be filled with earth or other material to reduce future subsidence within the disposal unit.		TDEC 0400-20-11-.17(3)(e)
	Closure and stabilization measures must be carried out as each disposal unit is filled and covered.		TDEC 0400-20-11-.17(3)(i)
	Active waste disposal operations must not have an adverse effect on completed closure and stabilization measures.		TDEC 0400-20-11-.17(3)(j)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Facility design, construction	Systems structures and components must be designed, constructed and operated to withstand the effects of natural phenomena as necessary to ensure confinement of hazardous material, the operation of essential facilities, and the protection of government property.	Construction of new non-nuclear facility under DOE-STD-1027-92 – **TBC**	DOE O 420.1
Control and stabilization	Control and stabilization features shall be designed to: • Provide to the extent reasonably achievable an effective life of 1,000 years with a minimum of at least 200 years; and • Provide reasonable assurance that releases of radon-222 to the atmosphere will not exceed an annual average release rate of 20 pCi/m2/s or will not increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than 0.5 pCi/L.	Long-term management of uranium, thorium, and their decay products – **TBC**	DOE O 458.1(4)(h)(1)(d)(1)(a) DOE O 458.1(4)(h)(1)(d)(1)(b)
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.	Closure of RCRA landfill – **applicable**	40 CFR 264.114 TDEC 0400-12-01-.06(7)(e)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Closure of RCRA landfill	Must close the a RCRA landfill unit in a manner that: • minimizes the need for further maintenance, and • 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 ground or surface waters or to the atmosphere, and	Closure of a RCRA hazardous waste management facility – **applicable**	40 CFR 264.111 TDEC 0400-12-01-.06(7)(b)
	• During the partial and final closure periods, all contaminated equipment, structures and soils must be properly disposed of or decontaminated unless otherwise specified in §§ 264.197, 264.228, 264.258, 264.280 or § 264.310.		40 CFR 264.114 40 CFR 264.197(a)
	• If owner/operator demonstrates that not all contaminated soils can be practicably removed or decontaminated as required in paragraph (a) above, then must close the tank system and perform post-closure care in accordance with the requirements that apply to landfills at 40 CFR 264.310.		40 CFR 264.197(b)
	Cleanups should generally achieve risk levels in the 10^{-4} to 10^{-6} range.	Cleanup of radioactive contaminants – **TBC**	OSWER Directive 9200.4-18

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Closure of RCRA landfill	Must cover the landfill or cell with a final cover designed and constructed to: • Provide long-term minimization of migration of liquids through the closed landfill; • Function with minimum maintenance; • Promote drainage and minimize erosion or abrasion of the cover; • Accommodate settling and subsidence so that the cover's integrity is maintained; and • Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	Closure of a RCRA hazardous waste management facility – **applicable**	40 CFR 264.310(a)(1) TDEC 0400-12-01-.05(14)(k)(1)(i) 40 CFR 264.310(a)(2) TDEC 0400-12-01-.05(14)(k)(1)(ii) 40 CFR 264.310(a)(3) TDEC 0400-12-01-.05(14)(k)(1)(iii) 40 CFR 264.310(a)(4) TDEC 0400-12-01-.05(14)(k)(1)(iv) 40 CFR 264.310(a)(5) TDEC 0400-12-01-.05(14)(k)(1)(v)
Closure of a LLW disposal facility	Covers must be designed to minimize the extent practicable water infiltration, to direct percolating or surface water away from the disposed waste, and to resist degradation by surface geologic processes and biotic activity.	Land disposal of LLW – **relevant and appropriate**	TDEC 0400-20-11-.17(2)(d)
Closure of an inactive asbestos waste disposal site	Either discharge no visible emissions to the outside air; or Cover the asbestos-containing waste with at least 6 in. of compacted non asbestos-containing material, and grow and maintain a cover of vegetation on the area adequate to prevent exposure of the asbestos containing waste; or	Disposal of asbestos containing waste material – **applicable**	40 CFR 61.151 (a)(1) 40 CFR 61.151(a)(2)
	Cover the asbestos-containing waste with at least 2 ft of compacted non asbestos-containing material, and maintain it to prevent exposure of the waste.		40 CFR 61.151 (a)(3)
	Maintain warning signs and fencing (if installed as specified in 40 *CFR* 61.154(b).		40 CFR 6 1. 151 (b)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Clean closure of RCRA container storage area	Must close the facility in a manner that: • Minimizes the need for further maintenance; • Controls, minimizes or eliminates, to the extent necessary to protect human health and environment, postclosure escape of hazardous waste, hazardous constituents, contaminated run-off or hazardous waste decomposition products to ground or surface waters or to the atmosphere; and • Complies with closure requirements of 40 *CFR* 264.178.	Management of RCRA hazardous waste in containers – **applicable**	40 CFR 264.111 TDEC 0400-12-01-.06(7)(b)
	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.		40 CFR 264.178 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 groundwater monitoring well(s)	Shall be accomplished by a licensed driller Shall be completely filled and sealed in such a manner that vertical movement of fluid either into or between formation(s) containing underground source of drinking water through the bore hole is not allowed. Shall be performed in accordance with the provisions for Seals at TDEC 1200-4-6-.09(6)(e), (f), and (g), for Fill Materials at 1200-4-6-.09(6)(h) and (i), for Temporary Bridges at 1200- 4--6-.09(6)(j), for Placement of Sealing Materials at 1200-4- 6-.09(7)(a) and (b), and Special Conditions at 1200-4-6- .09(8)(a) and (b), as appropriate.	Permanent plugging and abandonment of a well – **relevant and appropriate**	TDEC 0400-45-09-.16(2) TDEC 0400-45-06-.09(6)(d)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Closure of an above-grade RCRA tank system	Must close the facility in a manner that: • Minimizes the need for further maintenance; • 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 ground or surface waters or to the atmosphere; and • Complies with the closure requirements of 40 CFR 264.197 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). If owner/operator demonstrates that not all contaminated soils can be practicably removed or decontaminated as required in paragraph (a) above, then must close the tank system and perform post-closure care in accordance with the requirements that apply to landfills at 40 CFR 264.310.	Operation of a RCRA hazardous waste tank system— **relevant and appropriate**	40 CFR 264.111(a) TDEC 0400-12-01-.06(7)(b)(1) 40 CFR 264.111(b) TDEC 0400-12-01-.06(7)(b)(2) 40 CFR 264.111(c) TDEC 0400-12-01-.06(7)(b)(3) 40 CFR 264.197(a) TDEC 0400-12-01-.10(h)(1) 40 CFR 264.197(b) TDEC 0400-12-01-.10(h)(2)
Post-Closure Care			
Post-closure plan	Must have a written post-closure plan which identifies planned monitoring activities and frequency at which they will be performed for groundwater monitoring, containment systems and cap maintenance.	Closure of a RCRA landfill – **applicable**	40 CFR 264.118 TDEC 0400-12-01-.06(7)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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.	Closure of a RCRA landfill – **applicable**	40 CFR 264.119(a) TDEC 0400-12-01-.06(7)(j)
	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.	Closure of a RCRA landfill – **applicable**	40 CFR 264.119(b) TDEC 0400-12-01-.06(7)(j)(2)
Survey plat	Must submit to the local zoning authority or the authority with jurisdiction over local land use, a survey plot applicable 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 TDEC 0400-12-01-.06(7)(g)
	Within 60 days of closure 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 that: • The land has been used for disposal of asbestos-containing waste; • Survey plat and record of location and quantity of waste disposed within the site required in 40 *CFR* 61.154(f) have been filed; and • 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	Postclosure 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) TDEC 0400-12-01-.06(7)(h)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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.	Closure of a RCRA landfill – **applicable**	40 CFR 264.117(c) TDEC 0400-12-01-.06(7)(h)(3)
General post-closure care	Owner or operator must:	Closure of a RCRA landfill – **applicable**	40 CFR 264.310(b) TDEC 0400-12-01-.06(14)(k)
	• Maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.;		40 CFR 264.310(b)(1) TDEC 0400-12-01-.06(14)(k)(2)(i)
	• Continue to operate the leachate collection and removal system until leachate is no longer detected;		40 CFR 264.310(b)(2) TDEC 0400-12-01-.06(14)(k)(2) (ii)
	• 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);		40 CFR 264.310(b)(3) TDEC 0400-12-01-.06(14)(k)(2) (iii)
	• Prevent run-on and run-off from eroding or otherwise damaging final cover; and		40 CFR 264.310(b)(5) TDEC 0400-12-01-.06(14)(k)(2) (v)
	• Protect and maintain surveyed benchmarks used to locate waste cells.		40 CFR 264.310(B)(6) TDEC 0400-12-01-.06(14)(k)(2) (vi)
Waste left in place	Institutional controls are required and shall include, at a minimum, administrative restrictions for sale and use of property and securing area to prevent human contact with hazardous substances.	Hazardous substances left in place that might pose an unreasonable threat to public health, safety, or the environment – **relevant and appropriate**	TDEC 0400-15-01-.08(10)
Operation of leachate collection system	Must record the amount of liquids removed from the leak detection system at least monthly after the final cover is installed and thereafter as specified in 40 *CFR* 264.303(c)(2).	Closure of a RCRA landfill – **applicable**	40 CFR 264.303(c)(2) TDEC 0400-12-01-.06(14)(d)(3) (ii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Shall be monitored monthly for quantity and physicochemical characteristics of leachate produced. Water analysis shall be conducted as provided in 40 *CFR* 761.75(b)(6)(iii)(see above). The leachate should be either treated to acceptable limits for discharge or disposed of by another approved method.	Operation of a TSCA chemical waste landfill – **applicable**	40 CFR 761.75(b)(7)
Environmental Monitoring During Operations, Closure, and Post-Closure			
Monitoring and Response Program	All applicable units must comply with the applicable requirements of §§264.91 through 264.100 for purposes of detecting, characterizing and responding to releases to the uppermost aquifer.	A surface impoundment, waste pile or land treatment unit or landfill that receives waste after July 26, 1982, per 40 CFR 264.90(a)(1) – **applicable**	40 CFR 264.90(a)(2) 40 CFR 264.91(a)(4)
	Owners and operators must maintain and monitor a groundwater monitoring system and comply with all other applicable provisions 40 CFR 264, Subpart F		40 CFR 264.310(b)(4) TDEC 0400-12-01-.06(14)(k)(2) (iv)
Monitoring of LLW disposal facility	During site construction and operation, shall maintain a monitoring program, including a monitoring system. The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal unit before they leave the site boundary.	Operation of LLW disposal facility – **relevant and appropriate**	TDEC 0400-20-11-.17(4)(c)
General groundwater monitoring requirements	The groundwater monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer that:	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 CFR 264.97(a) TDEC 0400-12-01-.06(6)(h)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• represent the quality of background groundwater; • represent the quality of groundwater passing the point of compliance; and • allows for the detection of contamination when the hazardous waste or constituents have migrated from the waste management area to the uppermost aquifer.		40 CFR 264.97(a)(1) TDEC 0400-12-01-.06(6)(h)(1)(i) 40 CFR 264.97(a)(2) TDEC 0400-12-01-.06(6)(h)(1)(ii) 40 CFR 264.97(a)(3) TDEC 0400-12-01-.06(6)(h)(1)(iii)
	If underlying earth materials are homogenous, impermeable, and uniformly sloping in one direction, only three sampling points shall be necessary. These three points shall be equally spaced on a line through the center of the disposal area and extending from the area of highest water table elevation to the area of the lowest water table elevation.	Operation of TSCA chemical waste landfill groundwater monitoring program – **applicable**	40 CFR 761.75(b)(6)(ii)(A)
Monitoring well construction	All monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must be screened or perforated and packed with gravel or sand, where necessary to enable collection of groundwater samples. The annular space above the sampling depth must be sealed to prevent contamination of groundwater and samples.	Construction of RCRA groundwater monitoring well – **applicable**	40 CFR 264.97(c) TDEC 0400-12-01-.06(6)(h)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	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 storm water runoff.	Construction of a TSCA groundwater monitoring well – **applicable**	40 CFR 761.75(b)(6)(ii)(B)
Monitoring program	Groundwater monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide a reliable indication of groundwater quality below the waste management area.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 CFR 264.97(d) TDEC 0400-12-01-.06(6)(h)(4)
	Groundwater monitoring program must include sampling and analytical methods that are appropriate and accurately measure hazardous constituents in groundwater samples.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 CFR 264.97(e) TDEC 0400-12-01-.06(6)(h)(5)
	Groundwater monitoring program must include a determination of the groundwater surface elevation each time groundwater is sampled.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 CFR 264.97(f) TDEC 0400-12-01-.06(6)(h)(6)
Sample collection	The number and size of samples collected to establish background and measure groundwater quality at the point-of-compliance shall be appropriate for the form of statistical test employed following generally accepted statistical principles and otherwise comply with the provisions of this section.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 CFR 264.97(g) TDEC 0400-12-01-.06(6)(h)(7)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The groundwater 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. As a minimum, all samples shall be analyzed for the following parameters: • PCBs • pH • Specific conductance • Chlorinated organics Sampling methods and analytical procedures for these parameters shall comply with those specified in 40 CFR Part 136, as amended in 41 Federal Register 52779 on December 1, 1976.	Operation of TSCA groundwater monitoring wells – **applicable**	40 CFR 761.75(b)(6)(ii)(B)
	Groundwater monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide a reliable indication of groundwater quality below the waste management area. At a minimum the program must include procedures and techniques for: • Sample collection • Sample preservation and shipment • Analytical procedures • Chain of custody control • Elevation		40 *CFR* 264.97(d)
	The ground-water monitoring program must include a determination of the ground-water surface elevation each time ground water is sampled.		40 CFR 264.97(f)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Detection monitoring	Owners or Operators of hazardous waste facilities must monitor for specified indicator parameters, waste constituents or reaction products that provide a reliable indication of the presence of hazardous constituents in groundwater.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.98(a) TDEC 0400-12-01-.06(6)(i)
	Must install a groundwater monitoring system at the compliance point as specified under 40 *CFR* 264.95 that complies with 264.97(a)(2), (b), and (c).		40 *CFR* 264.98(b) TDEC 0400-12-01-.06(6)(i)(2)
	Must conduct a monitoring program for each specified chemical parameter and hazardous constituent in accordance with 264.97(g).		40 *CFR* 264.98(c) TDEC 0400-12-01-.06(6)(i)(3)
	A sequence of at least four samples from each well (background and compliance wells) must be collected at specified frequencies.		40 *CFR* 264.98(d) TDEC 1200-1-11-.06(6)(i)(4)
	Must determine the groundwater flow rate and direction in the uppermost aquifer at least annually.		40 *CFR* 264.98(e) TDEC 0400-12-01-.06(6)(i)(5)
	Must determine whether there is statistically significant evidence of contamination of any specified chemical parameter or hazardous constituent at a specified frequency.		40 *CFR* 264.98(f) TDEC 0400-12-01-.06(6)(i)(6)
	If owner/operator determines that there is statistically significant evidence of contamination at any monitoring well at the compliance point, must follow the provisions of this section.		40 *CFR* 264.98(g) TDEC 0400-12-01-.06(6)(i)(7)
Corrective measures for LLW disposal facility	Must have plans for taking corrective measures if migration of radionuclides would indicate that the performance objectives of Rules of the TDEC 0400-20-11-.16 may not be met.	Closure of an LLW landfill – **relevant and appropriate**	TDEC 0400-12-01-.17(4)(b)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Monitoring	After the disposal site is closed, post-operational surveillance of the disposal site shall be maintained by a monitoring system based on the operating history and the closure and stabilization of the disposal site. The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal unit before they leave the site boundary.	Closure of an LLW landfill – **relevant and appropriate**	TDEC 0400-12-01-.17(4)(d)
Waste left in place	Institutional controls are required and shall include, at a minimum, administrative restrictions for sale and use of property and securing area to prevent human contact with hazardous substances.	Hazardous substances left in place that might pose an unreasonable threat to public health, safety, or the environment – **relevant and appropriate**	TDEC 0400-15-01-.08(10)

Table E-4. Action-specific ARARs and TBC Guidance for the Off-Site Disposal Alternative

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
Transportation of hazardous materials	Hazardous material transport 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 radioactive waste	LLW shall be packaged and transported in accordance with DOE O 460.1A and DOE O 460.2.	Shipment of LLW off-site – **TBC**	DOE M 435.1-(I)(1)(E)(11)
Transportation of LLW	To the extent practical, the volume of LLW and the number of the shipments shall be minimized.	Shipment of LLW off-site – **TBC**	DOE M 435.1-1(IV)(L)(2); DOE M 435.1-1(III)(L)(2)
Transportation of PCB wastes	PCB waste transport must comply with the manifesting provisions at 40 *CFR* 761.207 through 40 *CFR* 761.218.	Relinquishment of control over PCB wastes by transporting or offering for transport – **applicable**	40 CFR 761.207 (a)
Transportation of hazardous waste off-site	RCRA hazardous waste transport must comply with the generator requirements of 40 *CFR* 262.20–23 for manifesting, Section 262.30 for packaging, Section 262.31 for labeling, Section 262.32 for marking, Section 262.33 for placarding, Section 262.40, 262.41(a) for record keeping, and Section 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. A transporter who meets all applicable requirements of 49 *CFR* 171–179 and 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); TDEC 0400-12-01-.04(1)(a)(1)

Table E-4. Action-specific ARARs and TBC Guidance for the Off-Site Disposal Alternative (Continued)

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
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) TDEC 1200-1-11-.03(a)(6)
Transportation of LLW off site	LLW waste shall be packaged and transported in accordance with DOE O 1460. 1A and DOE O 460.2.	Shipment of LLW off site – **TBC**	DOE M 435.1-1(1)(1)(E)(11)
	To the extent practicable, the volume of waste and number of shipments shall be minimized		DOE M 435. 1-1 (lV)(L)(2)
	Authorized limits shall be consistent with limits and guidelines established by other applicable Federal and State laws.		
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; DOE O 460.1
	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 – **applicable**	40 *CFR* 262 Subpart B; 40 *CFR* 263 Subpart B
	Generators must certify before the shipment that the waste meets the waste acceptance criteria of the receiving facility.	Waste shipped from one field organization to another for disposal – **TBC**	DOE O 435.1

Table E-4. Action-specific ARARs and TBC Guidance for the Off-Site Disposal Alternative (Continued)

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
	LLW must be disposed of on-site; if off-site disposal is required due to lack of capacity, disposal must be to a DOE facility.	Shipments of LLW – **TBC**	DOE O 435.1
	Off-site disposal of LLW to a commercial facility requires an exemption from the on-site disposal requirements of DOE O 435.1; requests for exemption must be approved by the DOE ORO Field Office. Must meet DOE Order and Implementing procedural requirements for off-site shipments.	Shipments of LLW – **TBC**	DOE M 435.1-1(I)(2)(F)(4)

8. REFERENCES

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APPENDIX F:

ON-SITE DISPOSAL FACILITY
PRELIMINARY WASTE ACCEPTANCE CRITERIA

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CONTENTS

FIGURES

TABLES

ACRONYMS

ASA	Auditable Safety Analysis
BCV	Bear Creek Valley
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	contaminant of 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
HDPE	high-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HI	hazard index
K_d	solid-to-liquid partition coefficient
LLW	low-level waste
MOC	Method of Characteristic
MSL	mean sea level
NRC	Nuclear Regulatory Commission
NT	Northern Tributary
ORR	Oak Ridge Reservation
PWAC	Preliminary Waste Acceptance Criteria
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SOF	sum of fractions
TMR	telescopic mesh refinement
U.S.	United States
UBCV	Upper Bear Creek Valley
USGS	U.S. Geological Survey
VWSOF	volume weighted sum of fractions
WAC	waste acceptance criteria

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1. INTRODUCTION

The purpose of this Appendix is to develop analytic Preliminary Waste Acceptance Criteria (PWAC) to meet applicable risk and dose criteria using fate and transport analysis for a proposed Environmental Management Disposal Facility (EMDF). This analysis provides the basis for demonstrating that the On-site Disposal Alternative would be protective of human health and the environment, meet remedial action objectives, and be a viable disposal option for most future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste.

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/Feasibility Study (RI/FS) evaluates a proposed EMDF 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 and east of the current EMWMF site and has similar engineering design and hydrogeologic attributes.

1.1 WAC COMPONENTS

Radiological and chemical releases from wastes disposed in the proposed EMDF and the potential risks to the public from such releases would be mitigated by disposal cell design and hydrogeologic attributes. A previously negotiated waste acceptance criteria (WAC) attainment process for the EMWMF involves the completion of four separate sets of requirements (DOE 2001a):

- Administrative WAC were derived from applicable or relevant and appropriate requirements in the EMWMF Record of Decision (ROD) (DOE 1999), and from other agreements between the DOE, the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation.
- Analytic WAC were derived from the approved risk assessment model in the EMWMF RI/FS and RI/FS Addendum (DOE 1998a, DOE 1998b) for the EMWMF.
- Auditable Safety Analysis (ASA)-derived WAC were derived from facility authorization basis documentation for the EMWMF.
- Physical WAC were derived from operational constraints and contractual agreements for EMWMF operations.

The 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 11e(2) byproduct waste, and places limits on total uranium concentrations in waste separate from and in addition to analytic WAC considerations.

The ASA-derived WAC limits disposal of radionuclide based on a maximum credible release of material that would occur during an extreme wind event at the operating facility. These limits are also separate from and in addition to analytic WAC considerations.

The focus of this Appendix is the risk-based analytic PWAC for the proposed EMDF. The analytic PWAC are numerical limits developed by applying fate and transport analysis using conceptual design elements of the EMDF and risk/dose analytical approaches. As described in the WAC Attainment Plan for EMWMF (DOE/OR/01-1909&D3), the analytic WAC is the numerical concentration of a constituent in a given waste lot such that, if the waste form with this concentration occupied the entire disposal cell volume, risk or hazard index (HI) to a public receptor would be equal to specified criteria. However, it is unlikely that a single waste type will occupy the entire facility. Rather, the disposal cell will ultimately contain many waste forms, each having a specific volume of radiological and chemical contaminants. To accommodate these different waste forms, an approach to apply the contaminant-specific WAC to various waste streams was developed for the EMWMF. The sum of fractions (SOF) calculation method is used to determine whether a waste containing multiple contaminants is acceptable for disposal. The SOF calculations are specific to a single waste lot. The volume weighted sum of fractions (VWSOF) calculation method is used to account for the fact that not all waste lots will contain the same volume of waste.

The four separate WAC components and compliance process for the EMWMF are the product of formal negotiations between the Federal Facility Agreement (FFA) parties during the pre-ROD and post-ROD stages of the CERCLA process. At the RI/FS stage for a proposed facility, it is early in the conceptual design and decision making process to determine what final WAC components will be agreed to by the FFA parties. It is assumed at this stage that a similar WAC approval process would be followed for a proposed facility. It is also assumed that administrative, ASA-derived, and physical WAC components for the new facility and the WAC compliance approach, including the SOF and VWSOF calculations methodology, for the new facility would be similar to the WAC components and compliance approach for EMWMF.

The analytic PWAC would be finalized as the design for the disposal facility proceeds and final design parameters, site layout, and additional site-specific characterization data are available. It is acknowledged that the analytic PWAC results presented in this Appendix are a preliminary data set. The analytic PWAC were developed to show protectiveness and viability of land disposal at the proposed site. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC (administrative, analytic, ASA-derived, and physical) would be approved for a new facility at the selected site prior to waste receipt. The final WAC approved by the FFA parties may be similar to the WAC approved for EMWMF.

The site conceptual model and exposure pathways are discussed in Chapter 2. Preliminary WAC development and applied models are summarized in Chapter 3. Chapter 4 describes site-specific model development for the proposed EMDF site. Risk/dose modeling and calculations are discussed in Chapter 5. Chapter 6 provides analytic PWAC calculations and results and a discussion of results relative to the EMWMF WAC. Chapter 7 lists references used in the analysis. Attachment A provides supplemental modeling information.

2. SITE CONCEPTUAL MODEL AND RISK EXPOSURE PATHWAYS

The proposed EMDF would be an on-site, 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 sites and demolition of contaminated buildings from CERCLA cleanup projects. The proposed EMDF has a conceptual design capacity of 2.5 million yd^3. Figure F-1 illustrates the site plan of the proposed EMDF.

The conceptual design of the EMDF is described in Section 6.2 of this RI/FS and site characteristics are described in Appendix C. Summary information about the proposed site characteristics, site conceptual model and risk exposure pathway, and receptor and risk criteria is provided below.

2.1 PROPOSED EMDF SITE DESCRIPTION

The 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 to 1,260 ft above mean sea level (MSL). The elevation of the Bear Creek Valley (BCV) floor ranges from about 940 to 1,000 ft-MSL.

The stratigraphic section exposed in BCV includes rocks ranging in age from Early Cambrian to Early Mississippian. 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 C.

The early Cambrian Rome Formation, which is the oldest unit exposed in the site area, outcrops on the ridge top of Pine Ridge and dips 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 the BCV, the Conasauga Group is subdivided into six formations: Pumpkin Valley, Rutledge, Rogersville, Maryville, Nolichucky, and Maynardville. The Maynardville Formation, composed mostly of limestone, underlies the valley floor. The Knox Group of late Cambrian is composed primarily of massive, siliceous dolomite that forms the Chestnut Ridge on the south side of BCV.

Small-scale geologic features, such as fractures and solution features, are a major factor in groundwater 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 groundwater flow through geologic formations, such as shales and limestones, that typically have little intrinsic permeability. Fractures are well developed in all stratigraphic units as a result of tectonic activity and geostatic relief, and are the most pervasive groundwater-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 hydraulic and dominant strike-parallel groundwater flow paths. Fracture aperture width and frequency generally decrease with depth in all formations and thus restrict the depth of active groundwater circulation. The unconsolidated materials, or regolith, overlying bedrock in the EBCV site include a mixture of residuum and bedrock remnants and weathered bedrock saprolite.

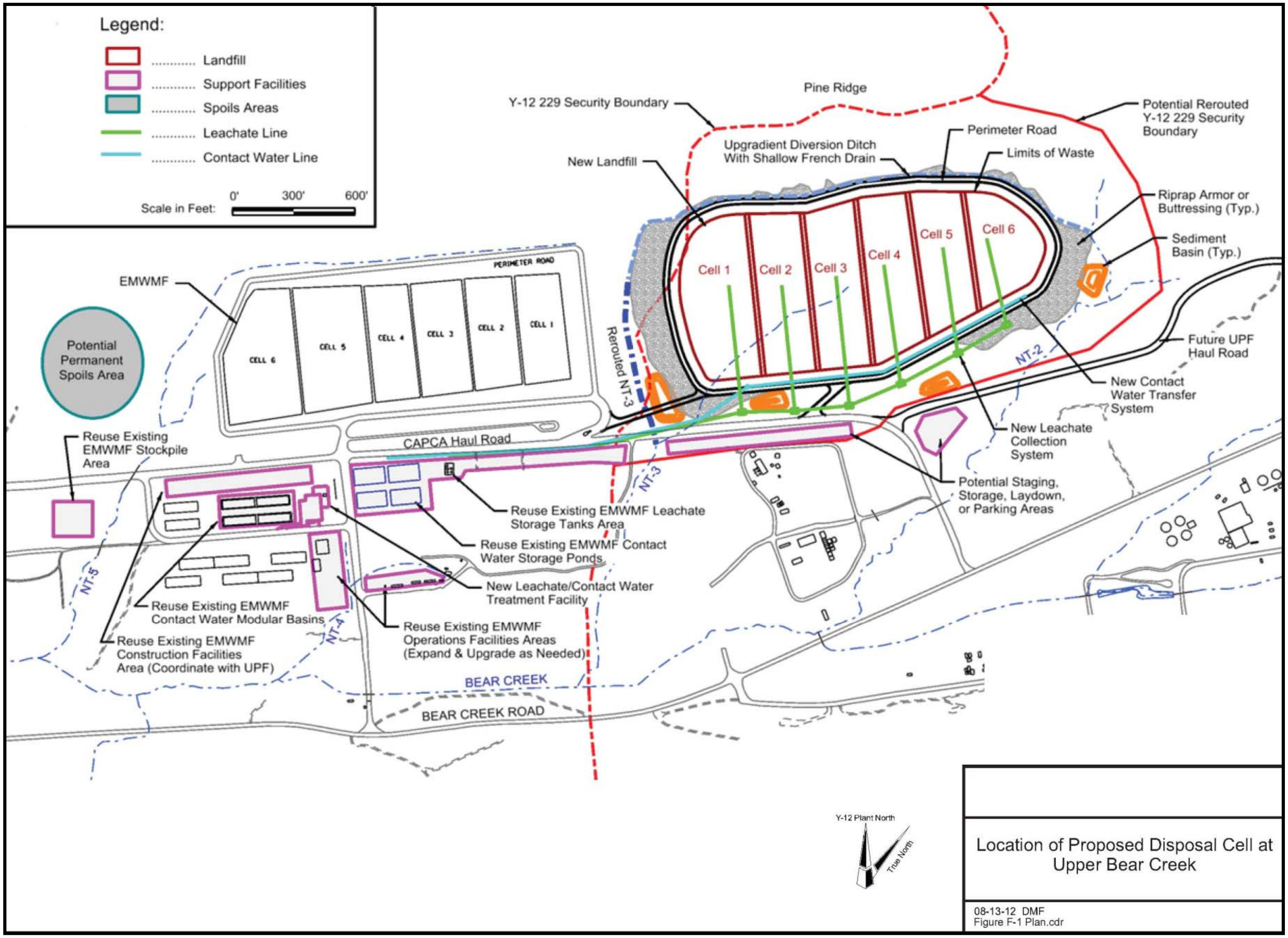

Figure F-1. Location of the Proposed EMDF Cell at Upper Bear Creek

Within BCV, the majority of groundwater flow occurs primarily within the upper 100 ft of the aquifer system (Solomon et al. 1992). The occurrence and movement of groundwater in the bedrock is closely related to the presence of bedding planes, joints, fractures, and solution cavities. In general, groundwater in the bedrock occurs under water-table conditions but becomes increasingly confined with depth. Downward recharge to the groundwater system occurs along the flanks of Pine Ridge and Chestnut Ridge.

BCV hydrogeologic units behave as an anisotropic system in all three dimensions, evidenced by the elongated drawdown along strike direction observed during pumping tests and the spatial distribution of contaminant plumes. The anisotropic nature of hydraulic conductivity associated with the bedrock underlying BCV is apparently caused by the orientation and intersection of fractures, joints, and/or bedding planes. Due to this anisotropy, groundwater flow is primarily along strike (i.e., east to west). Due to the along-strike flow directions, a large portion of the shallow groundwater discharges into the tributaries and eventually flows into Bear Creek.

Bear Creek flows southwestward from its headwaters for approximately 4.5 miles along the BCV axis, and then turns northward to flow into East Fork Poplar Creek by cutting through Pine Ridge. The drainage area of BCV is approximately 5.2 mi^2 (Robinson and Johnson 1995). Most of the tributaries of Bear Creek originate along the flanks of the Pine Ridge.

2.2 CONCEPTUAL SITE MODEL AND RISK EXPOSURE PATHWAY

Development of a conceptual site 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 the contaminants may move through and the receptor that could become exposed to such contaminants. In this application, the conceptual site model is a continuum flow model, meaning that flow occurs in pore, fractures, and conduits, but that 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 are used to develop the WAC modeling processes. See Section 3.5 of Appendix C for additional information about the conceptual site model.

Figure F-2 shows the conceptual disposal cell leachate movement and groundwater flow characteristics at the area. Exposure pathways include the migration of contaminants in groundwater and surface water from the disposal facility after the cap and liner systems have experienced some degree of failure, allowing water to percolate through the landfill. After the closure of the disposal cell and degradation of the synthetic components of the disposal cell, water is able to infiltrate the waste and leach contaminants from the wastes. Contaminants would then migrate vertically through the unsaturated zone and into the groundwater zone where they would be transported to a nearby well or discharged to surface water. Most of the groundwater flow occurs in the upper part of the soil and bedrock system and mostly discharges into surface water bodies of Bear Creek and its tributaries, as well as in conduits in the Maynardville Limestone. The modeling process calculates the risks related to exposure to contaminants for a defined hypothetical receptor. Groundwater 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. Development of the analytic PWAC is based on an evaluation of this likely exposure pathway. The location of the hypothetical receptor for the proposed EMDF used to define exposure assumptions is analogous to that used for the EMWMF analytic WAC modeling.

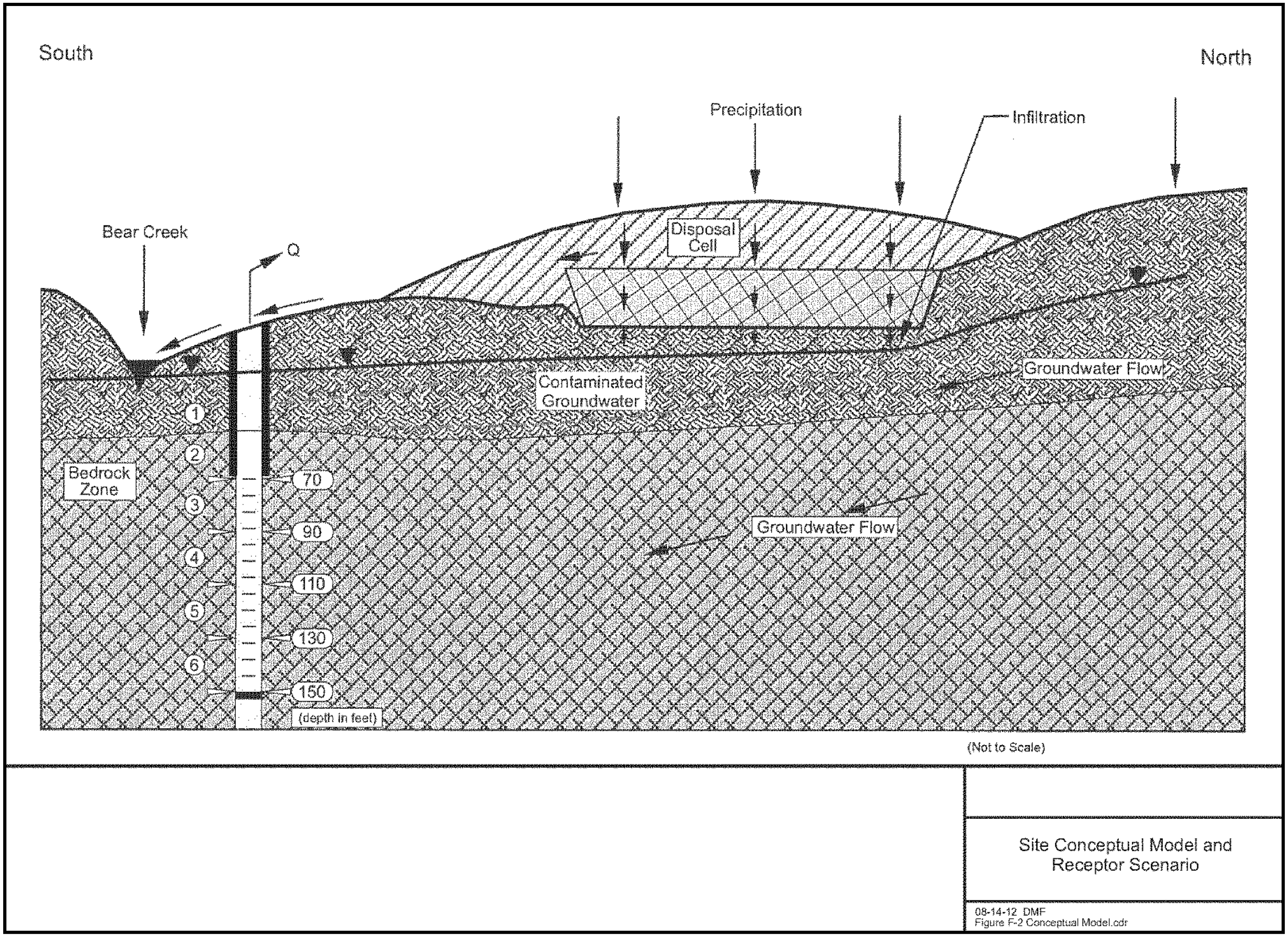

Figure F-2. Conceptual Site Model and Receptor Scenario

DOE would provide long-term care of the facility (institutional controls) such that an inadvertent intruder (e.g., someone digging into and being directly exposed to the waste after landfill closure) is not a likely risk exposure pathway. However, if it is assumed that institutional controls are lost in the future, inadvertent intruder scenarios are not considered plausible based on the conceptual design aspects of the disposal facility, including the biointrusion layer and the cap thickness. The 13 ft multi-layer cap system described in Section 6.2.2.4 of the RI/FS includes a 3 ft thick biointrusion layer of free-draining, coarse granular material (i.e., 4 in. to 12 in. diameter riprap) to inhibit penetration by humans, burrowing animals, and plants.

2.3 RECEPTOR AND RISK CRITERIA

For the proposed EMDF, concentration-based “analytic” PWAC were developed assuming a hypothetical resident farmer receptor. The resident farmer is assumed to live between the EMDF and Bear Creek (in the downgradient direction of general groundwater flow and discharge). The hypothetic farmer uses groundwater 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 and regulations in Tennessee, the upper, more active, weathered bedrock zone would not be used for domestic water supplies. The shallow portion of the well is cased and the well is screened in the unweathered fractured bedrock as shown in Figure F-2.

The contaminant leaching/transport analysis and exposure conceptual model is presented in Figure F-3. For the rural residential farmer there is a potential for exposure to contaminated media through the following pathways:

- Ingestion of contaminated water
- Consumption of home-grown vegetables/fruits irrigated with contaminated water
- Consumption of milk and meat from livestock fed with vegetation irrigated with the contaminated water

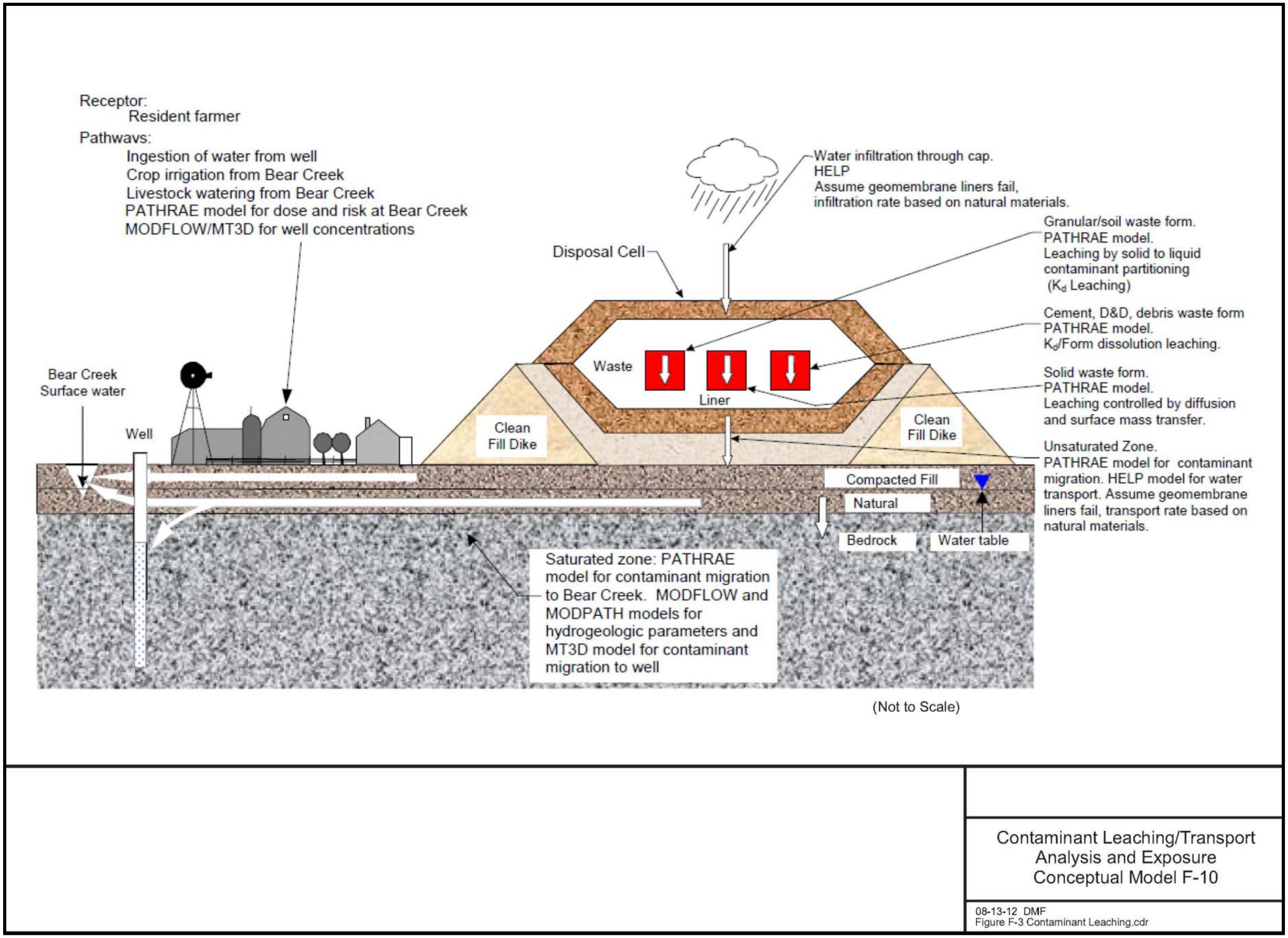

Figure F-3. Contaminant Leaching/Transport Analysis and Exposure Conceptual Model

DOE Order 435.1 (DOE 2001c) requires analysis of low-level waste disposal facilities using a performance-based approach with little to no reliance on engineered controls for a performance period of 1,000 years .

The following risk goals 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 WAC:

- An Excess Lifetime Cancer Risk (ELCR) (carcinogenic risk) $\leq 1 \times 10^{-5}$ and an HI[1] ≤ 1 for the first 1,000 years after closure.
- Carcinogenic risk $\leq 10^{-4}$ and HI ≤ 3 for >1,000 years to 100,000 years after closure.

These risk criteria are the same as those approved for the currently operational EMWMF. The 1,000-year compliance period is consistent with the regulatory timeframe in DOE Order 435.1. For PWAC development presented in this Appendix, peak risks beyond 1,000 years were calculated for uncertainty/sensitivity analyses to evaluate the long-term characteristics of the disposal cell design and performance. However the results of modeling beyond the 1,000-year compliance timeframe are not required by DOE Order 435.1 and are less reliable.

To calculate analytic PWAC, the proposed EMDF was conceptualized as one large waste cell containing a uniform concentration of a single contaminant. Risks were then calculated for this uniform concentration, and analytic PWAC were back-calculated from these derived risks using the appropriate risk goals listed above based upon the time of peak risk and the type of risk being calculated.

[1] The HI is a summation of the hazard quotients for all chemicals to which an individual is exposed. A HI value of 1.0 or less indicates that no adverse human health effects (non-cancer) are expected to occur.

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3. PRELIMINARY WAC DEVELOPMENT AND MODELS

Information about the PWAC 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.

3.1 OVERVIEW OF PWAC DEVELOPMENT

Linkage and application of the contaminant leaching/transport models and steps used to develop the PWAC are depicted in Figure F-4.

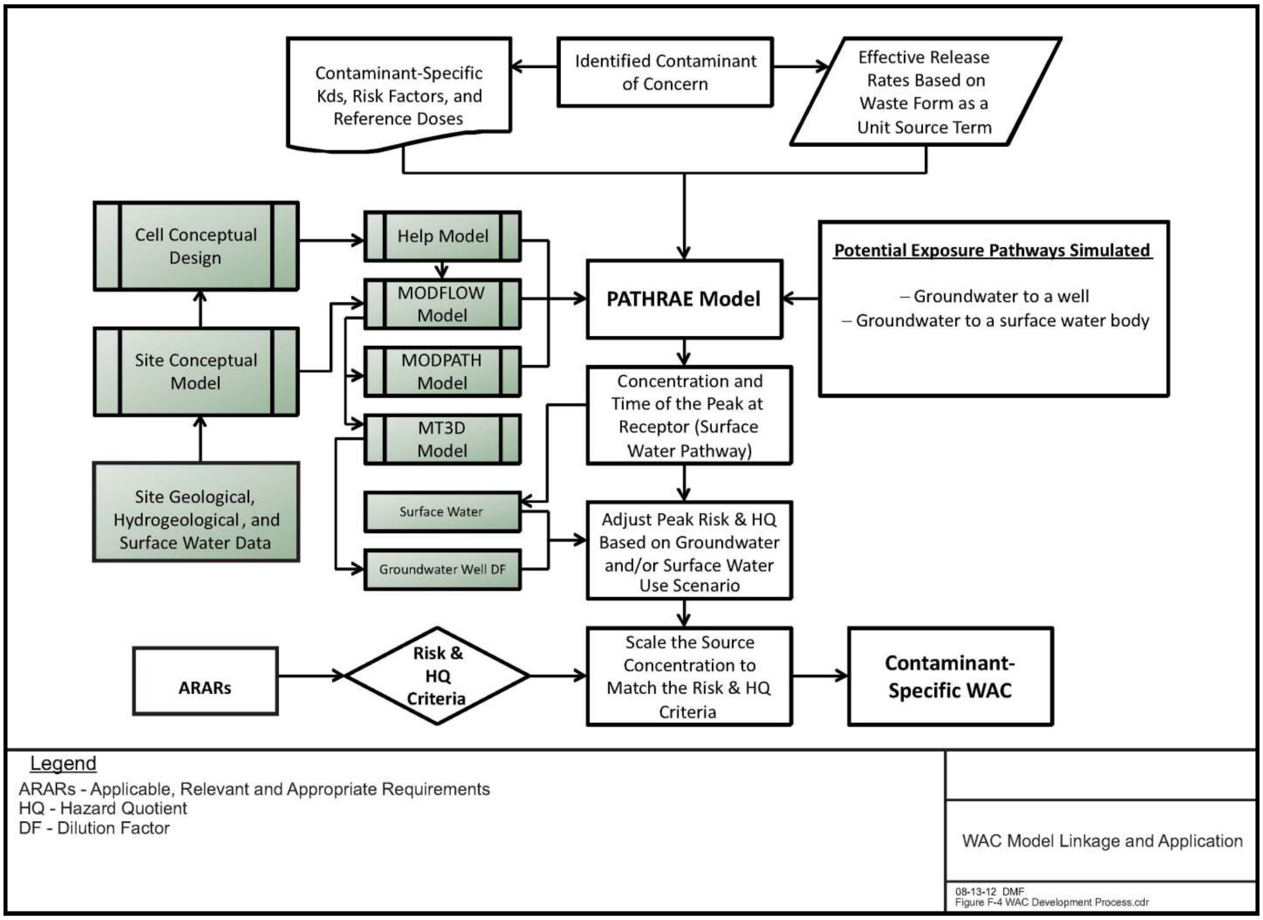


Figure F-4. WAC Model Linkage and Application

The main design and site features, calculations, and models used in these analyses were as follows:

- Determination of water infiltrating the cap, passing through the waste, and entering the vadose zone and groundwater was accomplished by mass balancing analysis of precipitation and evapotranspiration, cap drain removal of water, and hydraulic flow with the steady-state infiltration rate conservatively taking no credit for man-made cover and liner components. The Hydrologic Evaluation of Landfill Performance (HELP) computer code (Schroeder et al. 1994) was used for these calculations.

- Solid-to-liquid partition coefficient (K_d) values of contaminants from soil were used as input to unsaturated, one-dimensional, time-dependent modeling of source leaching and contaminant transport in the waste and vadose zones to groundwater. The PATHRAE code (Rogers and Associates Engineering 1995a and b) was used for these calculations. K_d values are for neutral pH conditions.
- Groundwater condition and flow characteristics in the disposal cell area and groundwater travel time to tributaries or Bear Creek were evaluated using the three-dimensional, finite difference, time-dependent MODFLOW (McDonald and Harbaugh 1988) and MODPATH (Pollock 1989) models, respectively.
- Discharge of groundwater to tributaries and/or Bear Creek, solute mixing with tributary/stream flow, and contaminant uptake by receptors were calculated using the PATHRAE code. Average surface water flow data were also used for these calculations.
- Groundwater dilution factors (DFs) at the receptor well location relative to source concentrations due to advection process were established using the MT3D model (Zheng 1990). Other processes, such as contaminant specific dispersion, retardation due to absorption, and degradation, were considered during PATHRAE application.
- The PATHRAE results and EPA applicable slope factors were used to calculate risk for a resident farmer (WAC receptor) using contaminated well water for domestic use and contaminated Bear Creek water for agricultural purposes.

To ensure that both carcinogenic risk and HI toxicity goals are met, separate analytic PWAC concentration limits for individual radiological and chemical constituents at the EMDF are calculated. These limits correspond to the maximum permissible concentration of the constituent that could be placed in the facility if the waste containing the single constituent were to occupy the entire disposal cell volume in a soil like matrix.

The PWAC development process used for the proposed EMDF is similar to the process 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 waste characteristic data, PATHRAE-HAZ/RAD relies on parameter input from other models, such as HELP for infiltration rate through the landfill, MODFLOW for groundwater flow field, path, and discharge locations and rates, and MODPATH for constituent travel times and paths from specific groundwater entrance points below the cell to receptor locations. The peak contaminant concentration in the well is determined by scaling the concentrations and doses modeled for the surface water using DLs. The well DL is the ratio of the concentration of a constituent in the well water to a unit concentration in solute seepage entering the groundwater beneath the disposal facility. The creek DL is calculated using the measured surface water volume and flow rate. The well DL is calculated based on an analysis performed using MODFLOW and MT3D.

The contaminant leaching/transport analysis and exposure conceptual models are depicted in Figure F-3. The contaminant movement includes the following processes:

- Infiltration of water into the waste cell
- Leaching of contaminants from the waste disposed into the underlying groundwater zone
- Transport of contamination from the site to the receptor well and discharge to surface water bodies
- Subsequent uptake by the hypothetical receptor via applicable groundwater and surface water exposure route

3.2 MODELS USED TO SUPPORT PWAC DEVELOPMENT

The relevant HELP, MODFLOW/MODPATH MT3D, and PATHRAE-HAZ/RAD models are described in following sections.

3.2.1 Hydrologic Evaluation of Landfill Performance Model

The HELP model (Schroeder et al., 1994) is used to evaluate the water budget for the proposed EMDF and estimate infiltration rates to groundwater. This information is needed for groundwater flow and fate and transport modeling as the precursor to risk/dose analysis using PATHRAE-HAZ/RAD and groundwater 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, unsaturated vertical drainage, and leakage through soil, geomembrane, or composite liners. These input data are described in Section 2 of Attachment A 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 help hazardous waste landfill designers and regulators evaluate 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 (McDonald and Harbaugh 1988) and MODPATH (Pollock 1989) are used to evaluate the hydrogeologic conditions and parameters at the proposed waste disposal site. The parameters estimated include groundwater flow path, travel time, groundwater velocity, and flux rate.

MODFLOW is a modular, block-centered finite-difference groundwater flow code developed by the U.S. Geological Survey (USGS). MODFLOW is capable of simulating both transient and steady-state saturated groundwater 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 towards wells, and groundwater 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 presentation of hydraulic properties within the MODLFOW also provides flexibility to present fracture orientation and distribution. This approach is acceptable for BCV given the large scale of the model domain, the highly fractured nature of the hydrostratigraphic units, and the degree of accuracy that is required to support the WAC analysis.

MODFLOW is widely used by the industrial, scientific, and governmental communities. The code has been rigorously tested and verified, and varieties of software tools are publicly available for graphical preprocessing and post processing. Various MODFLOW models have been developed for Oak Ridge area and used extensively for the BCV RI/FS and EMWMF modeling and performance evaluation (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 various receptors outside of the waste disposal site in groundwater is simulated by using MT3D (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, single-species contaminants in complex saturated ground-water systems. MT3D calculates concentration distributions, concentration histories at selected receptor 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 (Rogers and Associates Engineering, 1995a and b), 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 through multiple pathways, of contaminants 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 persons 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 as other pathway analysis codes, such as RESRAD (Yu et al. 1993). A benchmarking comparative study by 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.

PATHRAE-HAZ/RAD can model the movement of contaminants via groundwater to surface water. This movement results from the leaching of contaminants by precipitation that infiltrates through the cap and percolates through the waste. A one-dimensional model of this movement through a uniform medium is used. 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. 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.

Although PATHRAE-HAZ/RAD can also model movement of contaminants to a groundwater well, it uses a simple one-dimensional flow assumption that would not be representative of the complex BCV groundwater flow regime. Therefore, the contaminant movement in the aquifer system is modeled using the MODFLOW and MT3D code.

Some of the PATHRAE-HAZ/RAD input values (such as uptake and intake parameters) used for the proposed EMDF site are generic numbers obtained from literature sources, and some are measured, site-specific values (such as stream flow rates). Some key parameters were calculated using additional models and site-specific information (e.g., water infiltration rates, groundwater transport parameters, and contaminant release rates for various waste forms). Key parameters used in the PATHRAE model are summarized in Table F-1.

Table F-1. Key PATHRAE-HAZ/RAD Parameters

Physical Process	Solution Methodology	Parameters Needed
Rate of water infiltration into the waste cell	HELP model	Site-specific climatic parameters; disposal cell design parameters; vadose zone hydrological parameters
Contaminant release rates from the waste disposal forms to the surrounding backfill soils	K_d leaching mechanisms and waste diffusion processes	Site-specific and generic K_d factors for soils; generic diffusion parameters
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
Groundwater transport characteristics	MODFLOW and MT3D models	Site-specific and generic hydrogeologic parameters
Groundwater interactions with surface water	MODFLOW, MODPATH, and PATHRAE model	Surface water flow parameters and MODFLOW/MODPATH results
Contaminant uptake parameters for the food chain, and the intake rates for human receptors consuming contaminated food and water	PATHRAE model	EPA and Nuclear Regulatory Commission (NRC) literature values

4. DEVELOPMENT OF SITE-SPECIFIC MODELS

Development of a site-specific HELP model, site-specific groundwater flow models, and application of the fate-transport model for the proposed EMDF site are described in the following sections.

4.1 HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE MODEL

The landfill conceptual design and HELP model simulation and results for the proposed EMDF are described below.

4.1.1 Conceptual Design of Disposal Facility

A conceptual design of the proposed on-site waste disposal facility has been developed 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 10 discrete layers incorporated into the cover design and nine layers incorporated into the basal liner design below the waste. 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 13 ft and includes a 5 ft vegetation layer (a soil/rock matrix) on its top slope, underlain by a 1 ft drainage layer (graded natural materials such as sand and gravel) and a 3 ft biointrusion layer (larger rocks and boulders). Combined, these 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.
- The cover includes a geomembrane layer over a two-part 2 ft thick low-permeability clay layer. The two-part clay layer is comprised of a 1 ft thick amended clay layer 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 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 5.1 of this Appendix). Water moving through the waste will form leachate with an average pH of 7.3 S.U. and a range from 5.69 to 9.13 S.U.
- The liner system 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 drainage layers will intercept all the water migrating from the waste.

- The liner design has a geosynthetic clay liner layer, 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 wastes from beneath the cell. The fully designed and functional landfill system will not allow any precipitation recharging to the groundwater 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 F-2 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. A lesson learned from the EMWMF construction is that a similar landfill can be successfully constructed over tributaries in BCV. An underdrain is necessary for the proposed EMDF within the tributary channel to provide a flow path for groundwater immediately below the landfill and prevent upwelling, since tributaries are natural discharge areas for groundwater.

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 would be to intercept upwelling groundwater and 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 groundwater away from the landfill. The upper portion of NT-3 would be diverted to the west of the landfill.

Table F-2. EMDF Conceptual Design Profile and Material Characteristics

Layer #	**Material**	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 (%)
1	Top Soil/Rock Mix	1	60	4	0.437	0.105	0.047	1.70E-03		
2	Sand/Gravel	1	12	3	0.457	0.083	0.033	3.10E-03		
3	Biointrusion (rip-rap)	1	36	1	0.417	0.045	0.018	1.00E-02		
4	Drainage	2	12	21	0.397	0.032	0.013	3.00E-01	100	5
5	HDPE (FML)	4	0.06	35				2.00E-13		
6	Amended Compact Clay	3	12	16	0.427	0.418	0.367	3.50E-08		
7	Cover Compacted Clay	1	12	0	0.427	0.418	0.367	1.00E-07		
8	Contour Gravel	1	12	21	0.397	0.320	0.013	3.00E-01		
9	Waste	1	600	22	0.419	0.307	0.18	1.90E-05		
10	Protective Soil	1	12	26	0.445	0.393	0.277	1.90E-06		
11	Drainage (Leachate collection)	2	12	21	0.397	0.032	0.013	3.00E-01	100	2.5
12	HDPE (FML)	4	0.06	35				2.00E-13		
13	GCL	3	0.24	17	0.75	0.747	0.4	3.00E-09		
14	Geonet Leak Detection Layer	2	0.3	20	0.85	0.01	0.005	1.00E+01	100	2.5
15	HDPE (FML)	4	0.06	35				2.00E-13		
16	Compacted Clay Layer	3	36	16	0.427	0.418	0.367	1.00E-07		
17	Soil Geobuffer	1	120	26	0.445	0.393	0.277	1.90E-06		

HDPE – high density polyethylene
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)

4.1.2 Hydrologic Evaluation of Landfill Performance Model Simulations and Results

Performance of the proposed EMDF cell cover/liner system is analyzed using HELP model. The performance of the system will likely undergo three stages after the closure of the EMDF.

- Fully Functional Stage – All layers are assumed to be functional and every aspect of the system performs as designed, including all design features, such as high-density polyethylene (HDPE) liners, leachate collection system, and drainage layers. HELP Model simulation result for infiltration rate to groundwater in this stage is 0.0 in. per year.
- Partially Functional Stage – The HDPE flexible membrane layer (FML) is 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. HELP Model simulation result for the infiltration rate in this stage is 0.38 in. per year.
- Long-term Performance Stage – This is a conservative worst-case scenario of the EMDF cell cover/liner system performance. All engineered features (i.e., 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, HELP model simulations resulted in an infiltration rate of 0.42 in. per year.

For simplified and conservative consideration, the long-term (worst case) scenario is used to develop the PWAC. This constant long-term infiltration rate is assumed as soon as the disposal cell is closed and used as an input value in subsequent modeling and calculations.

Table F-3 shows the results of HELP Model analysis for the worst case, long-term performance scenario. Section 2 of Attachment A to this Appendix provides additional detail about the HELP model.

Table F-3. HELP Model Predicted Mass Balance and Infiltration Rates for Long-term Performance (Worst Case)

Cell Layer System			Performance – Worst Case	
Cover System	Layer Performance	Top Soil/Rock Mix (5 ft)	YES	
		Sand/Gravel (1 ft)	YES	
		Bio-Intrusion Layer (3 ft Rip-rap)	YES	
		Drainage (1 ft)	YES	
		FML	Degraded	
		Amended Clay	YES	
		Compacted Clay/Contour Gravel	YES	
	Modeled Results		**Mass Balance (in/yr)**	**Mass Balance (%)**
		Precipitation	54.39	100
		Runoff	0.69	1.26
		Evapotranspiration	30.90	56.81
		Drain Collection	22.37	41.13
		Flux Rate into Waste (in/yr)	**0.42**	0.78
Waste Zone				
Liner System	Layer Performance	Soil (1 ft)	YES	
		Leachate Collection Drainage (1 ft)	Not Functional	
		FML	Degraded	
		Leak Detection Drainage Geonet	Degraded	
		GCL	Degraded	
		FML	Degraded	
		Compacted Clay (3 ft)	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)	**0.42**	0.78

FML – flexible membrane liner

GCL- geosynthetic clay liner

4.2 SITE-SPECIFIC GROUNDWATER FLOW MODELS

To develop required key input parameters to support analytic PWAC development and future design of a potential new disposal facility, a site-specific groundwater flow model for the Upper BCV (UBCV) Model has been developed for the proposed EMDF based on the Bear Creek regional groundwater flow model (DOE 1997) and EMWMF models (BJC 2003, DOE 1998b, and 2010).

A telescopic mesh refinement (TMR) modeling approach was used to develop the refined UBCV model from the calibrated BCV flow model constructed by 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. However, further refinements of locations of streams and waste units were made after the site-specific flow model was constructed.

4.2.1 Model Development Procedure

The UBCV model was developed in two stages. The UBCV model representing current site conditions (Year 2012) was the first stage. The current condition model was compared to existing and current site-specific data (such as stream flow and groundwater levels) and model parameters were adjusted to match model results with actual conditions. A sensitivity analysis of the current condition model was also conducted based on field data and the conceptual model. The sensitivity analysis used a strike-parallel linear high hydraulic conductivity zone in the Maynardville Formation to simulate conduit flow.

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 the disposal facility construction and closure.

The construction of the disposal cell site-specific UBCV model consisted of the following steps:

1. <u>Establish model domain and dimension.</u>

   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.

2. <u>Refine for current condition (2012) model.</u>

   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, allow for future EMDF engineering features, and to meet the need for risk/performance evaluation.
   b. The refined and improved parameters used in extensive calibrated EMWMF models were incorporated into the UBCV model.
   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. <u>Create the EMDF (future condition) model.</u>

   The future condition model was used for prediction and to provide required parameters of risk analysis and calculation.

   a. EMDF design and post-closure topography were incorporated into the future condition model to predict the flow condition after disposal cell construction.
   b. Parameters representing the construction/engineered features for the proposed EMDF were incorporated into the future condition model.
   c. Future landfill performance parameters, such as long-term recharge rate through waste zone, were included.

4.2.2 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 F-5 shows the 2012 topography and UBCV model domain. Figure F-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 x 10 ft is used for the model domain.

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 current (2012) topography for the current condition model 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 to 25 ft. The bottom of layer three corresponds approximately to the unweathered bedrock surface. Fractured bedrock is represented by layers 4 through 8, each of which are 20 ft thick. Layers 9, 10, and 11 are 150 ft, 200 ft, and 300ft thick, respectively, representing less fractured and less permeable deeper bedrock. Figure F-7 shows the vertical discretization for the model along the two cross sections.

There are a total of 4,540,800 cells in the UBCV Model, of which 3,572,049 are active in groundwater flow.

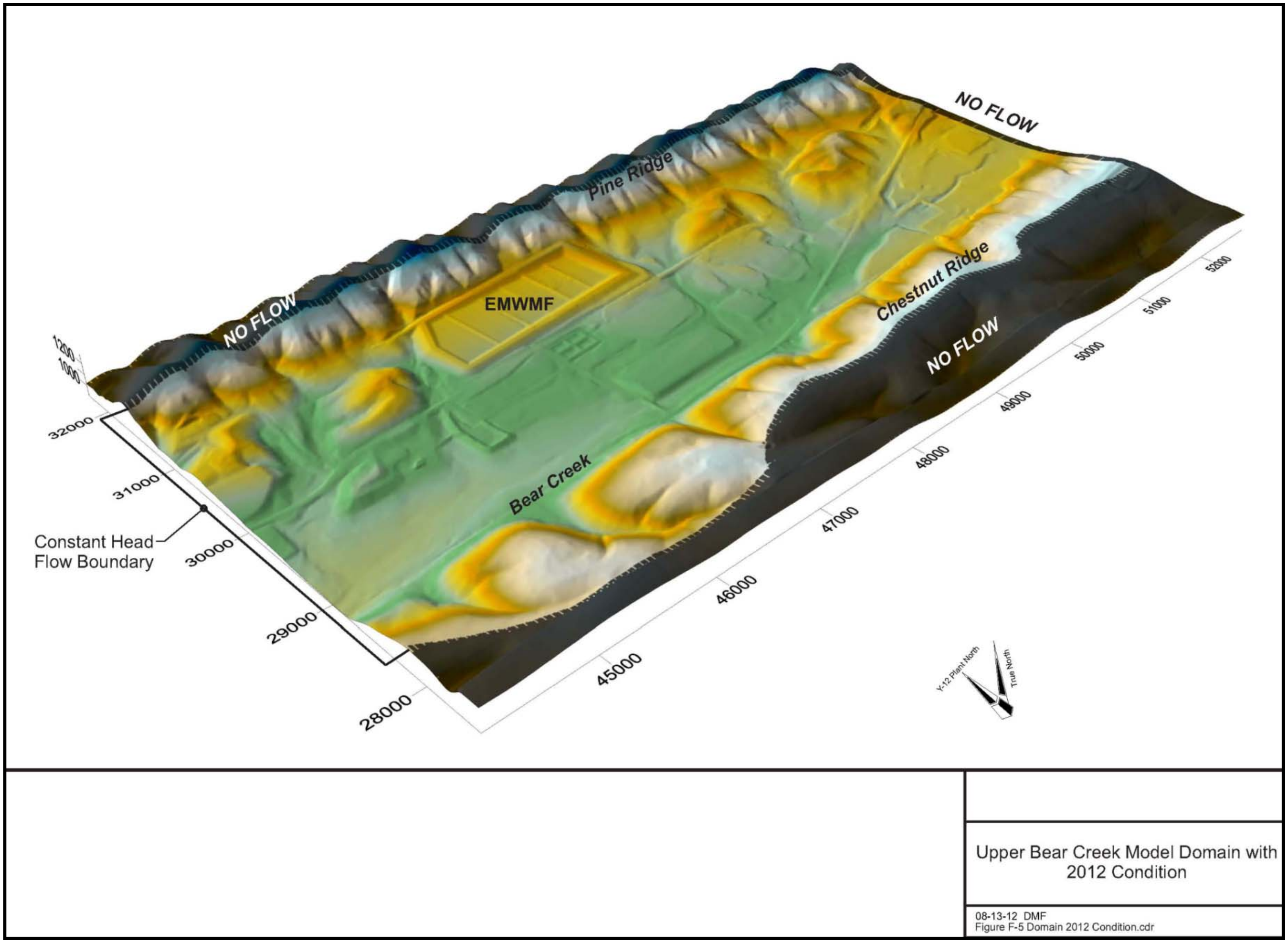


Figure F-5. Upper Bear Creek Model Domain with 2012 Condition

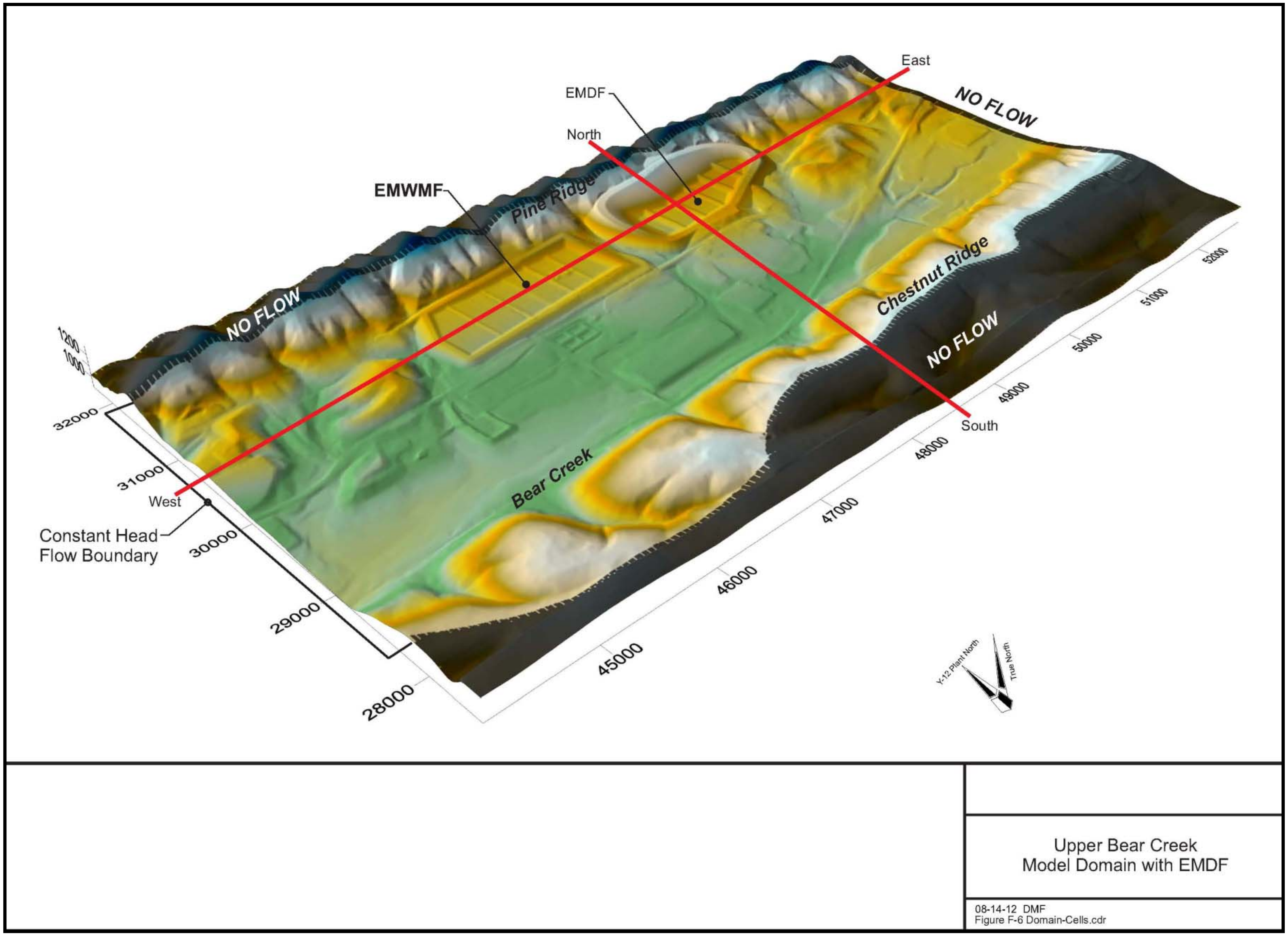


Figure F-6. Upper Bear Creek Model Domain with New Disposal Cell

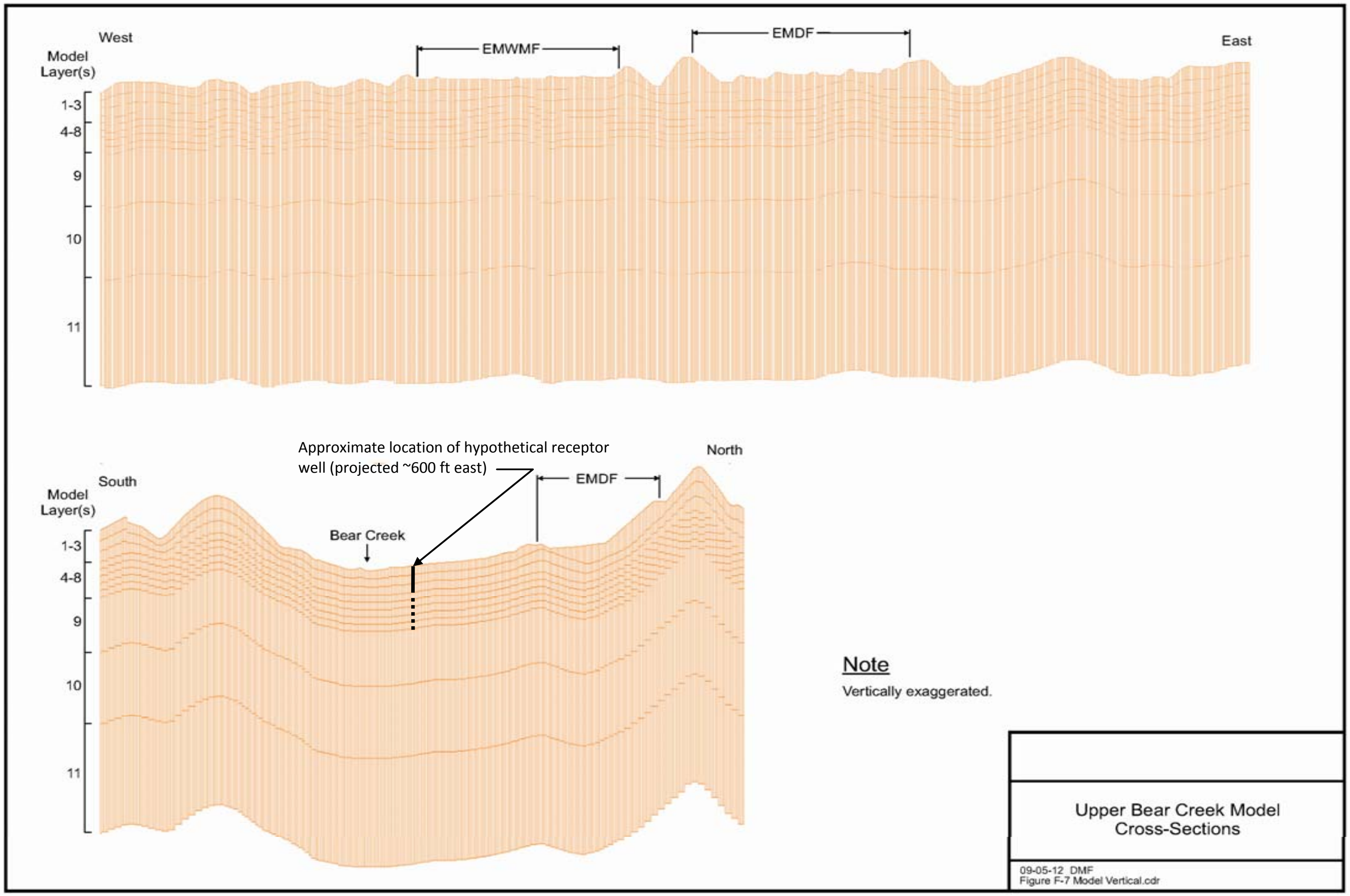


Figure F-7. Upper Bear Creek Model Cross-Sections

4.2.3 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 groundwater divide between BCV and Upper East Poplar Creek to the east (Figure F-5 and F-6). These boundaries match the natural groundwater divide. Constant head boundary conditions to the west were assumed based on a steady state simulation of the calibrated regional BCV groundwater flow model. The model boundary was established at a sufficient distance from the EMDF site to not be affected by topographic alterations associated with disposal cell development.

The base of the model is a no-flow boundary because minimal exchange of meteoric water with mineralized groundwater (i.e., brine) occurs below this depth (see Section 3.3.3.3 in Appendix C). 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, and French drains. The surface drainage features are represented in the model as drain cells (see Figure F-8). Drain cells allow groundwater to discharge into a surface water body. Actual stream bottom elevations were assigned in the model.

Infiltration from precipitation is assumed to be the sole source of recharge to groundwater for the site-specific UBCV model as the site is bounded on three sides by no-flow boundaries. Excluding the disposal cell area, infiltration is precipitation minus runoff and evapotranspiration and the recharge rate is a function of geologic media, surface slope, and vegetation. Five different recharge rates were assigned in the model (see Figure F-9) corresponding to (1) natural recharge to the carbonates, (2) natural recharge to the shales, (3) natural recharge to the sandstones, (4) reduced recharge through existing caps at former and operating waste disposal sites, and (5) the reduced recharge through the proposed disposal cell in a degraded state. An infiltration precipitation recharge rate of 0.42 in. per year through the proposed disposal cell cap was used in the future condition model. This value, considered to be a worst-case condition, was derived from a hydrologic analysis conducted with the HELP Model (Schroeder, et. al., 1994) as described in Section 4.1.2.

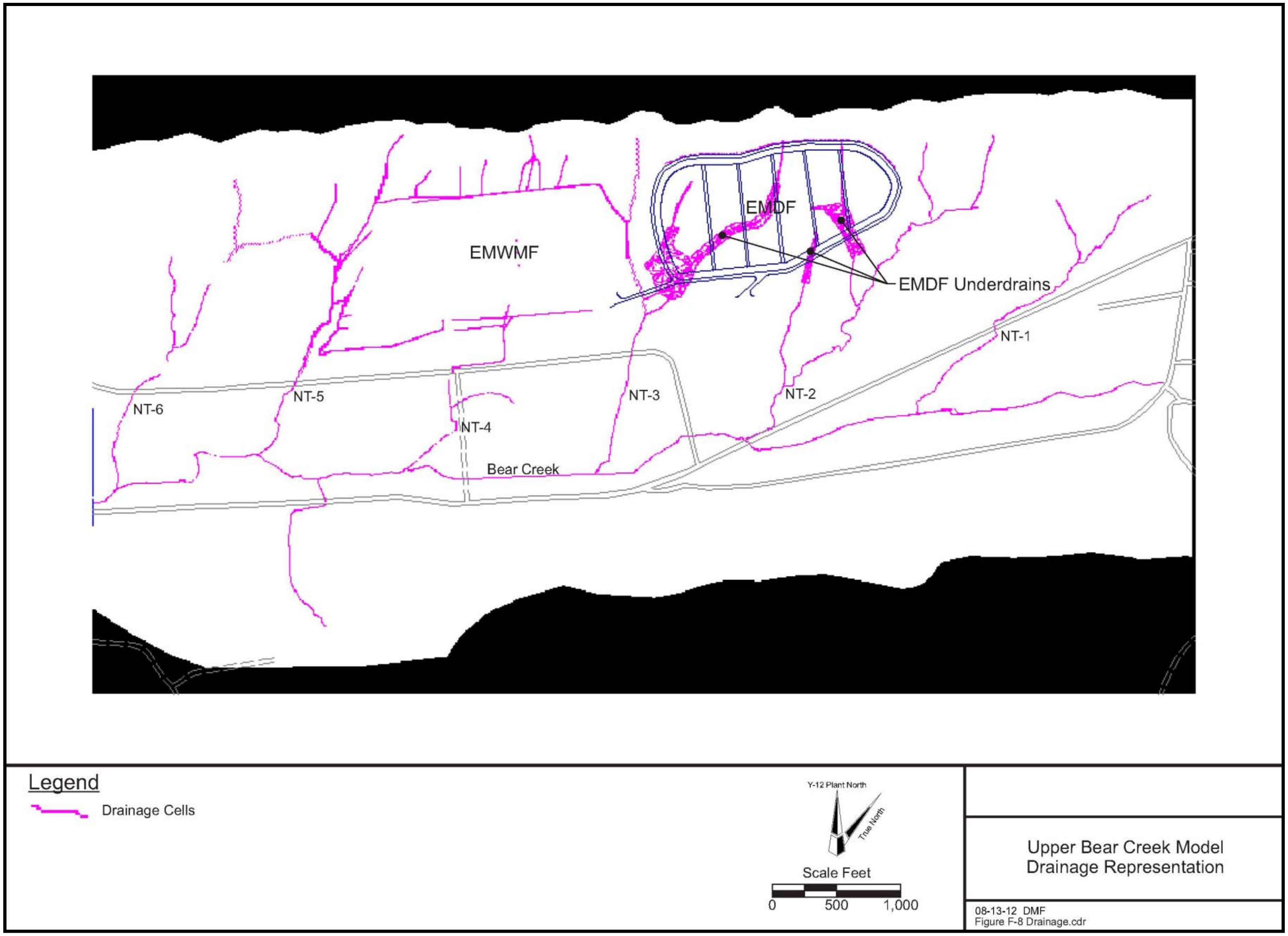


Figure F-8. Upper Bear Creek Model Drainage Representation

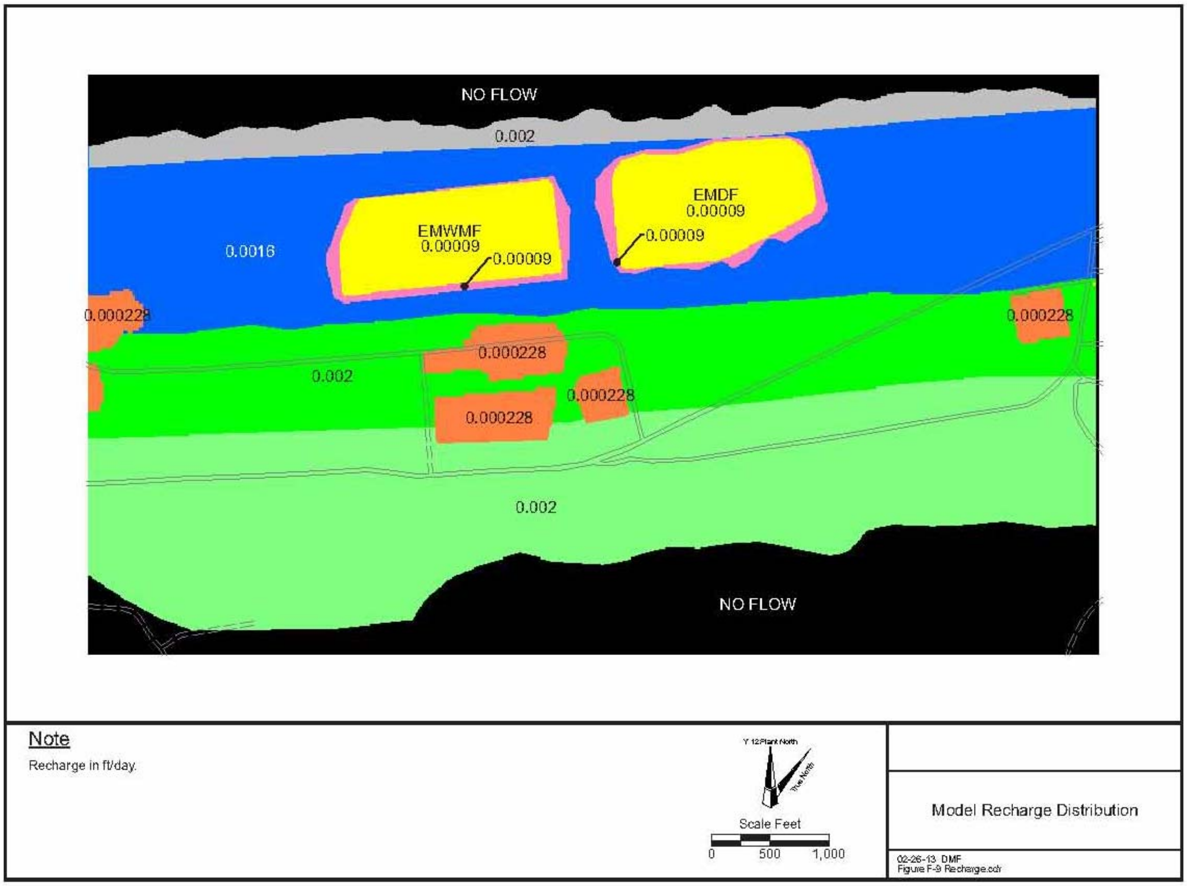


Figure F-9. Model Recharge Distribution

4.2.4 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 vs. Kx (Kz)] of five to one (for weather bedrock zone) and ten to one (for fractured bedrock zone) were used to represent the preferred fracture/bedding orientation of the natural 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 Bear Creek Valley (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 FS report (DOE 1997). A summary was also presented in a journal publication (Evans, et al. 1996). All these data indicated the anisotropy nature in the aquifer of Bear Creek and the anisotropic relationship with depth. 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 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 degree dip is input by staggering of hydrogeologic units with depth. Model layers 1-3 represent the unconsolidated/weathered bedrock zone. Model layers 4 through 6 represent the top bedrock interval between 50 and 150 ft. Model layers 7 through 9 represent the intermediate/deep bedrock zone.

Figure F-10 shows the zones of hydraulic conductivities used to represent hydrogeologic units in Model Layer 1. Figure F-11 shows the hydraulic conductivity field in a vertical south-north cross section. Table F-4 provides a summary of model parameters for the future condition UBCV model. All parameter values shown in Table F-4 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.

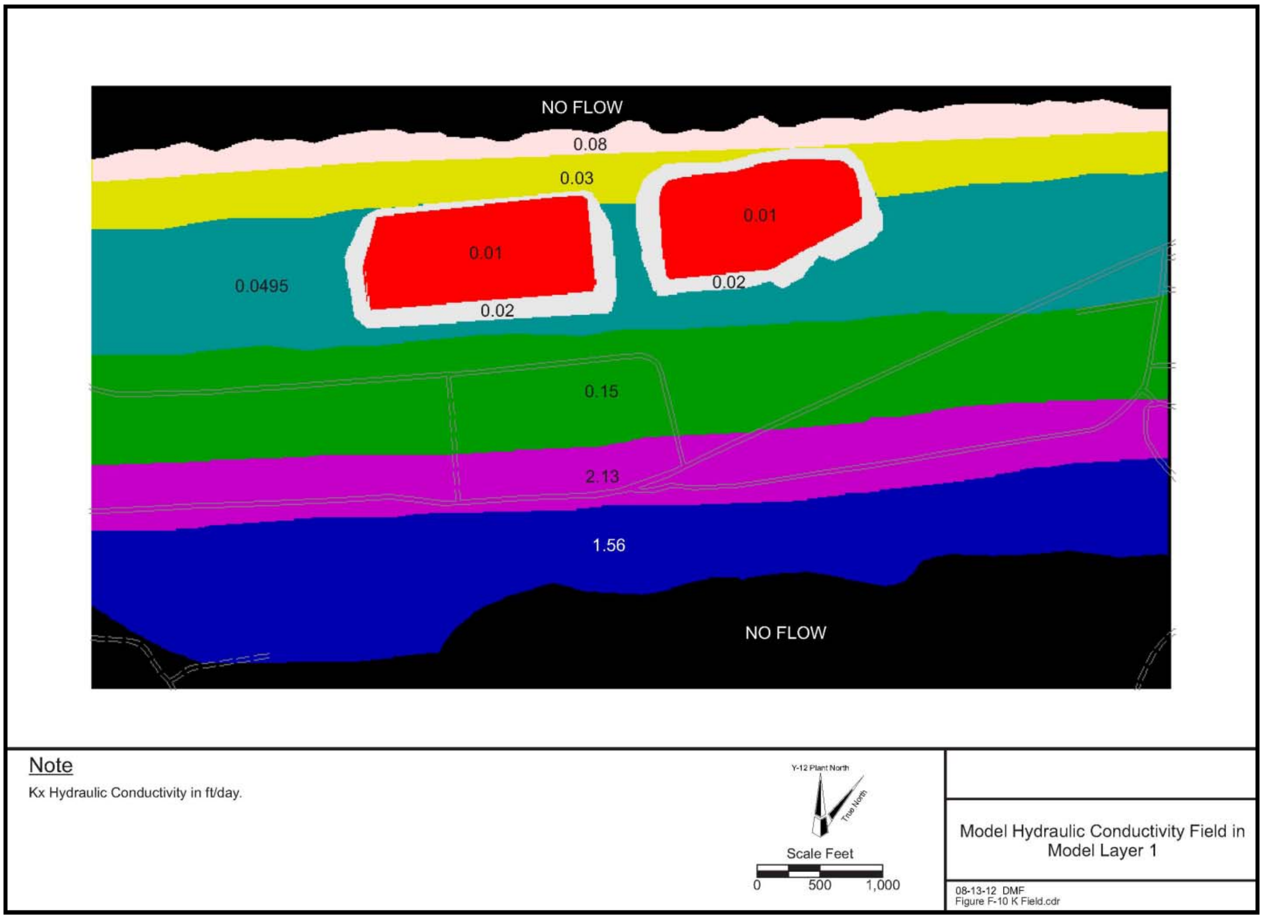


Figure F-10. Model Hydraulic Conductivity Field in Model Layer 1

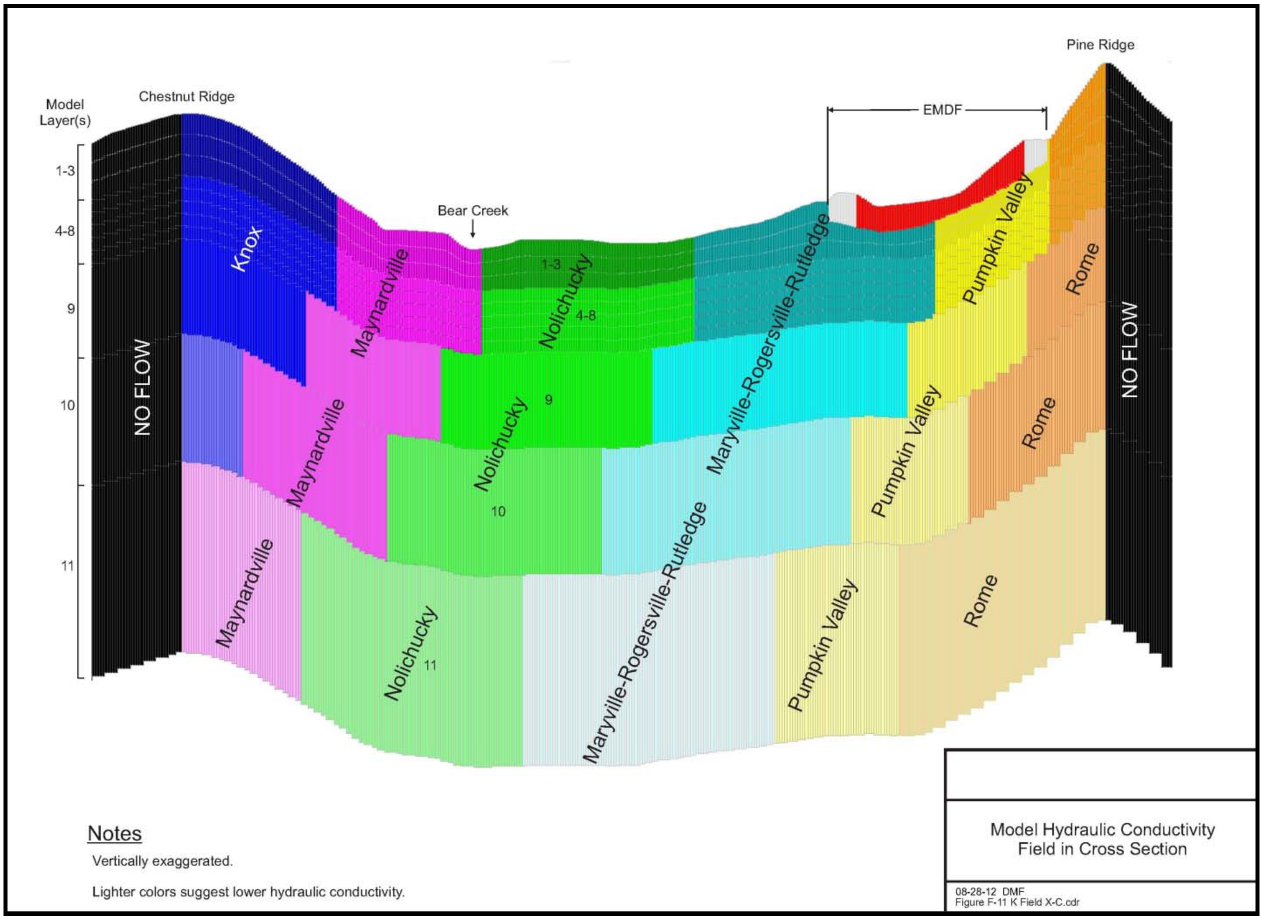


Figure F-11. Model Hydraulic Conductivity Field in Cross Section

Table F-4. UBCV Groundwater 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	ft	

Table F-4. UBCV Groundwater Model Parameter Summary (Future Condition) (Continued)

GRID DIMENSIONS (CONTINUED)					
Vertical Spacing					
Layers 1 – 3	Variable (10-25)	ft			
Layers 4 - 8	20	ft			
Layer 9	150	ft			
Layer 10	200	ft			
Layer 11	300	ft			
COORDINATE TRANSFORMATION					
X Offset (to Y-12 Coordinate System)	52723.33	ft			
Y Offset (to Y-12 Coordinate System)	27510.47	ft			
Rotation	90.23	degree			
MODEL BOUNDARY CONDITIONS					
Constant Heads	3,981	# of cells			
Rivers	0	# of cells			
Drains*	126,126	# of cells			
General Heads	0	# of cells			
Wells	8	# of cells			
No Flow	968,751	# of cells			
RECHARGE					
Areas/Geologic Units	**Recharge Rate**	**Unit**			
Closed Landfill/Paved Park Area	2.28E-04	ft/day			
Rome	2.00E-03	ft/day			
Maryville-Rogersville-Rutledge	1.60E-03	ft/day			
Nolichucky	2.00E-03	ft/day			
Knox	2.00E-03	ft/day			
EMDF* and EMWMF	9.00E-05	ft/day			
HYDRAULIC CONDUCTIVITY					
Material or Geologic Formation	**Model Layer**	**Kx**	**Ky**	**Kz**	**Unit**
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	ft/day
Knox	9	2.54E-03	2.54E-02	2.54E-03	ft/day
Knox	10	1.16E-03	1.16E-02	1.16E-03	ft/day
Knox	11	3.60E-04	3.60E-03	3.60E-04	ft/day
Maynardville	1--3	2.13E+00	1.07E+01	2.13E+00	ft/day
Maynardville	4--8	1.21E-02	1.21E-01	1.21E-02	ft/day
Maynardville	9	3.34E-03	3.34E-02	3.34E-03	ft/day
Maynardville	10	1.52E-03	1.52E-02	1.52E-03	ft/day
Nolichucky	1--3	1.50E-01	7.50E-01	1.50E-01	ft/day
Nolichucky	4--8	6.81E-03	6.81E-02	6.81E-03	ft/day
Nolichucky	9	2.52E-03	2.52E-02	2.52E-03	ft/day
Nolichucky	10	6.10E-04	6.10E-03	6.10E-04	ft/day
Nolichucky	11	5.00E-05	5.00E-04	5.00E-05	ft/day

Table F-4. UBCV Groundwater Model Parameter Summary (Future Condition) (Continued)

HYDRAULIC CONDUCTIVITY (CONTINUED)					
Material or Geologic Formation	**Model Layer**	**Kx**	**Ky**	**Kz**	**Unit**
Maryville-Rogersville-Rutledge	1--3	4.95E-02	2.48E-01	4.95E-02	ft/day
Maryville-Rogersville-Rutledge	4--8	3.60E-03	3.60E-02	3.60E-03	ft/day
Maryville-Rogersville-Rutledge	9	1.35E-03	1.35E-02	1.35E-03	ft/day
Maryville-Rogersville-Rutledge	10	3.20E-04	3.20E-03	3.20E-04	ft/day
Maryville-Rogersville-Rutledge	11	4.50E-05	4.50E-04	4.50E-05	ft/day
Pumpkin Valley	1--3	3.00E-02	1.50E-01	3.00E-02	ft/day
Pumpkin Valley	4--8	4.72E-03	4.72E-02	4.72E-03	ft/day
Pumpkin Valley	9	1.75E-03	1.75E-02	1.75E-03	ft/day
Pumpkin Valley	10	4.20E-04	4.20E-03	4.20E-04	ft/day
Pumpkin Valley	11	5.60E-05	5.60E-04	5.60E-05	ft/day
Rome	1--3	8.00E-02	4.00E-01	8.00E-02	ft/day
Rome	4--8	5.00E-03	5.00E-02	5.00E-03	ft/day
Rome	9	2.00E-03	2.00E-02	2.00E-03	ft/day
Rome	10	5.00E-04	5.00E-03	5.00E-04	ft/day
Rome	11	8.00E-05	8.00E-04	8.00E-05	ft/day
compacted clay	1	1.00E-02	1.00E-02	1.00E-02	ft/day
compacted clay berm	1	2.00E-02	2.00E-02	2.00E-02	ft/day

* Indicates the parameter shown for the future condition model is different from the current condition (2012) model parameter

4.2.5 Model Calibration

Calibration of a groundwater 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 groundwater 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 groundwater flow model, additional extensive calibration of the refined model is usually not necessary. Since there are no new groundwater monitoring wells installed within the proposed EMDF area and all previous monitoring wells have been used in UBCV model calibration, well-specific head comparison with the monitoring wells within the EMDF area was not performed. Instead, model predicted water level distribution pattern, flow path, and mass (water) balance were used for the model calibration process using the current condition UBCV model.

The water balance conducted for the calibrated current condition UBCV model compared observed and predicted groundwater discharge rates. Groundwater 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 groundwater discharge above the Bear Creek/NT-3 junction is 0.31 cfs. For comparison, the average flow rate measured at the location is 0.55 cfs (Appendix C, Section 3.0), which includes both base flow (groundwater 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 5%. The water balance shows that essentially all water has been mathematically accounted for and that MODFLOW simulation has correctly solved the governing flow equations. The comparison suggests that the UBCV model provides very good discharge result, indicating that the parameters (K) and recharge rates are properly represented in the model.

4.2.6 Sensitivity Analysis

The Maynardville Formation in BCV, composed of interbedded limestone and shale, underlies the valley floor. The main channel of Bear Creek tends to follow the lower Maynardville units. The Maynardville contains numerous well-developed cavities which form an interconnected strike-parallel conduit system. A dense network of fractures also occurs in the Maynardville Limestone, and these are connected to fractures in the other stratigraphic units of the BCV. See Section 3.3.1.3 in Appendix C for a more detailed discussion of cavities/conduits in BCV.

To evaluate the possible impact of these features on flow velocities and contaminant transport, a sensitivity analysis was conducted using the current condition (2012) model. The sensitivity analysis was conducted by assigning very high permeabilities to simulate the presence of a highly conductive fracture or conduit in the bedrock unit along geologic strike in the valley axis.

Two scenarios were analyzed in the sensitivity analysis. The first scenario assumed the high density fractures/conduits occur within the bedrock zone (model layers 4 - 8) and second assumed that they occur in both weathered and bedrock zones (model layer 1 - 8) in the Maynardville. In both scenarios, the hydraulic conductivity in the strike (valley axis) direction of the zone was increased by a factor of 10 from the base (current condition) model. Figures F-12 and F-13 show the model predicted water levels compared to the base case for Scenarios 1 and 2 in shallow and intermediate groundwater zones, respectively. As shown in the figures, the impact of extremely high permeability along the valley axis causes changes in the groundwater levels and flow field. For the first scenario where a higher density of fractures/conduits occur only within the bedrock zone (model layers 4 -8), the impact is minimal because most of the active groundwater flow is within weathered bedrock zone. In the second scenario, where high density fractures/conduits occur in both weathered and bedrock zone (model layer 1 - 8), the water levels in the intermediate groundwater zone are primarily impacted in the Maynardville Limestone, and not the surrounding units. The change to groundwater levels and the flow field in the EMDF footprint area is negligible. The model predicted water levels and flow field for the second scenario are inconsistent with current groundwater levels observed in the field. This indicates that there may not be full down-valley connectivity of conduits in the Maynardville Limestone, or that there are some limiting restrictions within the conduit system. Thus, it is an unlikely scenario.

The sensitivity analysis suggests that although the presence of larger and denser fractures or dissolution/karst features may impact the groundwater flow velocity within the Maynardville Limestone, it has minimal impact on the protectiveness of the PWAC, as demonstrated by the results of the fate-transport model. In addition, because the peak risk calculated for any time during the 0 to 100,000-year period modeled for each individual constituent is used to develop the analytic PWAC, the rapid first arrival of contaminants (e.g., as reported for tracer tests) is less important than the overall water balance data used to establish dilution ratios for calculating the PWAC. Because the risk receptor is assumed to be near the junction of Bear Creek and NT-3, higher conductivities in this area would result in higher DFs and lower contaminant concentrations. The base-case current condition model accurately represents hydraulic heads and surface water discharge as determined by the water budget, and is therefore appropriate to develop the future condition model that is used to calculate risks from DLs between source and exposure area that are based on ratios of Darcy fluxes.

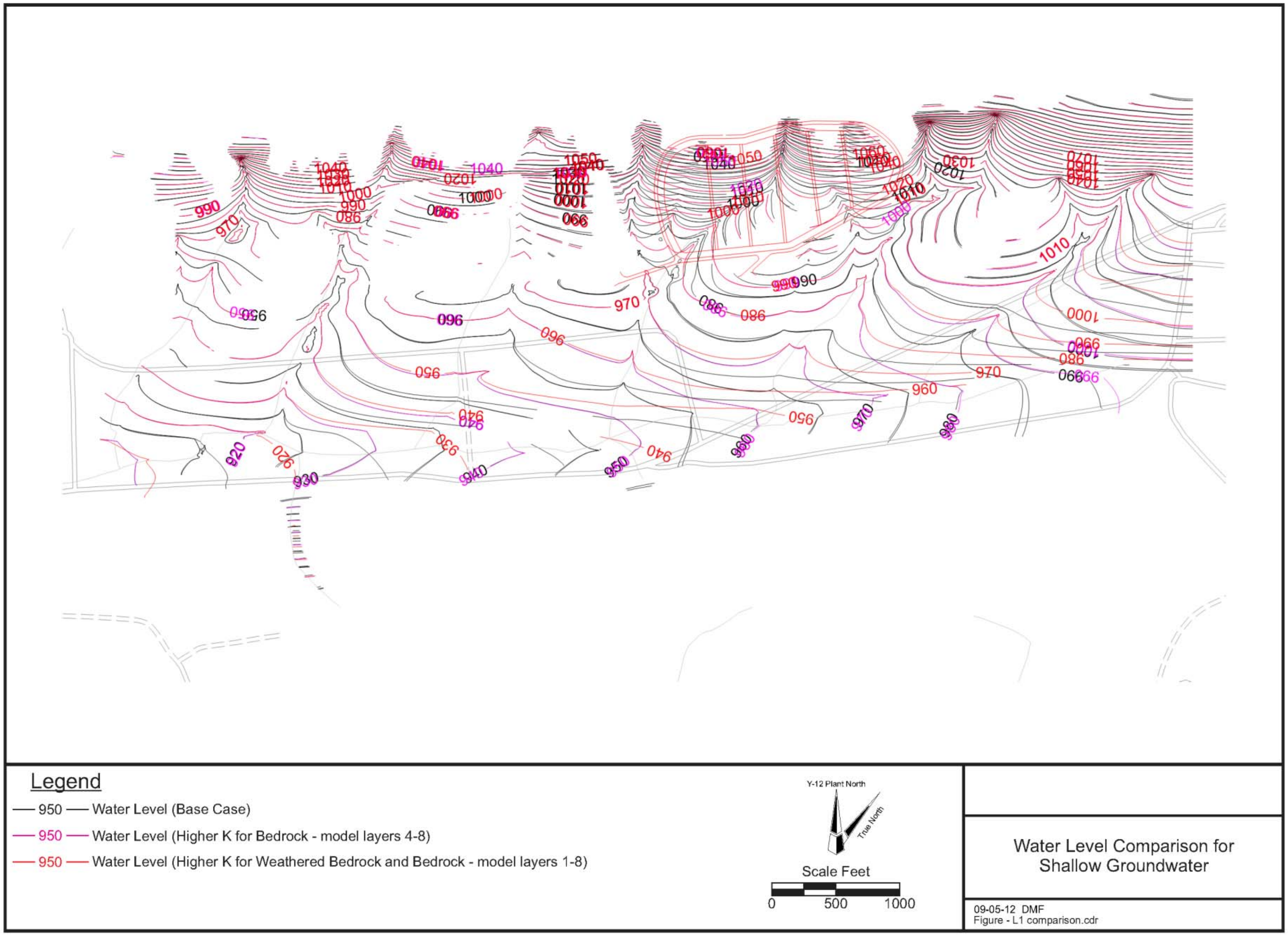


Figure F-12. Water Level Comparison for Shallow Groundwater

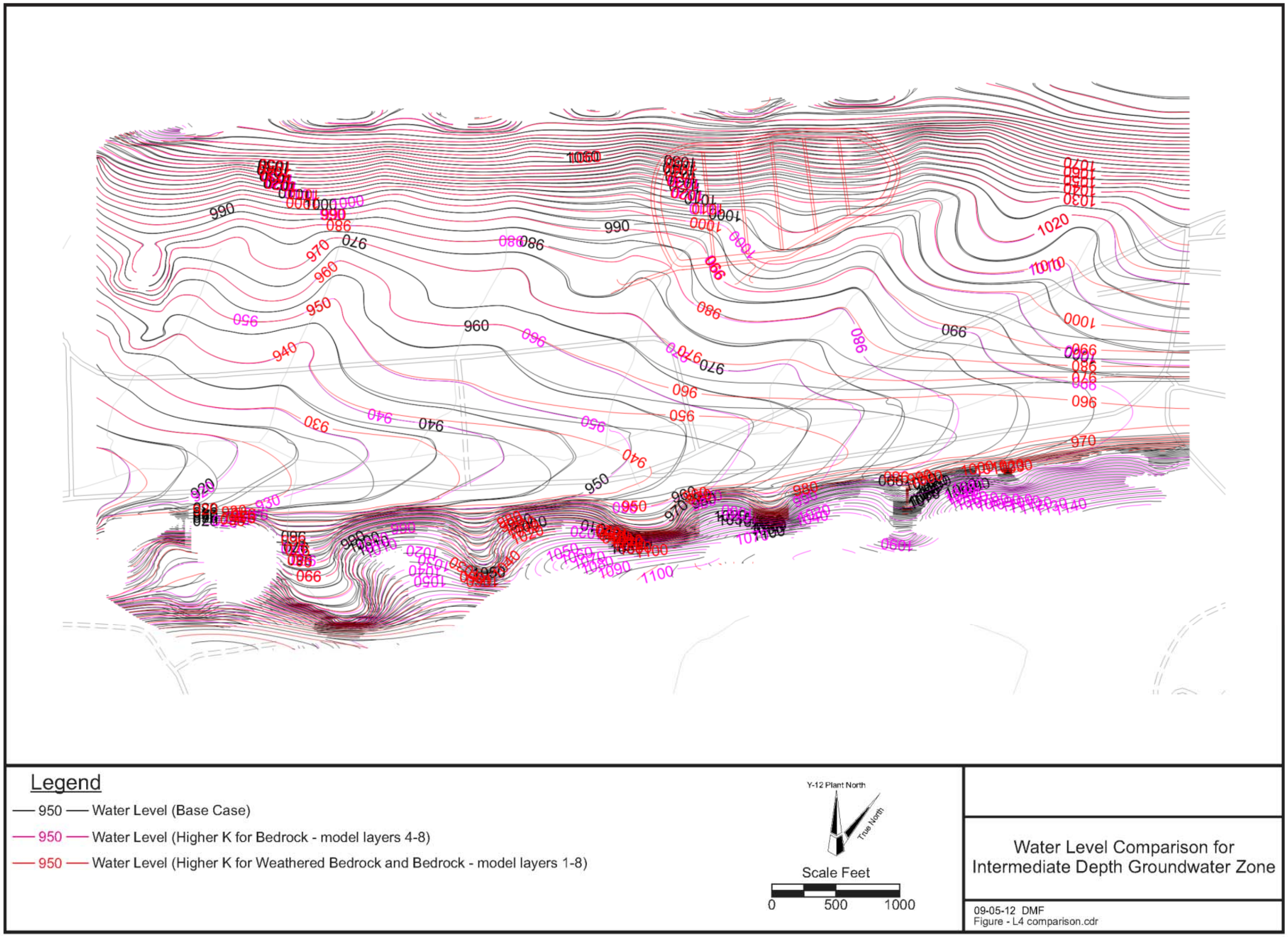


Figure F-13. Water Level Comparison for Intermediate Depth Groundwater Zone

4.2.7 Groundwater Model Results – Future Condition

Figures F-14 and F-15 show the future condition model predicted shallow and intermediate zone groundwater levels and flow direction and gradient. Generally, the figures indicate that shallow groundwater discharges into Bear Creek and its tributaries. However the tributaries exhibit a less pronounced influence on groundwater flow in the intermediate bedrock groundwater zone. Even though there is an upward gradient toward the NTs in the intermediate zone, the flow vectors indicate deeper groundwater may underflow the NTs. The simulated groundwater 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 C.

Groundwater flow paths and particle travel times from cells to surface discharge locations are determined using the MODPATH model (Pollock 1989). Figure F-16 shows the groundwater flow paths and discharge locations from various cell locations. The data are used to calculate the flow velocity in the groundwater zone that are used for PATHRAE modeling.

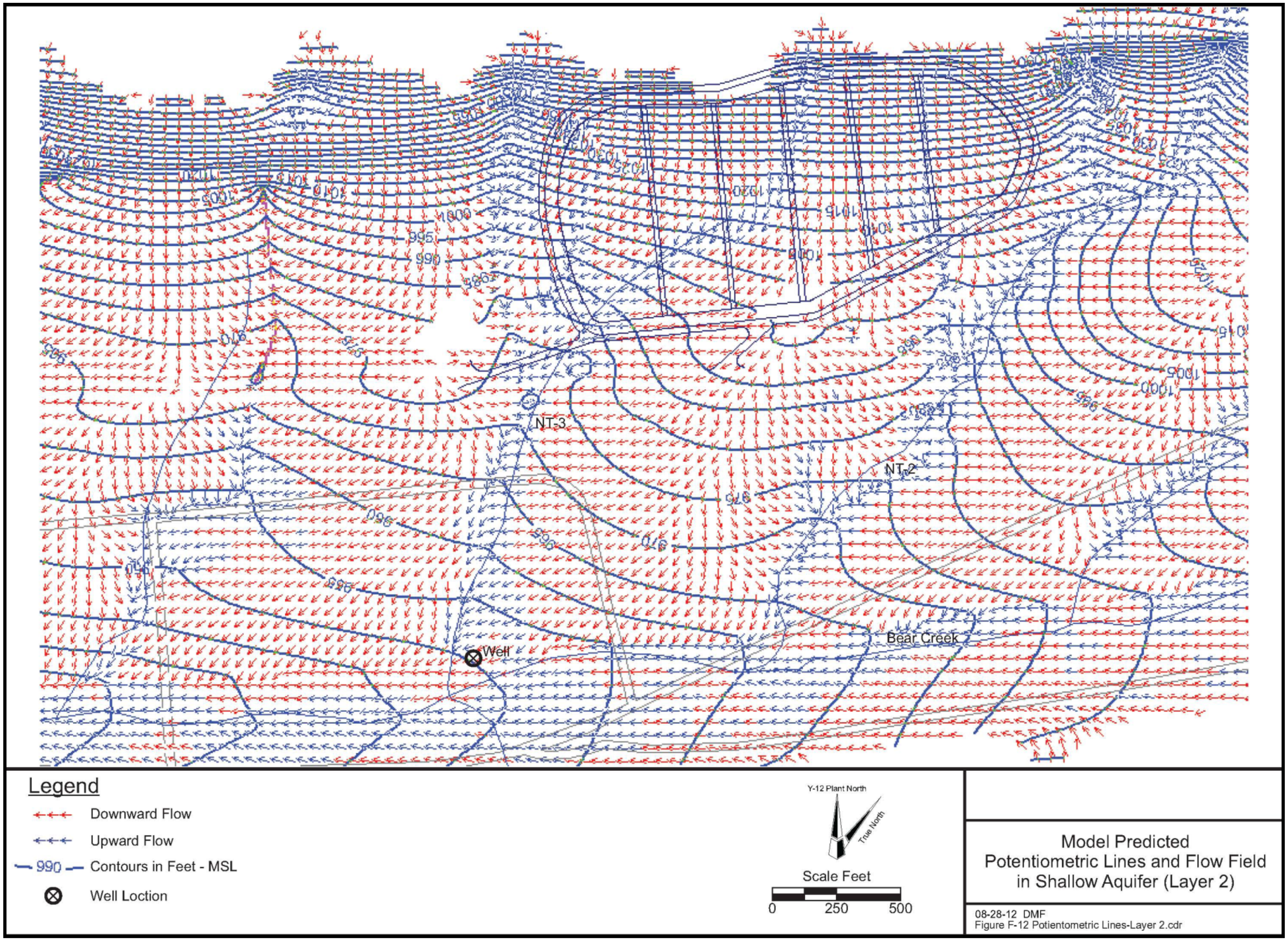


Figure F-14. Model Predicted Potentiometric Lines and Flow Field in Shallow Aquifer

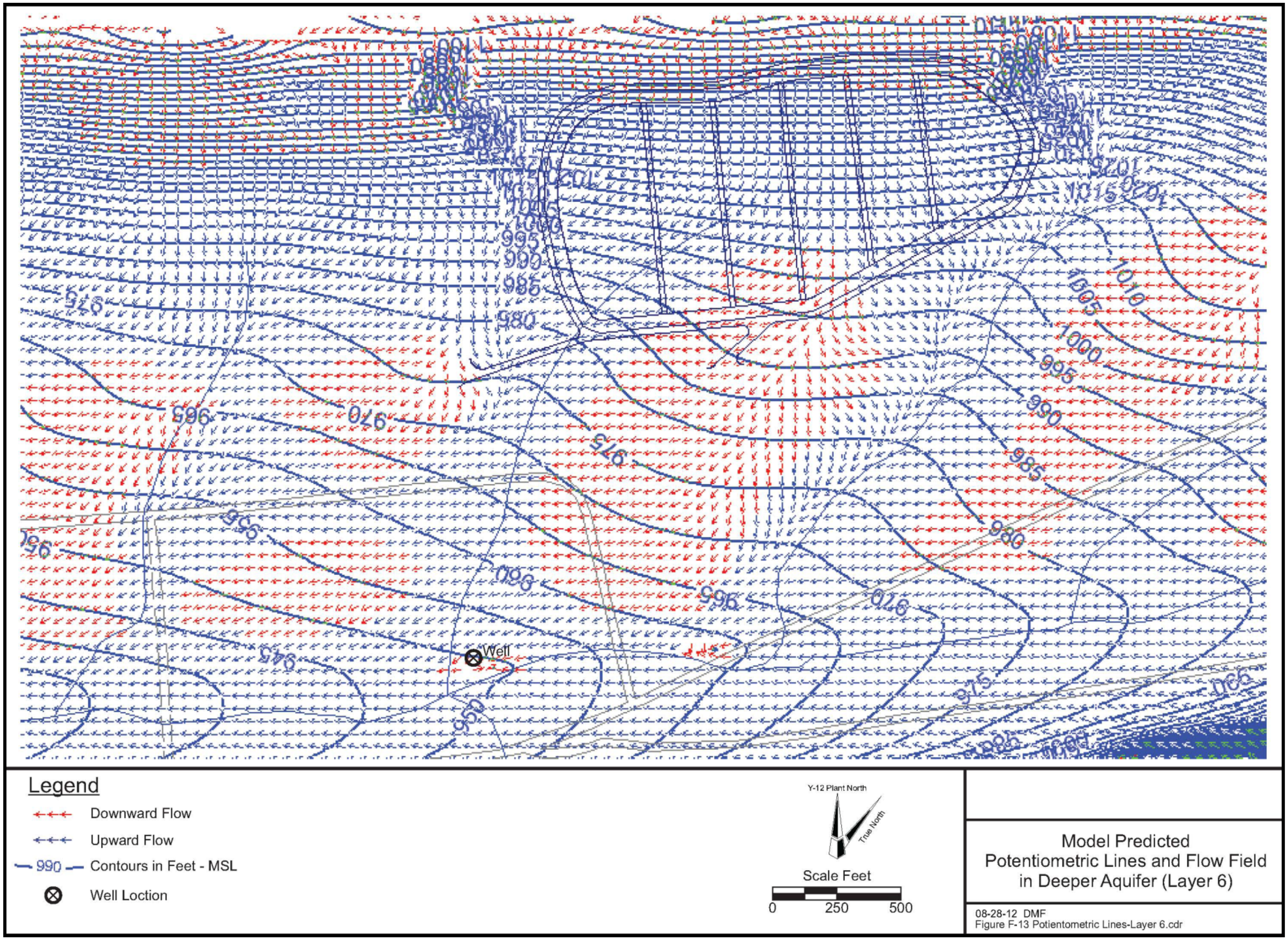


Figure F-15. Model Predicted Potentiometric Lines and Flow Field in Intermediate Aquifer

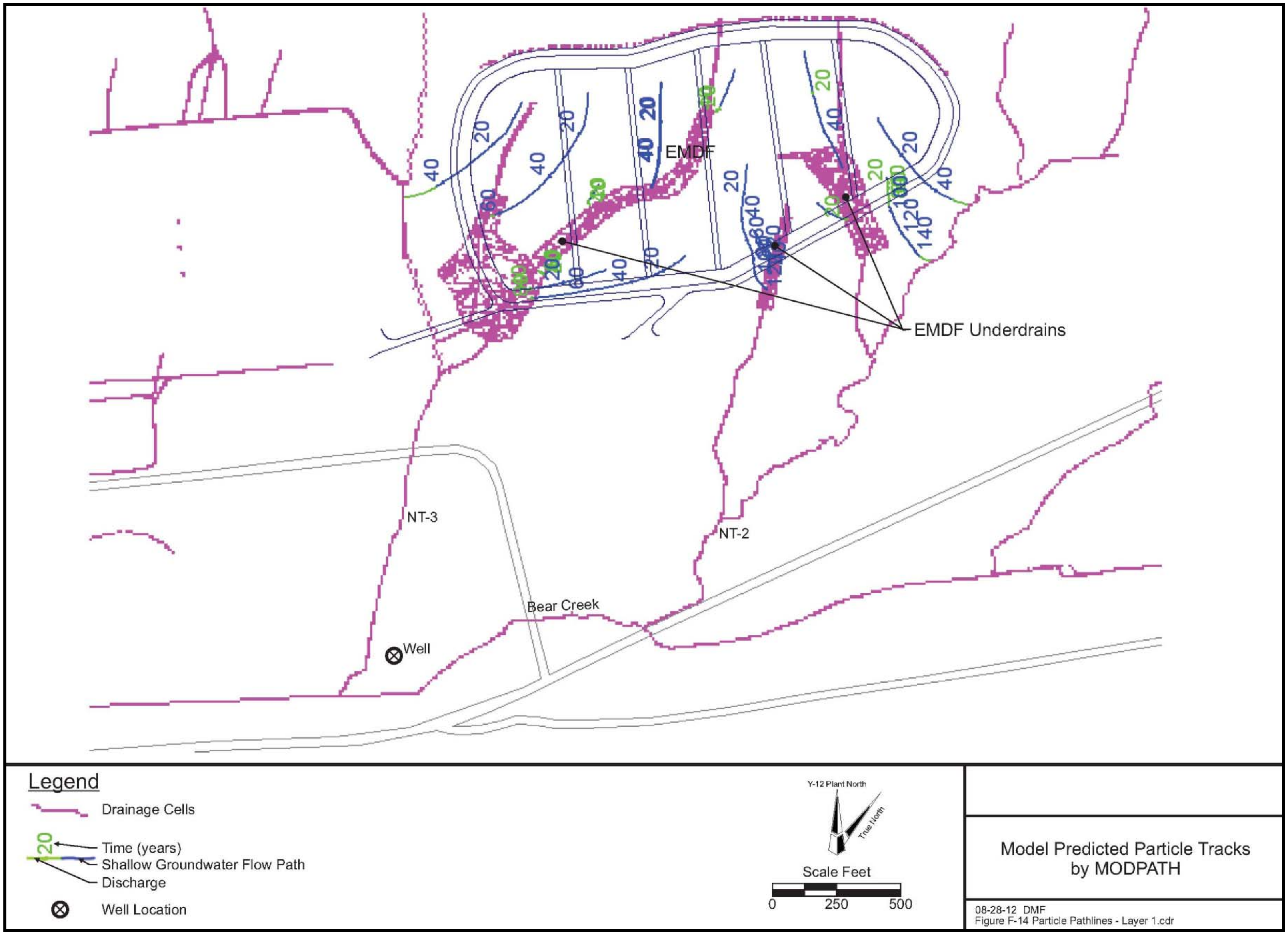


Figure F-16. Model Predicted Particle Tracks by MODPATH

4.3 FATE-TRANSPORT MODEL APPLICATION

The movement of contaminants from the waste cell to various receptors outside of the waste disposal site in groundwater were simulated by using MT3D (Zheng, 1990), a fate-transport model code that is coupled to the groundwater flow field results for the future site condition generated by MODFLOW. Based on the results of MODFLOW flow simulation for the future closed EMDF scenario, MT3D is used to predict the contaminant concentration distribution in the site.

A constant leaching source from the waste disposal cell to groundwater underneath the cell was assumed in the model (see Figure F-17). This is a very conservative assumption as the contaminant mass (thus leaching rate) will likely decrease due to reduced mass in the cells. 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.

To perform risk analysis on the proposed EMDF, a risk scenario was analyzed in which a hypothetical domestic groundwater supply well is placed hydraulically downgradient from the disposal cell. The hypothetical well is assumed to be located on the BCV floor between the EMDF and Bear Creek before the intersection of downgradient tributary NT-3 as shown in Figure F-17. The location is similar to the well setting for the EMWMF WAC analysis, and is completed in model layers 5 through 8. The well location was selected in the Nolichucky Shale near the more permeable Maynardville/Nolichucky formation boundary at a depth where sufficient water yield is met. Other factors, such as distance to the resident farmer's house and the topography of EBCV were considered. The well is assumed to be a typical domestic water supply well that pumps water from the bedrock aquifer. The well is pumped at a rate (240 gallons per day) to supply water adequate for a family of four.

The model analyses were carried out in the following steps:

1. For the pumping well location and well scenario, a groundwater flow simulation run was performed to determine the specific groundwater 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 (C_L= 1) for the duration of the model simulation. This establishes a constant DF that is later applied to all contaminants.
3. For the risk scenario, a concentration versus time graph was plotted to show the concentration change with pumping at the well location.

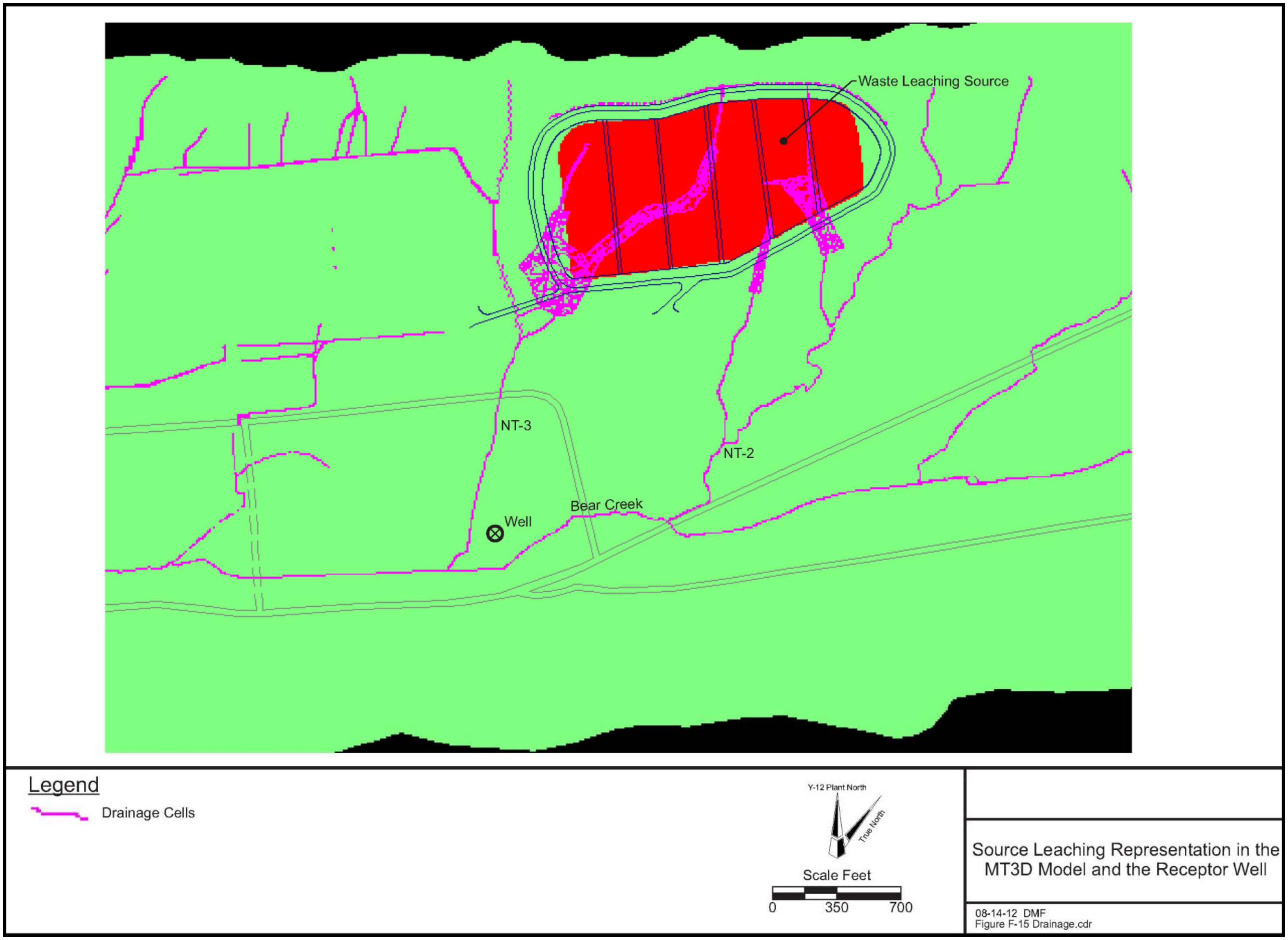


Figure F-17. Source Leaching Representation in the MT3D Model and the Receptor Well

Based on the results of UBCV flow simulations for the closed-cell scenario (i.e., permanent cover system in place) with a water supply well, the MT3D code was used to predict the contaminant concentration distribution in the site. Figure F-18 shows the steady-state plume in the shallow groundwater intervals. 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 F-18 shows the relative groundwater concentration as compared to the leachate concentration at the source. As predicted by the site conceptual model, most of the shallow plume discharges into surface water features (gravelly backfilled former tributaries, NT-3, and Bear Creek).

Figure F-19 shows the steady state plume in Model Layer 6 and is representative of the plume at the screened interval of the hypothetical receptor well. The plume shows some local irregularities because the model layers cross stratigraphic boundaries and vary in elevation across the modeled area. Figure F-20 shows the steady plume distribution in a south-north cross section. The plume maps in Figures F-18 through F-20 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. As noted above, model layers 1 through 8 are relatively thin, reflecting the fact that most groundwater flow occurs in the shallow interval. Model layers 9 through 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 were calculated in the same manner as for the EMWMF. The DF_{well} values are defined as the ratios of C_{well} [the peak steady-state contaminant concentrations in the continuously pumped well (240 gallons per day)] to C_L [the unit contaminant concentrations (leachate) entering the groundwater beneath the disposal facility]. Figure F-21 shows the predicted concentrations in model layers at the hypothetical domestic groundwater supply well location. The hypothetical receptor well is screened at depths corresponding to model layers 5 through 8. The average C_{well}/C_L or DF_{well} extracted from the well screen is also shown in Figure F-21. This calculated average ratio of the concentration at the well relative to leachate concentration at the cells is 0.000015 which equals the DF_{well}.

The calculated DFs for the residential well, along with DF calculated for surface water at Bear Creek, are used to calculate the projected peak risks and doses from radioactive or hazardous constituents for risk analysis as discussed in Section 5.2.

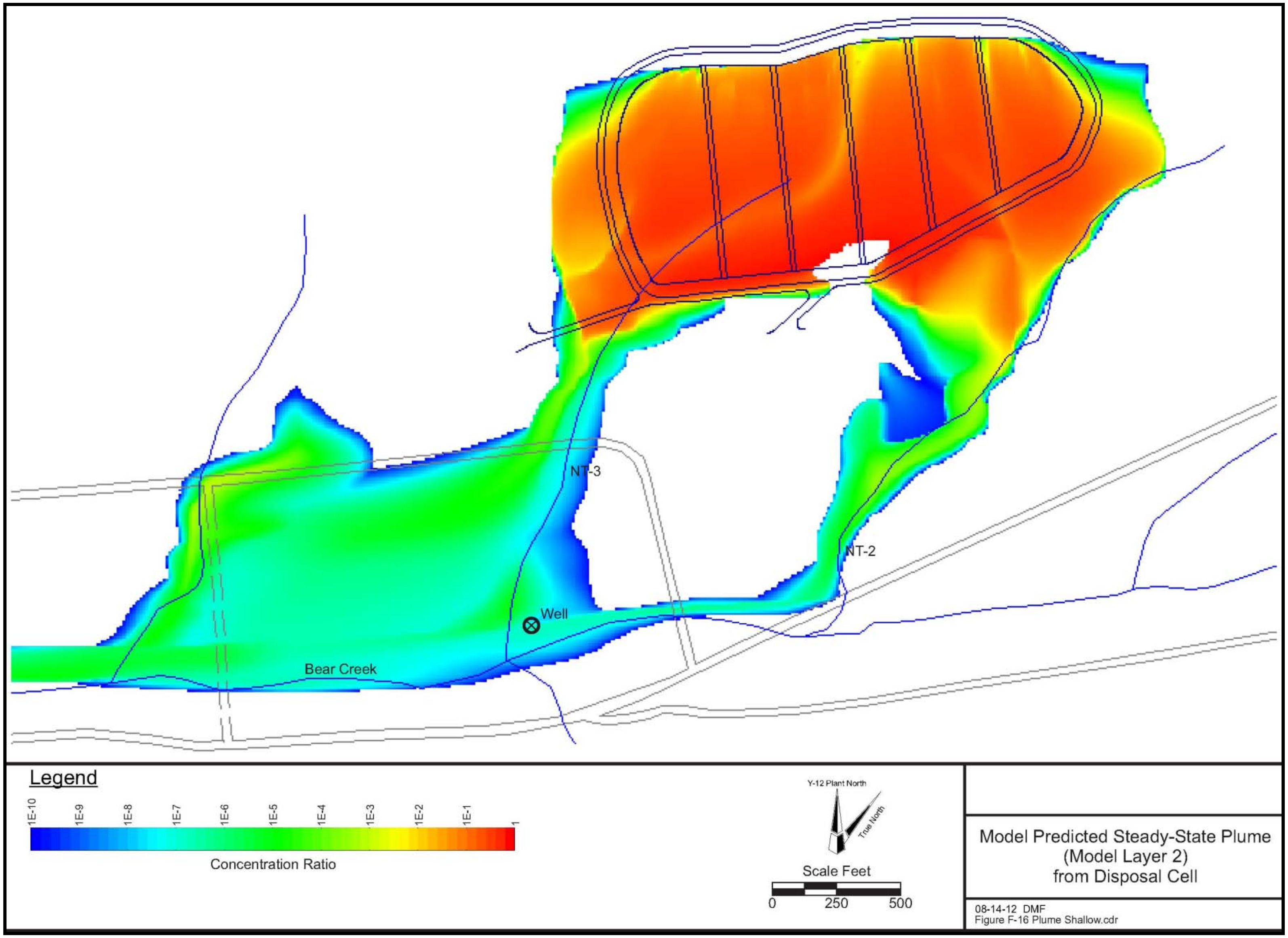


Figure F-18. Model Predicted Steady-state Plume (Model Layer 2) Result from Disposal Cell

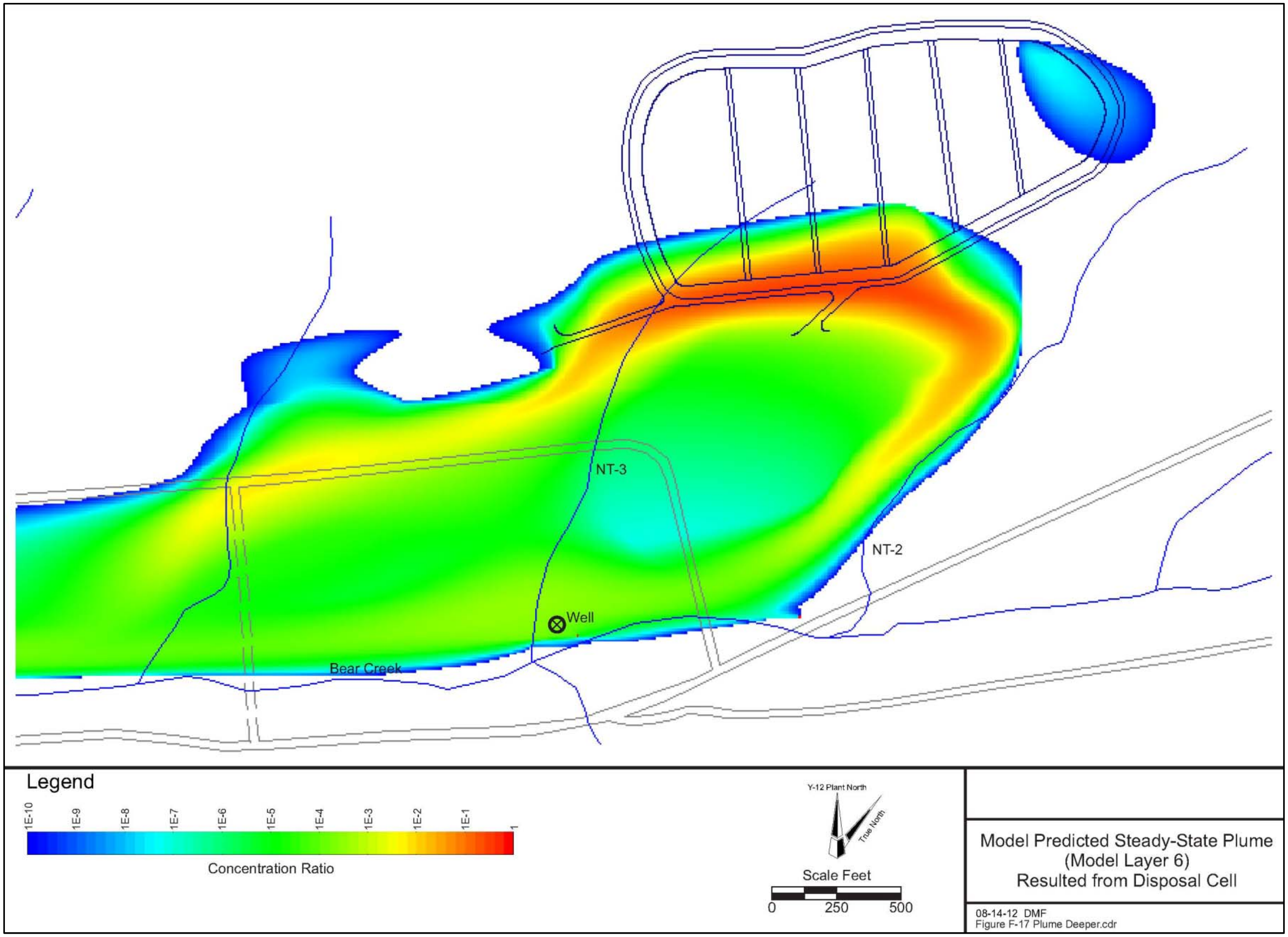


Figure F-19. Model Predicted Steady-state Plume (Model Layer 6) Result from Disposal Cell

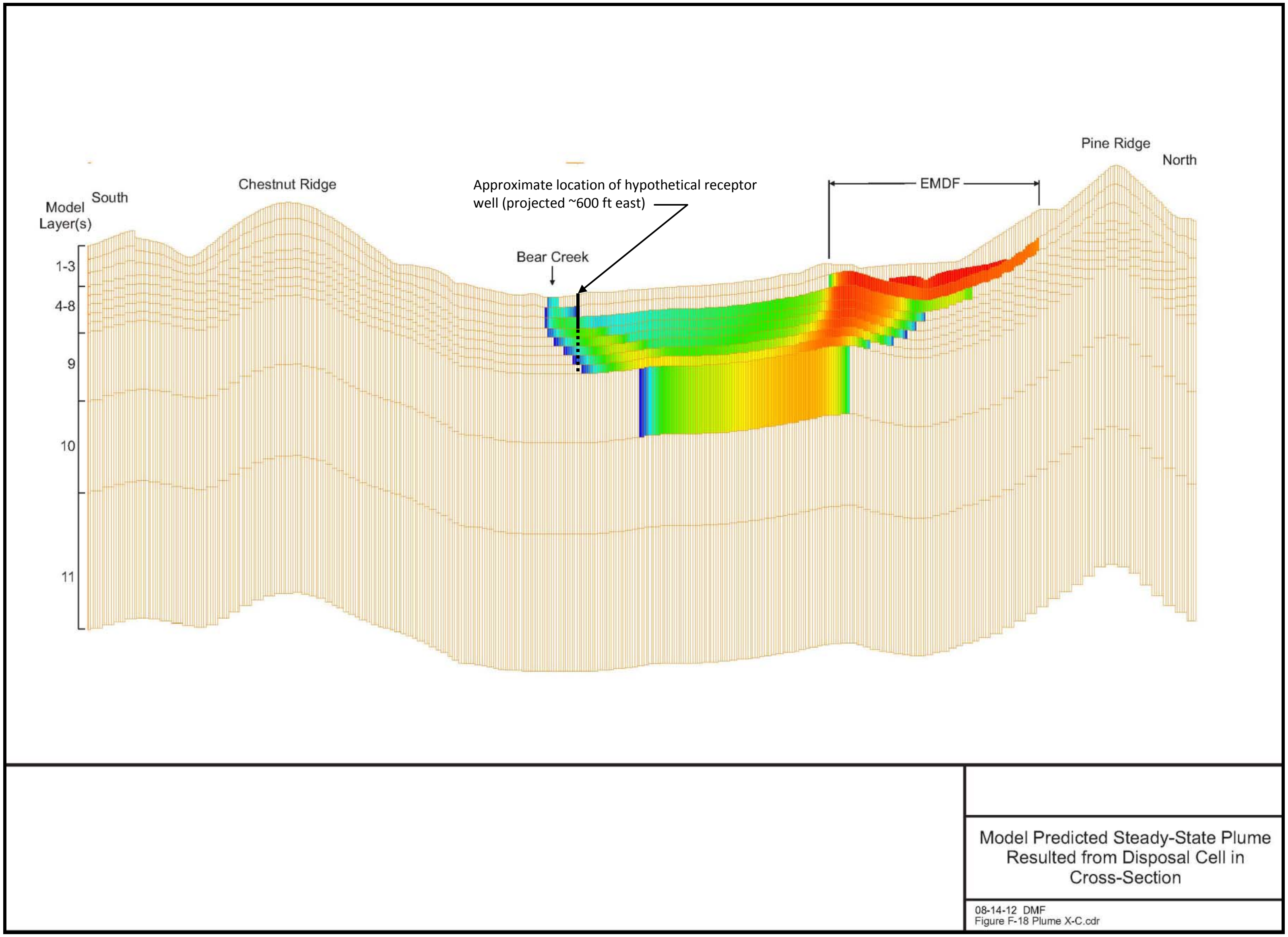
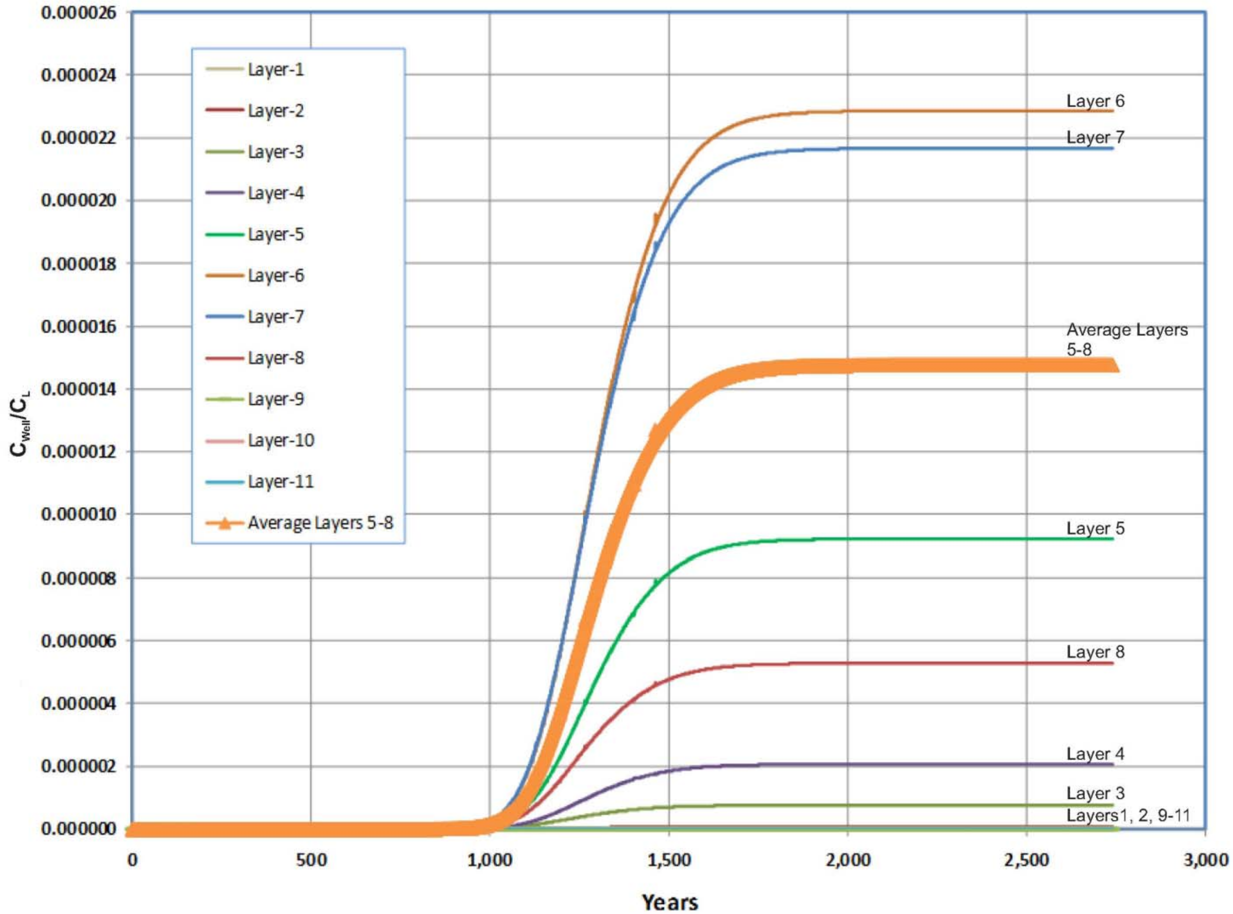


Figure F-20. Model Predicted Steady-state Plume Result from Disposal Cell in Cross-section



Legend

C_{well} - Well Concentration
C_L - Leachate Concentration

Model Predicted Groundwater Concentrations (Relative to Leachate) with Time

08-28-12 DMF
Figure F-19 Concentrations.cdr

Figure F-21. Model Predicted Groundwater Well Concentrations (Relative to Leachate) with Time

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5. PATHRAE MODELING AND RISK/DOSE ANALYSIS

The PWAC development methodology used for the proposed EMDF is similar to the methodology used to develop the EMWMF WAC (DOE 1998a, b). The PATHRAE model is used to estimate the risk and dose for the surface water pathway and additional calculations are used to determine overall risk and dose for the hypothetical receptor. It is assumed under the hypothetical receptor scenario that a resident farmer family of four consumes drinking water from a well and uses Bear Creek surface water for agricultural purposes.

PATHRAE model input and assumptions are described in Section 5.1. PATHRAE model output and risk/dose calculations are described in Section 5.2.

5.1 PATHRAE MODEL INPUT AND ASSUMPTIONS

Developing a PWAC for a constituent requires determining the risk/dose to a potentially exposed resident farmer from a unit concentration in the waste that occupied the entire disposal facility volume (1 Ci/m^3 for radiological and 1 mg/kg for toxicological constituents, respectively). The risk and hazard index calculated for unit source terms is then used to rescale the allowable waste concentration (PWAC) to correspond to the risk and dose criteria for the 0 to 1,000 - and >1,000 to 100,000-year time frames (see Section 2.3 of this Appendix).

Using the input parameters generated from supporting models and site-specific data, PATHRAE-RAD and PATHRAE-HAZ modeling are used to perform risk analysis. The PATHRAE analyses are conducted for the points of assessment of the EMDF.

The assumed waste contaminant leaching characteristics used a simple K_d release mechanism. The K_d values that were used to develop the EMWMF WAC are also used, with minor updates, to develop the PWAC for the proposed EMDF and all waste being modeled is assumed to be soil-like. Since the waste zone is assumed to be a constant leaching source with fixed leaching characteristics for each contaminant through the duration of the model, using a K_d for a neutral pH condition is the most representative approach. The majority of projected waste to be generated is debris; however, as shown in Fig. 2-2 in Chapter 2 of this RI/FS, the volume of clean fill and waste fill that would actually occupy the proposed 2.5M yd^3 facility is roughly twice the volume of debris. Debris would be surrounded in the landfill by clean and waste soil fill to meet void fill 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. Section 6.2 of this Appendix provides additional information about the soil-like material assumption.

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 2012) are used to calculate risk/dose in groundwater and surface water pathways. Where no values are provided in the EPA risk guidance, values previously used to calculate the EMWMF WAC are used. Also, site-specific parameters for the proposed EMDF design and conditions are used. Table F-5 summarizes the input parameters used to conduct PATHRAE analysis.

Table F-5. EMDF Parameters for PATHRAE and PWAC Calculation

Zone	Parameter	Value	Unit
Top/Surface	Cover thickness	13	ft
	Porosity of surface soil	0.25	vol/vol
Waste Zone	Waste volume	2500000	cubic yard
	X (along groundwater flow path)	1596	ft
	Y (cross groundwater flow path)	798	ft
	Disposal cell surface area	1273134	ft^2
	Waste thickness (average)	53	ft
	Waste density	1600	kg/m^3
	Recharge rate to groundwater from waste zone	0.4	in/yr
	Amount of water percolating through the waste cell	0.00135	cfs
Vadose Zone	Depth to groundwater	23	ft
	Bulk soil density	1600	kg/m^3
	Porosity of vadose zone	0.25	vol/vol
	Saturated hydraulic conductivity of vadose zone	1.00E-06	cm/s
Groundwater	Bedrock density	1800	kg/m^3
	Soil/Weathered bedrock porosity	0.2	vol/vol
	Bedrock porosity	0.05	vol/vol
	Longitudinal dispersivity in bedrock aquifer	6	meter
	Transverse dispersion coefficient in bedrock aquifer	0	m^2/yr
	Horizontal groundwater velocity (calculated using particle tracking trajectories)	14	ft/yr
Surface Water	Stream flow rate at compliance point (Junction NT-3 and Bear Creek)	0.55	cfs
	Surface water Dilution Factor	0.00245	unitless
	Distance from nearest edge of waste to surface water compliance location	1570	ft
Groundwater Well	Groundwater well Dilution Factor	0.000015	unitless

5.2 PATHRAE MODEL OUTPUT AND RISK/DOSE CALCULATIONS

PATHRAE-RAD and PATHRAE-HAZ models were used to calculate the arrival and peak time for the radioactive constituents and toxicological constituents at the surface water receptor location, respectively. For each contaminant that has peaked within the 100,000-year timeframe, the peak concentration of the contaminant in the creek is used.

The PATHRAE model was used to determine the equivalent annual water consumption per year for the creek water for each nuclide based on the three exposure pathways, as stated in Section 2.3. PATHRAE uses total equivalent uptake (EU) factors to represent and quantify the annual amount of nuclide consumed by a individual from all potential exposure pathways (EPA 1987). For the ingestion pathway, it 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, milk, and drinking water. Thus, the specific pathways by which contaminants are ingested and the quantities of the contaminated foods ingested are built into the uptake factors.

The input and output text files for the PATHRAE model runs (PATHRAE-RAD and PATHRAE-HAZ) are included in the Section 3 of the modeling attachment to this Appendix. The input files contain all the input parameters in tabulated form.

The calculated DFs for the creek and residential well were used for scaling the constituent concentrations in the creek to corresponding well concentrations. The DF calculations are carried out in the following steps:

- The steady state well concentration (maximum concentration) obtained while pumping (C_{well}) was compared (i.e., ratioed) to a unit seepage from the disposal cell (C_L) to obtain a well dilution factor DF_{well} = steady-state pumped (0.167 gpm) concentration in the well divided by unit concentration seeping from disposal cell or C_{well}/C_L as shown in Figure F-21. As discussed in Section 4.3, the DF_{well} is obtained from the MT3D model. The steady state was established by assuming a constant leaching source of 1 ($C_L = 1$) for the duration of the model simulation. This establishes a constant DF ratio ($DF_{well} = 0.000015$) that is later applied to all contaminants.

- The surface water dilution factor DF_{creek} = water flux from disposal cell divided by creek water flow rate at the location in Bear Creek near the hypothetical receptor ($DF_{creek} = 0.00245$).

- Therefore, the modeled contaminant concentration in the well due to a unit waste concentration is then calculated $C_{well} = (DF_{well}/DF_{creek}) \text{ x } C_{creek}$ (PATHRAE modeled contaminant concentration in the surface water).

The peak effective risk or dose was calculated as the risk or dose due to ingestion of 730 L per year of water drawn from the well, plus the consumption of agricultural products and livestock irrigated or consumed with the creek surface water. Thus:

$PR_{eff} = PR_{creek} \times [EU - 730 + (DF_{well}/DF_{creek}) \times 730]/EU$, where

PR_{eff} = Peak Effective Risk,

PR_{creek} = Peak Creek Risk,

EU = Equivalent Uptake,

and DF_{well} and DF_{creek} are the DLs calculated for the well and the creek, respectively. Similarly,

$PD_{eff} = PD_{creek} \times [EU - 730 + (DF_{well}/DF_{creek}) \times 730]/EU$, where

PD_{eff} = Peak Effective Dose, and

PD_{creek} = Peak Creek Dose.

The Peak Creek Risk (PR_{creek}) or Peak Creek Dose (PD_{creek}) corresponds to ingestion of the creek water at the annual EU rate.

5.2.1 Radioactive Constituents - Risk

The Peak Creek Risk for radioactive constituents is:

$PR_{creek} = PC_{creek} \times EU \times SF \times$ 30-yr exposure duration, where

PC_{creek} = Peak Creek concentration, and

SF = Slope Factor = Excess Lifetime Cancer Risk (ELCR)/Concentration (pCi)

The Peak Creek concentration is calculated directly by the PATHRAE-RAD computer code and slope factors are obtained from the latest EPA risk guidance (EPA 2012).

5.2.2 Hazardous Constituents - Risk and Dose

For hazardous constituents, both carcinogenic risk and non-carcinogenic dose are calculated. For carcinogens:

$PR_{creek} = PLI_{creek} \times SF$, where

PLI_{creek} = Peak Creek Lifetime Intake for Carcinogens = $PC_{creek} \times EU \times$ 30-yr exposure duration/ [70 kg body weight × 365 d/yr × 70-yr life].

For non-carcinogens the Peak Creek Daily Intake (Dose) for non-carcinogens (PD_{creek}) is calculated using PATHRAE-HAZ generated data and the formula below:

$PD_{creek} = PC_{creek} \times EU/(70 \text{ kg body weight} \times 365 \text{ d/yr})$

The peak effective risks and doses calculated using the PATHRAE-RAD and PATHRAE-HAZ results and equations listed above for EMDF, based on unit source terms, are given in Tables F-6 and F-7 for the radioactive and hazardous contaminants of concern (COCs), respectively. The COC list is based on the list of constituents in Table A.1 of the approved EMWMF WAC (DOE 2001a, Table A.1 revised 10/28/2008) for which a WAC limit is provided.

Table F-6. Peak Effective Risks for the Proposed EMDF for Radioactive Constituents

Nuclide COC	Peak Conc. in Bear Creek (pCi/L) or PC_{creek}	Ingestion Slope Factor (1/pCi)	Equivalent Uptake (L/yr)	Peak Effective Risk* or PR_{eff} (GW+SW) (ELCR)	Peak Time (yr)
H-3	7.23E-05	5.07E-14	1.166E+03	4.84E-14	401
C-14	1.14E+06	1.55E-12	9.564E+02	1.22E-02	570
Tc-99	1.05E+06	2.75E-12	7.403E+02	1.27E-03	607
I-129	5.37E+05	1.48E-10	8.327E+02	2.55E-01	1,096
U-233	3.14E+04	7.18E-11	7.380E+02	8.39E-04	42,452
U-234	3.35E+04	7.07E-11	7.380E+02	8.82E-04	42,472
U-235	3.78E+04	6.96E-11	7.380E+02	9.79E-04	51,628
U-236	3.78E+04	6.70E-11	7.380E+02	9.43E-04	42,593
U-238	3.78E+04	6.40E-11	7.380E+02	9.01E-04	51,628
Np-237	2.65E+04	6.18E-11	7.338E+02	4.03E-04	90,317
Pu-239	2.03E+03	1.35E-10	7.329E+02	6.01E-05	88,714
Pu-240	2.22E+00	1.35E-10	7.329E+02	6.57E-08	87,960
Am-241	**	1.04E-10	7.338E+02	**	**

*Based on a 1 Ci/m^3 concentration in the waste.

** Contamination migration was modeled and radioactively decays to an insignificant level.

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Antimony	1.99E-03	6.94E-02	50,363	4.00E-04	7.332E+02			2.07E-05
Barium	6.95E-04	2.41E-02	144,849**	2.00E-01	7.372E+02			1.09E-05
Boron	1.23E-02	4.21E-01	8,369	2.00E-01	7.474E+02			3.59E-04
Chromium (Total)	3.99E-03	1.31E-01	26,741	1.00E+00	7.787E+02			2.72E-04
Lead	3.83E-04	1.33E-02	262,956**	1.40E-03	7.369E+02			5.88E-06
Manganese	1.91E-04	6.64E-03	525,416**	1.40E-01	7.355E+02			2.57E-06
Molybdenum	1.93E-03	6.59E-02	52,987	5.00E-03	7.498E+02			6.23E-05
Selenium	4.50E-03	8.77E-02	39,864	5.00E-03	1.312E+03			2.01E-03
Strontium	3.02E-03	9.73E-02	34,515	6.00E-01	7.941E+02			2.61E-04
Tin	1.55E-02	5.00E-01	7,057	6.00E-01	7.907E+02			1.28E-03
Vanadium	3.87E-04	1.33E-02	262,956**	5.00E-03	7.457E+02			1.04E-05
U-233	7.93E-04	2.75E-02	42,452	3.00E-03	7.371E+02			1.24E-05
U-234	8.46E-04	2.93E-02	42,472	3.00E-03	7.371E+02			1.32E-05
U-235	9.54E-04	3.31E-02	51,628	3.00E-03	7.371E+02			1.49E-05
U-236	9.53E-04	3.30E-02	42,593	3.00E-03	7.371E+02			1.49E-05

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
U-238	9.55E-04	3.31E-02	51,628	3.00E-03	7.371E+02			1.49E-05
2,4-D	4.71E-02	1.64E+00	1,039	1.00E-02	7.328E+02			4.63E-04
2,4,5-T[Silvex]	1.38E-02	4.81E-01	1,101	8.00E-03	7.342E+02			1.62E-04
Acenaphthene	2.37E-04	8.23E-03	241,959**	6.00E-02	7.365E+02			3.51E-06
Acenaphthylene	1.11E-03	3.87E-02	32,515	6.00E-02	7.337E+02			1.23E-05
Acetone	1.90E-01	6.63E+00	849	9.00E-01	7.328E+02			1.87E-03
Acetonitrile	2.42E-01	8.42E+00	699	6.00E-03	7.329E+02			2.41E-03
Acetophenone	1.53E-01	5.34E+00	885	1.00E-01	7.328E+02			1.51E-03
Acrolein	2.40E-01	8.35E+00	704	5.00E-04	7.329E+02			2.39E-03
Acrylonitrile	2.37E-01	8.27E+00	710	4.00E-02	7.328E+02	5.40E-01	5.40E-04	2.33E-03
Aldrin	1.17E-06	4.09E-05	256,132**	3.00E-05	7.330E+02	1.70E+01	8.64E-08	1.18E-08
Aroclor-1221	3.18E-04	1.11E-02	556,946**	0.00E+00	7.351E+02	2.00E+00	3.54E-06	4.11E-06
Aroclor-1232	3.33E-04	1.16E-02	75,580	0.00E+00	7.331E+02	2.00E+00	2.92E-06	3.41E-06
Benzene	2.05E-02	7.16E-01	4,779	4.00E-03	7.328E+02	5.50E-02	4.76E-06	2.02E-04
Benzoic Acid	2.35E-01	8.18E+00	698	4.00E+00	7.328E+02			2.31E-03

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Benzyl Alcohol	2.03E-01	7.08E+00	808	1.00E-01	7.328E+02			2.00E-03
Benzidine	6.76E-03	2.36E-01	14,878	3.00E-03	7.328E+02	2.30E+02	6.56E-03	6.65E-05
alpha-BHC	5.53E-04	1.92E-02	9,734	8.00E-03	7.342E+02	6.30E+00	1.75E-05	6.48E-06
beta-BHC	5.53E-04	1.92E-02	11,729	0.00E+00	7.346E+02	1.80E+00	5.22E-06	6.78E-06
delta-BHC	5.52E-04	1.92E-02	11,729	0.00E+00	7.329E+02	1.80E+00	4.24E-06	5.51E-06
Bromodichloromethane	2.09E-01	7.29E+00	733	2.00E-02	7.328E+02	6.20E-02	5.47E-05	2.06E-03
Bromoform	6.90E-03	2.41E-01	1,388	2.00E-02	7.328E+02	7.90E-03	2.30E-07	6.79E-05
Bromomethane	2.06E-01	7.20E+00	797	1.40E-03	7.328E+02			2.03E-03
Butylbenzene	4.23E-03	1.47E-01	5,728	5.00E-02	7.334E+02			4.50E-05
Carbazole	1.24E-04	4.33E-03	18,290	0.00E+00	7.340E+02	2.00E-02	1.22E-08	1.42E-06
Carbon Disulfide	8.14E-02	2.84E+00	919	1.00E-01	7.328E+02			8.01E-04
Carbon tetrachloride	1.62E-02	5.64E-01	6,039	4.00E-03	7.329E+02	7.00E-02	4.84E-06	1.62E-04
Chlordane	4.17E-06	1.35E-04	454,552**	5.00E-04	7.905E+02	3.50E-01	5.14E-08	3.42E-07
Chlorobenzene	3.44E-02	1.20E+00	1,974	2.00E-02	7.329E+02			3.43E-04
Chloroform	4.91E-02	1.71E+00	2,058	1.00E-02	7.328E+02	3.10E-02	6.41E-06	4.83E-04

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Chloromethane [Methyl Chloride]	2.06E-01	7.19E+00	799	0.00E+00	7.328E+02	1.30E-02	1.13E-05	2.03E-03
o-Chlorotoluene	2.58E-02	9.00E-01	3,385	2.00E-02	7.332E+02			2.68E-04
m-Cresol	1.51E-01	5.28E+00	895	5.00E-02	7.328E+02			1.49E-03
o-Cresol	1.13E-01	3.93E+00	1,168	5.00E-02	7.328E+02			1.11E-03
p-Cresol	1.53E-01	5.35E+00	885	1.00E-01	7.328E+02			1.51E-03
Cumene [Isopropylbenzene]	4.23E-03	1.47E-01	5,791	1.00E-01	7.334E+02			4.50E-05
Cyanide	3.79E-03	1.32E-01	26,479	6.00E-04	7.328E+02			3.73E-05
DDD	7.20E-06	2.16E-04	240,909**	0.00E+00	8.493E+02	2.40E-01	1.08E-07	1.05E-06
DDE	3.11E-06	9.62E-05	6,043	0.00E+00	8.270E+02	3.40E-01	5.56E-08	3.81E-07
Di-n-butylphthalate	2.68E-01	8.50E+00	693	1.00E-01	8.061E+02			2.68E-02
Dibromochloromethane	1.28E-01	4.47E+00	1,038	2.00E-02	7.328E+02	8.40E-02	4.54E-05	1.26E-03
1,2-Dichlorobenzene	5.52E-03	1.92E-01	2,982	9.00E-02	7.333E+02			5.80E-05
1,3-Dichlorobenzene	2.35E-03	8.19E-02	42,646	8.90E-02	7.335E+02			2.53E-05

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
1,4-Dichlorobenzene	5.61E-03	1.96E-01	4,475	7.00E-02	7.332E+02	5.40E-03	1.35E-07	5.82E-05
1,2,-cis-Dichloroethylene	3.31E-02	1.15E+00	3,731	2.00E-03	7.328E+02			3.26E-04
1,2-trans-Dichloroethylene	1.64E-01	5.72E+00	973	2.00E-02	7.328E+02			1.61E-03
Dichlorodifluoromethane	1.93E-02	6.73E-01	850	2.00E-01	7.328E+02			1.90E-04
1,2-Dichloropropane	1.52E-01	5.31E+00	890	9.00E-02	7.328E+02	3.60E-02	2.31E-05	1.50E-03
Dieldrin	1.26E-03	3.89E-02	86,175	5.00E-05	8.286E+02	1.60E+01	1.08E-03	1.57E-04
Diethylphthalate	7.45E-02	2.60E+00	1,388	8.00E-01	7.328E+02			7.33E-04
1,2-Dimethylbenzene	1.52E-02	5.29E-01	2,106	2.00E-01	7.330E+02			1.54E-04
2,4-Dimethylphenol	1.42E-02	4.96E-01	8,531	2.00E-02	7.328E+02			1.40E-04
Dimethylphthalate	1.65E-01	5.77E+00	966	1.00E+01	7.328E+02			1.62E-03
2,4 Dinitrotoluene	1.86E-02	6.49E-01	916	2.00E-03	7.328E+02	3.10E-01	2.43E-05	1.83E-04
2,6 Dinitrotoluene	2.43E-02	8.47E-01	859	1.00E-03	7.328E+02	6.8E-01	6.97E-05	2.39E-04
Endosulfan plus metabolites	3.11E-05	1.08E-03	13,899	6.00E-03	7.334E+02			3.31E-07
Endrin	1.74E-05	6.01E-04	57,187	3.00E-04	7.400E+02			3.39E-07
Endrin Aldehyde	1.74E-05	6.01E-04	62,772	3.00E-04	7.400E+02			3.39E-07

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Endrin Ketone	1.74E-05	6.01E-04	62,772	3.00E-04	7.400E+02			3.39E-07
Ethylbenzene	1.17E-02	4.06E-01	1,879	1.00E-01	7.330E+02	1.10E-02	5.55E-07	1.18E-04
Ethylchloride	1.87E-01	6.52E+00	868	4.00E-01	7.328E+02	2.90E-03	2.29E-06	1.84E-03
Heptachlor	1.25E-05	4.33E-04	126,476**	5.00E-04	7.365E+02	4.50E+00	3.57E-07	1.85E-07
Heptachlor Epoxide	1.47E-05	4.81E-04	45,901	1.30E-05	7.789E+02	9.10E+00	3.91E-06	1.01E-06
Hexachlorobenzene	4.49E-07	1.49E-05	289,202**	8.00E-04	7.695E+02	1.60E+00	1.76E-08	2.56E-08
Hexachloroethane	3.46E-03	1.20E-01	9,839	7.00E-04	7.342E+02	4.00E-02	6.93E-07	4.06E-05
n-Hexane	6.57E-04	2.28E-02	1,533	6.00E-02	7.342E+02			7.70E-06
1-Hexanol	2.09E-01	7.29E+00	789	4.00E-02	7.328E+02			2.06E-03
2-Hexanone	2.09E-01	7.29E+00	789	5.00E-03	7.328E+02			2.06E-03
Isophorone	2.05E-02	7.16E-01	4,779	2.00E-01	7.329E+02	9.50E-04	8.34E-08	2.04E-04
Lindane	5.53E-04	1.92E-02	18,238	3.00E-04	7.337E+02	1.10E+00	2.87E-06	6.11E-06
Methanol	2.41E-01	8.40E+00	701	5.00E-01	7.330E+02			2.44E-03
Methylene Chloride	1.91E-01	6.65E+00	853	6.00E-03	7.328E+02	2.00E-03	1.61E-06	1.88E-03
Methylcyclohexane	9.66E-04	3.37E-02	793	6.00E-02	7.329E+02			9.63E-06

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Methyl Isobutyl Ketone	2.37E-01	8.25E+00	711	8.00E-02	7.328E+02			2.33E-03
Methyl Methacrylate	2.16E-01	7.54E+00	767	1.40E+00	7.328E+02			2.13E-03
1-Methyl-4-(1-methylethyl)-benzene	4.21E-03	1.47E-01	4,826	3.70E-02	7.334E+02			4.48E-05
2-Methylnapthalene	1.70E-03	5.92E-02	16,085	4.00E-03	7.342E+02			1.99E-05
(1-Methylpropyl)benzene	4.21E-03	1.47E-01	4,826	3.70E-02	7.334E+02			4.48E-05
Naphthalene	1.99E-03	6.94E-02	50,363	2.00E-02	7.332E+02			2.07E-05
4-Nitrobenzenamine [4-Nitroaniline]	7.38E-10	2.57E-08	1,678	4.00E-03	7.328E+02	2.00E-02	6.22E-14	7.26E-12
Nitrobenzene	1.34E-01	4.66E+00	1,001	2.00E-03	7.328E+02			1.32E-03
2-Nitrophenol	4.40E-02	1.53E+00	2,831	6.20E-02	7.328E+02			4.33E-04
4-Nitrophenol	3.70E-02	1.29E+00	2,789	6.20E-02	7.328E+02			3.64E-04
N-nitroso-di-n-propylamine	8.35E-02	2.91E+00	1,539	0.00E+00	7.328E+02	7.00E+00	2.46E-03	8.22E-04
N-Nitrosodiphenylamine	2.42E-03	8.42E-02	2,654	2.00E-02	7.330E+02	4.90E-03	5.13E-08	2.45E-05
Phenol	8.74E-02	3.05E+00	1,476	3.00E-01	7.328E+02			8.60E-04
Propylbenzene	4.21E-03	1.47E-01	4,826	3.70E-02	7.334E+02			4.48E-05
Propylene glycol	2.41E-01	8.40E+00	701	2.00E+01	7.334E+02			2.57E-03

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Pyridine	2.24E-01	7.81E+00	744	1.00E-03	7.328E+02			2.20E-03
Styrene	1.93E-02	6.72E-01	5,272	2.00E-01	7.329E+02			1.92E-04
1,1,1,2-Tetrachloroethane	7.38E-02	2.57E+00	1,596	3.00E-02	7.330E+02	2.60E-02	8.31E-06	7.46E-04
1,1,2,2-Tetrachloroethane	1.21E-01	4.23E+00	1,086	2.00E-02	7.328E+02	2.00E-01	1.02E-04	1.19E-03
Tetrachloroethene	5.18E-03	1.81E-01	18,639	6.00E-03	7.329E+02	2.10E-03	4.66E-08	5.17E-05
2,3,4,6-Tetrachlorophenol	1.53E-04	5.33E-03	654,022**	3.00E-02	7.351E+02			1.98E-06
Toluene	6.19E-03	2.16E-01	15,615	8.00E-02	7.330E+02			6.26E-05
1,2,4-Trichlorobenzene	3.94E-03	1.37E-01	5,130	1.00E-02	7.339E+02	2.90E-02	5.54E-07	4.46E-05
Trichloroethene	1.38E-02	4.82E-01	7,047	5.00E-04	7.329E+02	4.60E-02	2.72E-06	1.38E-04
Trichlorofluoromethane	7.59E-02	2.65E+00	1,438	3.00E-01	7.328E+02			7.47E-04
2,4,6-Trichlorophenol	4.82E-02	1.68E+00	2,165	1.00E-03	7.337E+02	1.10E-02	2.51E-06	5.33E-04
1,2,3-Trichloropropane	1.21E-01	4.19E+00	1,101	4.00E-03	7.400E+02	3.00E+01	3.04E-02	2.36E-03
Trimethylbenzene [mixture of isomers]	3.94E-03	1.37E-01	5,130	5.00E-02	7.339E+02			4.46E-05
1,2,4-Trimethylbenzene	3.94E-03	1.37E-01	5,130	5.00E-02	7.339E+02			4.46E-05

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
1,3,5-Trimethylbenzene	3.33E-03	1.16E-01	9,262	1.00E-02	7.333E+02			3.50E-05
Vinyl Chloride	7.21E-02	2.52E+00	1,766	3.00E-03	7.328E+02	7.20E-01	2.19E-04	7.09E-04
Xylene [mixture of isomers]	7.32E-03	2.55E-01	3,385	2.00E-01	7.332E+02			7.60E-05

*Based on a 1 kg/m^3 concentration in the waste.

** COC was modeled and did not arrive at the hypothetical receptor location within 100,000 years (model results indicate there would be no PWAC limit for the COC). The PATHRAE model predicts peak concentrations for a time period 10 times the defined time limit. For purposes of comparing EMDF PWAC values to the EMWMF WAC, a PWAC value was derived from the peak concentration in the 100,000 to 1,000,000 year timeframe.

6. ANALYTIC PWAC

Based on the peak effective risk and dose from PATHRAE modeling and calculations, the analytic PWAC for COC were calculated for radioactive and hazardous COCs as described below.

6.1 PWAC CALCULATION

The following risk/toxicity criteria for the radionuclides and hazardous constituents for the EMDF are used to calculate the analytic PWAC (see Section 2.3 of this Appendix).

- An ELCR (carcinogenic risk) $\leq 1 \times 10^{-5}$ and a hazard index (HI) ≤ 1 for the first 1,000 years after closure.
- Carcinogenic risk $\leq 10^{-4}$ and HI ≤ 3 for >1,000 years to 100,000 years after closure.

Respective ELCR and HI were used for each constituent based on their peak time at the receptor location.

For each radioactive constituent:

$$\text{Risk PWAC} = 6.25 \times 10^5 \times \text{ELCR} / [\text{PR}_{\text{eff}} \text{ from a 1 Ci/m}^3 \text{ source}]$$

The PWAC resulting from risk are expressed in picocuries per gram (pCi/g) and the factor 6.25×10^5 results from unit conversions. ELCR are 10^{-5} (for ≤1,000 years) and 10^{-4} (for >1,000 years), respectively.

For each hazardous constituent:

$$\text{Risk PWAC} = 625 \times \text{ELCR} / [\text{PR}_{\text{eff}} \text{ from a 1 kg/m}^3 \text{ source}]$$

$$\text{HI PWAC} = 625 \times \text{HI} / [\text{PD}_{\text{eff}} \text{ from a 1 kg/m}^3 \text{ source/RD}], \text{ where}$$

RD = Reference Dose

The PWAC are expressed in milligrams per kilogram (mg/kg) and the factor of 625 comes from unit conversions. ELCR is 10^{-5} (for ≤1,000 years) or 10^{-4} (for >1000 years), respectively, for carcinogens. HI is 1 (for ≤1,000 years) and 3 (for >1,000 years), respectively, for non-carcinogens.

Tables F-8 and F-9 summarize the analytic PWAC calculated for the 0 to 1,000-year and 1,000- to 100,000-year periods after EMDF closure for radioactive and hazardous constituents. The PWAC for each constituent is based on a calculation that assumes a single waste stream of that constituent occupies the entire cell.

Table F-8. EMDF Analytic PWAC for Radionuclides

Nuclide COC	Carcinogenic PWAC (pCi/g) 0 to 1000 Years	Carcinogenic PWAC (pCi/g) - >1000 to 100,000 Years
H-3	1.29E+14	
C-14	5.11E+02	
Tc-99	4.90E+03	
I-129		2.45E+02
U-233		7.45E+04
U-234		7.09E+04
U-235		6.38E+04
U-236		6.63E+04
U-238		6.94E+04
Np-237		1.55E+05
Pu-239		1.04E+06
Pu-240		9.51E+08
Am-241	NL	NL

NL = no limit. “NL” indicates contaminant migration was modeled and radioactively decays to an insignificant level.

Table F-9. EMDF Analytic PWAC for Hazardous Constituents

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Years	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mg/kg) - >1000 to 100,000 Years
Antimony				3.63E+04
Barium				3.43E+07**
Boron				1.04E+06
Chromium (Total)				6.89E+06
Lead				4.47E+05**
Manganese				1.02E+08**
Molybdenum				1.50E+05
Selenium				4.66E+03
Strontium				4.32E+06
Tin				8.81E+05
Vanadium				8.98E+05**
U-233				4.54E+05
U-234				4.26E+05
U-235				3.78E+05
U-236				3.78E+05
U-238				3.77E+05
2,4-D				4.05E+04
2,4,5-T[Silvex]				9.27E+04
Acenaphthene				3.20E+07**
Acenaphthylene				9.17E+06
Acetone		3.01E+05		
Acetonitrile		1.55E+03		
Acetophenone		4.15E+04		
Acrolein		1.31E+02		
Acrylonitrile	1.16E+01	1.07E+04		
Aldrin			7.23E+05*	4.76E+06**
Aroclor-1221			1.76E+04**	
Aroclor-1232			2.14E+04	
Benzene			1.31E+04	3.72E+04
Benzoic Acid		1.08E+06		
Benzyl Alcohol		3.13E+04		
Benzidine			9.52E+00	8.46E+04
alpha-BHC			3.58E+03	2.31E+06
beta-BHC			1.20E+04	
delta-BHC			1.47E+04	
Bromodichloromethane	1.14E+02	6.08E+03		
Bromoform			2.71E+05	5.52E+05
Bromomethane		4.32E+02		
Butylbenzene				2.08E+06
Carbazole			5.12E+06	

Table F-9. EMDF Analytic PWAC for Hazardous Constituents (Continued)

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Years	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mg/kg) - >1000 to 100,000 Years
Carbon Disulfide		7.80E+04		
Carbon tetrachloride			1.29E+04	4.64E+04
Chlordane			1.21E+06**	2.74E+06**
Chlorobenzene				1.09E+05
Chloroform			9.75E+03	3.88E+04
Chloromethane [Methyl Chloride]	5.53E+02			
o-Chlorotoluene				1.40E+05
m-Cresol		2.10E+04		
o-Cresol				8.43E+04
p-Cresol		4.15E+04		
Cumene [Isopropylbenzene]				4.16E+06
Cyanide				3.02E+04
DDD			5.81E+05**	
DDE			1.12E+06	
Di-n-butylphthalate		2.33E+03		
Dibromochloromethane			1.38E+03	2.98E+04
1,2-Dichlorobenzene				2.91E+06
1,3-Dichlorobenzene				6.58E+06
1,4-Dichlorobenzene			4.63E+05	2.25E+06
1,2,-cis-Dichloroethylene				1.15E+04
1,2-trans-Dichloroethylene		7.75E+03		
Dichlorodifluoromethane		6.58E+05		
1,2-Dichloropropane	2.70E+02	3.76E+04		
Dieldrin			5.81E+01	5.99E+02
Diethylphthalate				2.05E+06
1,2-Dimethylbenzene				2.44E+06
2,4-Dimethylphenol				2.68E+05
Dimethylphthalate		3.85E+06		
2,4 Dinitrotoluene	2.57E+02	6.83E+03		
2,6 Dinitrotoluene	8.97E+01	2.61E+03		
Endosulfan plus metabolites				3.40E+07
Endrin				1.66E+06
Endrin Aldehyde				1.66E+06
Endrin Ketone				1.66E+06
Ethylbenzene			1.13E+05	1.59E+06
Ethylchloride	2.73E+03	1.36E+05		
Heptachlor			1.75E+05**	5.06E+06**
Heptachlor Epoxide			1.60E+04	2.42E+04
Hexachlorobenzene			3.56E+06**	5.85E+07**
Hexachloroethane			9.02E+04	3.23E+04

Table F-9. EMDF Analytic PWAC for Hazardous Constituents (Continued)

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Year	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mgskg) - >1000 to 100,000 Years
n-Hexane				1.46E+07
1-Hexanol		1.22E+04		
2-Hexanone		1.52E+03		
Isophorone			7.49E+05	1.83E+06
Lindane			2.18E+04	9.20E+04
Methanol		1.28E+05		
Methylene Chloride	3.89E+03	2.00E+03		
Methylcyclohexane		3.89E+06		
Methyl Isobutyl Ketone		2.14E+04		
Methyl Methacrylate		4.12E+05		
1-Methyl-4-(1-methylethyl)-benzene				1.55E+06
2-Methylnapthalene				3.76E+05
(1-Methylpropyl)benzene				1.55E+06
Naphthalene				1.82E+06
4-Nitrobenzenamine [4-Nitroaniline]			1.01E+12	1.03E+12
Nitrobenzene				2.84E+03
2-Nitrophenol				2.69E+05
4-Nitrophenol				3.19E+05
N-nitroso-di-n-propylamine			2.54E+01	
N-Nitrosodiphenylamine			1.22E+06	4.56E+04
Phenol				6.54E+05
Propylbenzene				1.55E+06
Propylene glycol		4.87E+06		
Pyridine		2.84E+02		
Styrene				1.95E+06
1,1,1,2-Tetrachloroethane			7.53E+03	7.54E+04
1,1,2,2-Tetrachloroethane			6.11E+02	3.15E+04
Tetrachloroethene			1.34E+06	2.18E+05
2,3,4,6-Tetrachlorophenol				2.84E+07**
Toluene				2.40E+06
1,2,4-Trichlorobenzene			1.13E+05	4.20E+05
Trichloroethene			2.30E+04	6.81E+03
Trichlorofluoromethane				7.53E+05
2,4,6-Trichlorophenol			2.49E+04	3.52E+03
1,2,3-Trichloropropane			2.06E+00	3.18E+03

Table F-9. EMDF Analytic PWAC for Hazardous Constituents (Continued)

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Year	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mgskg) - >1000 to 100,000 Years
Trimethylbenzene [mixture of isomers]				2.10E+06
1,2,4-Trimethylbenzene				2.10E+06
1,3,5-Trimethylbenzene				5.36E+05
Vinyl Chloride			2.85E+02	7.93E+03
Xylene [mixture of isomers]				4.94E+06

* Waste with a constituent concentration greater than 1.00E+06 mg/kg is not physically possible. A PWAC value greater than 1.00E+06 mg/kg would be used only in the content of a SOF calculation (see Section 6.2).

** COC was modeled and did not arrive at the hypothetical receptor location within 100,000 years (model results indicate there would be no PWAC limit for the COC). The PATHRAE model predicts peak concentrations for a time period 10 times the defined time limit. For purposes of comparing EMDF PWAC values to the EMWMF WAC, a PWAC value was derived from the peak concentration in the 1,000,000 year timeframe.

6.2 DISCUSSION OF PWAC RESULTS

The analytic PWAC calculated for radioactive constituents consist mostly of long-lived radionuclides, such as Tc-99, uranium, and plutonium. Short-lived radionuclides rapidly decay before migrating to the environment. PWAC for hazardous constituents are developed for risk (carcinogenic PWAC) and dose (HI PWAC).

Note that the PWAC for many of the individual COCs are higher than the COC's physical limit (pure form), suggesting there is no analytic PWAC limit on the constituent if it is placed in the disposal cell as a single constituent occupying the entire disposal cell volume. However, as described in Section 1.1, the SOF calculation method was developed for the existing EMWMF to determine whether a waste containing multiple contaminants is acceptable for disposal. For those constituents with a calculated PWAC limit higher than the physical limit, even the presence of the constituent in a nearly pure form in a multi-contaminant waste stream would have a very small contributing impact on risk in a SOF calculation.

Several conservative assumptions were made for WAC development. It was assumed that organic constituents would not degrade and the initial contaminant mass would remain constant in the disposal cell. This assumption is conservative because organic COCs in the disposal cell would undergo biodegradation or volatilization during cell operation and during the early years after facility closure when the cell design features would be fully functional or during migration after release. Thus, there would be negligible adverse impact to the environment from organic COCs. Sensitivity runs were performed using biodegradation rates for organic COCs during the PATHRAE simulations for EMDF and resulted in unlimited PWAC for many of the COCs.

The development of the analytic PWAC assumed that all waste is a soil or 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.

Another conservatism in the analytic PWAC development is that no credit is taken in the performance period for the man-made geosynthetic components, such as HDPE liners, in the final cover and liner systems. Landfill design and disposal experts have recently developed evidence through empirical testing and research that HDPE liners could perform their intended function for upwards of 500 to 1,000 years or more (Rowe, et al. 2009) in the likely soil temperature range for this region. An additional conservative aspect of the methodology used to develop the EMWMF analytic WAC was the use of an additive approach to calculate risk from each radioisotope and/or chemical constituent that individually occurs within the post-closure modeled period. The peak risk from each single constituent to the hypothetical resident farmer was combined and collectively compared against the performance measures. This is more conservative than typical time-dependent based analytic WAC that are widely used at other DOE and/or NRC-regulated LLW disposal facilities.

There are uncertainties in the PWAC analysis due to data gaps in site-specific information and the conceptual stage of the disposal facility design at the proposed EMDF site. As the site selection and design process proceeds, additional site-specific data obtained through site investigation and hydrogeological/geotechnical analysis (e.g., groundwater depth), 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 PWAC analysis would be re-evaluated to confirm that the EMDF WAC is still protective for radionuclide and chemical constituents.

6.3 COMPARISON TO EMWMF ANALYTIC WAC

Table F-10 compares the analytic PWAC developed for EMDF with the EMWMF analytic WAC. As shown in the table, the analytic PWAC for EMDF are generally 10 to 100 times higher than the analytic WAC for EMWMF.

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC

RADIONUCLIDES				
COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (pCi/g)	HI PWAC (pCi/g)	Carcinogenic PWAC (pCi/g)	HI PWAC (pCi/g)
Am-241	2.00E+21		NL	
C-14	1.65E+02		5.11E+02	
I-129	1.30E+01		2.45E+02	
Np-237	3.20E+02		1.55E+05	
Pu-239	7.20E+02		1.04E+06	
Pu-240	5.80E+03		9.51E+08	
Tc-99	1.72E+02		4.90E+03	
H-3 (Tritium)	1.50E+05		1.29E+14	
U-233	1.70E+03	4.50E+07	7.45E+04	4.54E+05
U-234	1.70E+03	2.80E+07	7.09E+04	4.26E+05
U-235	1.50E+03	9.50E+03	6.38E+04	3.78E+05
U-236	1.70E+03	2.80E+05	6.63E+04	3.78E+05
U-238	1.20E+03	1.50E+03	6.94E+04	3.77E+05

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

INORGANICS				
COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
Antimony		1.60E+02		3.63E+04
Barium		1.50E+05		3.43E+07**
Boron		2.40E+04		1.04E+06
Chromium (Total)		1.40E+05		6.89E+06
Lead		1.50E+03		4.47E+05**
Manganese		3.60E+05		1.02E+08**
Molybdenum		3.90E+03		1.50E+05
Selenium		1.60E+03		4.66E+03
Strontium		3.00E+05		4.32E+06
Tin		2.20E+03		8.81E+05
Vanadium		2.50E+04		8.98E+05**

ORGANICS				
COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
2,4-D		1.19E+02		4.05E+04
2,4,5-T[Silvex]		3.30E+02		9.27E+04
Acenaphthene		3.90E+05		3.20E+07**
Acenaphthylene		9.32E+04		9.17E+06
Acetone		2.70E+02		3.01E+05
Acetonitrile		1.30E+01		1.55E+03
Acetophenone		3.30E+02		4.15E+04
Acrolein		1.10E+00		1.31E+02
Acrylonitrile	9.30E-02	2.10E+00	1.16E+01	1.07E+04
Aldrin	6.60E+03	4.40E+04	7.23E+05**	4.76E+06**
Aroclor-1221	2.30E+03		1.76E+04**	
Aroclor-1232	1.00E+03		2.14E+04	
Benzene	2.00E+02		1.31E+04	3.72E+04
Benzoic Acid		9.81E+03		1.08E+06
Benzyl Alcohol		1.20E+03		3.13E+04
Benzidine	1.61E-01	1.20E+00	9.52E+00	8.46E+04
alpha-BHC	3.90E+01		3.58E+03	2.31E+06
beta-BHC	1.40E+02		1.20E+04	
delta-BHC	1.40E+02		1.47E+04	

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
Bromodichloromethane	1.00E+00	5.50E+01	1.14E+02	6.08E+03
Bromoform	1.60E+01	1.10E+02	2.71E+05	5.52E+05
Bromomethane		3.50E+00		4.32E+02
Butylbenzene		1.51E+04		2.08E+06
Carbazole	1.10E+05		5.12E+06	
Carbon Disulfide		7.10E+02		7.80E+04
Carbon tetrachloride	5.60E+01	6.60E+01	1.29E+04	4.64E+04
Chlordane	9.20E+04	2.10E+05	1.21E+06**	2.74E+06**
Chlorobenzene		3.30E+02		1.09E+05
Chloroform	4.00E+01	1.00E+02	9.75E+03	3.88E+04
Chloromethane [Methyl Chloride]	4.40E+00		5.53E+02	
o-Chlorotoluene		4.40E+02		1.40E+05
m-Cresol		1.70E+02		2.10E+04
o-Cresol		2.32E+02		8.43E+04
p-Cresol		1.70E+02		4.15E+04
Cumene [Isopropylbenzene]		4.08E+04		4.16E+06
Cyanide		8.10E+03		3.02E+04
DDD	7.70E+04		5.81E+05**	
DDE	1.30E+05		1.12E+06	
Di-n-butylphthalate		1.90E+02		2.33E+03
Dibromochloromethane	1.10E+00	7.90E+01	1.38E+03	2.98E+04
1,2-Dichlorobenzene		9.40E+03		2.91E+06
1,3-Dichlorobenzene		5.80E+04		6.58E+06
1,4-Dichlorobenzene	1.00E+02	2.40E+04	4.63E+05	2.25E+06
1,2,-cis-Dichloroethylene		1.50E+02		1.15E+04
1,2-trans-Dichloroethylene		6.20E+01		7.75E+03
Dichlorodifluoromethane		6.00E+03		6.58E+05
1,2-Dichloropropane	1.10E+00		2.70E+02	3.76E+04
Dieldrin	7.10E+00	6.00E+01	5.81E+01	5.99E+02
Diethylphthalate		6.18E+03		2.05E+06
1,2-Dimethylbenzene		7.56E+04		2.44E+06
2,4-Dimethylphenol		2.15E+03		2.68E+05
Dimethylphthalate		3.07E+04		3.85E+06
2,4 Dinitrotoluene	1.00E+00	6.20E+01	2.57E+02	6.83E+03
2,6 Dinitrotoluene	8.10E-01	2.40E+01	8.97E+01	2.61E+03
Endosulfan plus metabolites		3.30E+05		3.40E+07
Endrin		3.00E+04		1.66E+06
Endrin Aldehyde		3.00E+04		1.66E+06

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
Endrin Ketone		3.00E+04		1.66E+06
Ethylbenzene		4.90E+03	1.13E+05	1.59E+06
Ethylchloride	2.20E+01	1.10E+03	2.73E+03	1.36E+05
Heptachlor	2.40E+03	6.90E+04	1.75E+05**	5.06E+06**
Heptachlor Epoxide	1.00E+03	1.50E+03	1.60E+04	2.42E+04
Hexachlorobenzene	3.97E+06	7.73E+05	3.56E+06**	5.85E+07**
Hexachloroethane	2.80E+03	5.00E+02	9.02E+04	3.23E+04
n-Hexane		5.30E+04		1.46E+07
1-Hexanol		9.70E+01		1.22E+04
2-Hexanone		9.70E+01		1.52E+03
Isophorone	6.10E+03	1.50E+04	7.49E+05	1.83E+06
Lindane	1.80E+02	9.40E+02	2.18E+04	9.20E+04
Methanol		1.10E+03		1.28E+05
Methylene Chloride	7.30E+00	1.40E+02	3.89E+03	2.00E+03
Methylcyclohexane		3.60E+04		3.89E+06
Methyl Isobutyl Ketone		1.70E+02		2.14E+04
Methyl Methacrylate		3.30E+03		4.12E+05
1-Methyl-4-(1-methylethyl)-benzene		1.51E+04		1.55E+06
2-Methylnapthalene		4.00E+03		3.76E+05
(1-Methylpropyl)benzene		1.51E+04		1.55E+06
Naphthalene		9.90E+03		1.82E+06
4-Nitrobenzenamine [4-Nitroaniline]	8.70E+08	2.30E+09	1.01E+12	1.03E+12
Nitrobenzene		1.98E+00		2.84E+03
2-Nitrophenol		1.80E+00		2.69E+05
4-Nitrophenol		8.50E+02		3.19E+05
N-nitroso-di-n-propylamine	1.90E-02		2.54E+01	
N-Nitrosodiphenylamine	1.10E+03	4.80E+03	1.22E+06	4.56E+04
Phenol		3.20E+03		6.54E+05
Propylbenzene		1.51E+04		1.55E+06
Propylene glycol		1.10E+03		4.87E+06
Pyridine		2.20E+00		2.84E+02
Styrene		1.60E+04		1.95E+06
1,1,1,2-Tetrachloroethane	7.00E+00	2.30E+02	7.53E+03	7.54E+04
1,1,2,2-Tetrachloroethane	4.89E-01	2.50E+02	6.11E+02	3.15E+04
Tetrachloroethene	4.40E+02	2.90E+03	1.34E+06	2.18E+05
2,3,4,6-Tetrachlorophenol		1.08E+04		2.84E+07**
Toluene		4.90E+04		2.40E+06

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
1,2,4-Trichlorobenzene		5.10E+03	1.13E+05	4.20E+05
Trichloroethene	7.80E+02		2.30E+04	6.81E+03
Trichlorofluoromethane		2.30E+03		7.53E+05
2,4,6-Trichlorophenol	2.20E+01		2.49E+04	3.52E+03
1,2,3-Trichloropropane	1.60E-02	2.80E+01	2.06E+00	3.18E+03
Trimethylbenzene [mixture of isomers]		2.20E+04		2.10E+06
1,2,4-Trimethylbenzene		2.18E+04		2.10E+06
1,3,5-Trimethylbenzene		2.60E+04		5.36E+05
Vinyl Chloride	2.90E-01	7.77E+00	2.85E+02	7.93E+03
Total Xylenes [mixture of isomers]		1.50E+04		4.94E+06

NL = no limit. "NL"indicates contaminant migration was modeled and contamination radioactively decays to an insignificant level.

* Waste with a constituent concentration greater than 1.00E+06 mg/kg is not physically possible. A PWAC value greater than 1.00E+06 mg/kg would be used only in the context of a SOF calculation (see Section 6.2).

** COC was modeled and did not arrive at the hypothetical receptor location within 100,000 years (model results indicate there would be no PWAC limit for the COC). The PATHRAE model predicts peak concentrations for a time period 10 times the defined time limit. For purposes of comparing EMDF PWAC values to the EMWMF WAC, a PWAC value was derived from the peak concentration in the 1,000,000 year timeframe.

The higher analytic PWAC for the EMDF relative to EMWMF are the result of several factors. The most significant factor is the distance from the disposal cell to the receptor location and DF_{well}. The EMWMF analytic WAC were developed based on an initial conceptual design of a cell located closer to Bear Creek than the 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 F-22). The distance between the original EMWMF cell conceptual design and the hypothetical receptor location used to develop the EMWMF WAC is shorter than the distance between the as-built EMWMF and the hypothetical receptor location. Similarly, the distance between the original EMWMF cell conceptual design and the hypothetical receptor location used to develop the EMWMF WAC is shorter than the distance between the proposed EMDF and the assumed hypothetical receptor for EMDF near NT-3.

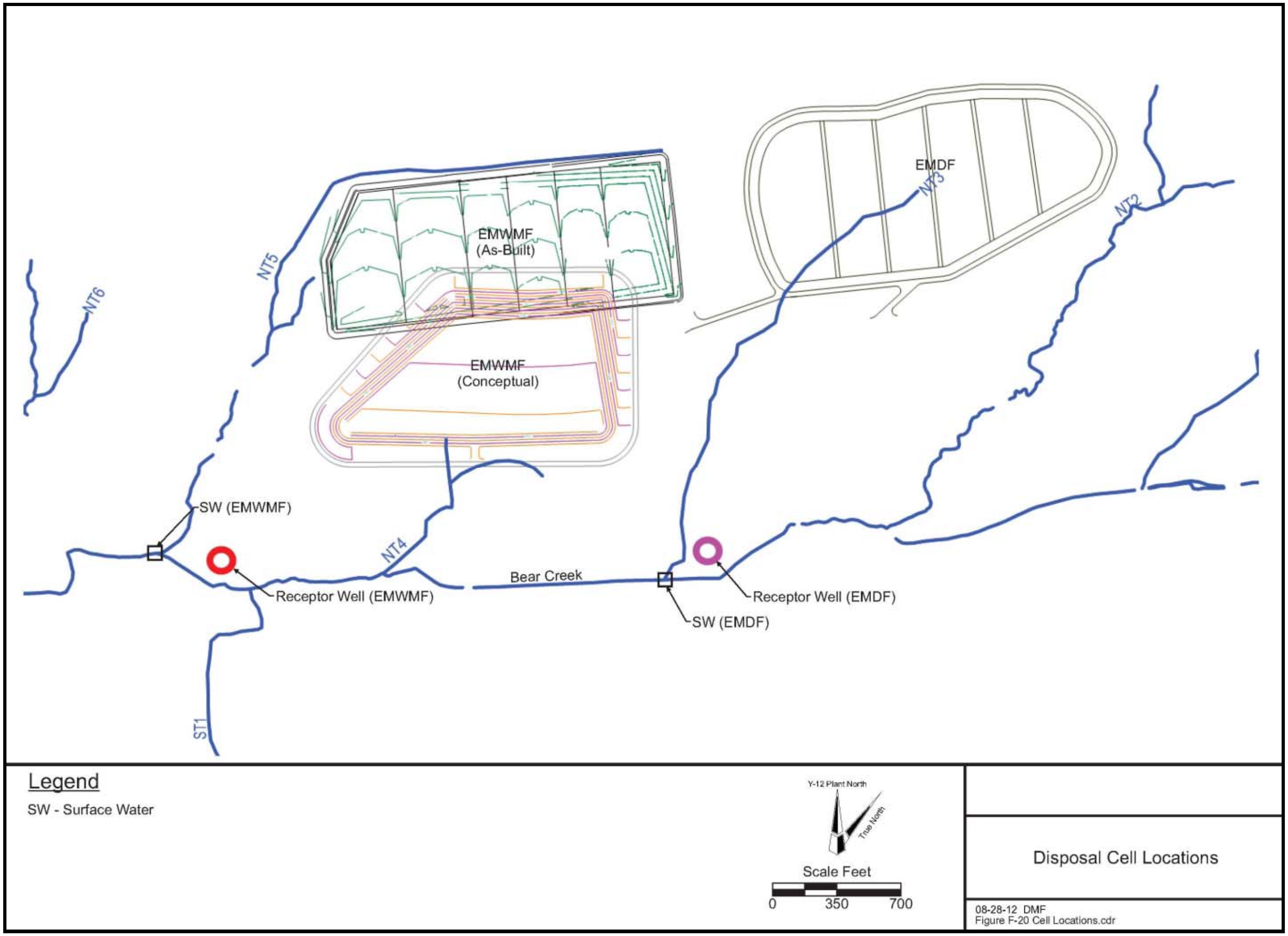

Figure F-22. EMWMF Conceptual Design, EMWMF As-built, EMDF Conceptual Design, and Hypothetical Receptor Well Locations

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 groundwater DL. 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 PWAC value. As a result, a lower DF_{well} results in a lower C_{well} and a higher analytic PWAC value.

Another contributing factor to a higher PWAC is the underdrain system and the impact of backfilled existing channels within the proposed EMDF footprint. Disposal cell siting requires the groundwater separation between the bottom of the disposal cell liner system and top of the water table. Lessons learned from the EMWMF construction and operation (BJC 2003) guided the conceptual design of the EMDF.

To prevent the groundwater from rising within the proposed EMDF, the major existing drainage features within the landfill footprint would be backfilled with gravelly conductive material so the future groundwater flow system after cell construction would be similar to the current condition. These backfilled existing channels would behave hydraulically as underdrains to allow shallow groundwater discharge preferably to surface water.

The underdrain system would act as a preferred migration pathway for contaminant movement under some conditions. While contaminant leachate could percolate into the groundwater system and migrate downgradient in the groundwater zone, some leachate would be captured in the underdrain system and discharge into the surface water, resulting in lower contaminant concentrations in groundwater and a higher PWAC.

The analysis demonstrates that an analytic PWAC 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 WAC 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 (administrative, analytic, ASA-derived, and physical) would be approved for a new facility at the selected site prior to waste receipt. The final analytic WAC approved by the FFA parties may be similar to the analytic WAC approved for EMWMF.

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ATTACHMENT A TO APPENDIX F

SUPPLEMENTAL MODELING INFORMATION

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CONTENTS

TABLES

ACRONYMS

COC	contaminant of concern
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
HELP	Hydrologic Evaluation of Landfill Performance
K_d	solid-to-liquid partition coefficient
PWAC	preliminary waste acceptance criteria
RD	Reference Dose
SF	Slope Factor
U.S.	United States
WAC	waste acceptance criteria

1. INTRODUCTION

This attachment provides supplemental modeling information to Appendix F, *On-site Disposal Facility Preliminary Waste Acceptance Criteria* (PWAC). 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 PWAC calculations, including PATHRAE input and output files.

2. HELP MODEL

Detailed information about the HELP modeling analysis that was conducted to support PWAC 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 PWAC 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 (U.S.) 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 both complete design profile and long-term scenarios.

```
          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
4.57	4.34	5.68	4.08	4.68	4.34
5.45	3.70	3.86	3.18	4.59	5.30

```
          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
35.00	38.80	47.90	56.80	64.90	72.40
75.80	75.20	69.10	57.40	47.30	38.60

```
          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    KNOXVILLE           TENNESSEE
                     AND STATION LATITUDE  =  35.49 DEGREES
```

2.1.2 Complete Design Profile and Parameters

```
                         LAYER  1
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   4
  THICKNESS                   =     60.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.1050 VOL/VOL
  WILTING POINT               =      0.0470 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1832 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  =      0.1947 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.310000009000E-02 CM/SEC


                         LAYER  3
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   1
  THICKNESS                   =     36.00   INCHES
  POROSITY                    =      0.4170 VOL/VOL
  FIELD CAPACITY              =      0.0450 VOL/VOL
  WILTING POINT               =      0.0180 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1395 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  =      0.0369 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC
  SLOPE                       =      5.00   PERCENT
  DRAINAGE LENGTH             =    100.0    FEET


                         LAYER  5
```

```
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                     =      0.06   INCHES
POROSITY                      =      0.0000 VOL/VOL
FIELD CAPACITY                =      0.0000 VOL/VOL
WILTING POINT                 =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY           =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS      =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD


                        LAYER  6
                        --------

              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  7
                        --------

          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    =      0.4128 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000001000E-06 CM/SEC


                        LAYER  8
                        --------

          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    =      0.0349 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.300000012000     CM/SEC


                        LAYER  9
                        --------

          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 10
                        --------

          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 11
                        --------

            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 =      0.0320 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
SLOPE                      =      2.50   PERCENT
DRAINAGE LENGTH            =    100.0    FEET


                        LAYER 12
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.06   INCHES
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  3 - GOOD


                         LAYER 13
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                  =      0.24   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC
```

```
                    LAYER 14
                    --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                    =      0.30   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
SLOPE                        =      2.50   PERCENT
DRAINAGE LENGTH              =    100.0    FEET


                    LAYER 15
                    --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                    LAYER 16
                    --------

              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 17
                    --------

          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

```
                    LAYER  1
                    --------
```

```
            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   4
  THICKNESS                    =     60.00   INCHES
  POROSITY                     =      0.4370 VOL/VOL
  FIELD CAPACITY               =      0.1050 VOL/VOL
  WILTING POINT                =      0.0470 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1832 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  =      0.1947 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.310000009000E-02 CM/SEC

                          LAYER  3
                          --------
            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   1
  THICKNESS                    =     36.00   INCHES
  POROSITY                     =      0.4170 VOL/VOL
  FIELD CAPACITY               =      0.0450 VOL/VOL
  WILTING POINT                =      0.0180 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1395 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  =      0.0368 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   =      0.4191 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   =      0.0470 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    =      2.910  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     =    281.301  INCHES
TOTAL INITIAL WATER                  =    281.301  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 2.2.2, respectively.

2.2.1 Complete Design Scenario

```
******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                               -------------------  -------------   ---------
  PRECIPITATION                54.39    (   7.835)   6910300.5     100.00

  RUNOFF                        0.685   (  1.3124)     87066.65      1.260

  EVAPOTRANSPIRATION           30.899   (  2.7986)   3925722.50     56.810

  LATERAL DRAINAGE COLLECTED   22.79604 (  5.99463)  2896236.500   41.91188
    FROM LAYER  4

  PERCOLATION/LEAKAGE THROUGH   0.00004 (  0.00001)        5.618     0.00008
    LAYER  6

  AVERAGE HEAD ON TOP           0.074 (    0.019)
    OF LAYER  5

  LATERAL DRAINAGE COLLECTED    0.00080 (  0.00358)      101.185    0.00146
    FROM LAYER 11

  PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)        0.314     0.00000
    LAYER 13

  AVERAGE HEAD ON TOP           0.000 (    0.000)
    OF LAYER 12

  LATERAL DRAINAGE COLLECTED    0.00000 (  0.00000)        0.254    0.00000
    FROM LAYER 14

  PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)        0.060     0.00000
    LAYER 16

  AVERAGE HEAD ON TOP           0.000 (    0.000)
    OF LAYER 15

  PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)        0.000     0.00000
    LAYER 17

  CHANGE IN WATER STORAGE       0.009   (  2.6932)      1171.86      0.017
 ******************************************************************************
```

2.2.2 Long-term (Worst Case) Scenario

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	54.39	(7.835)	6910300.5	100.00
RUNOFF	0.685	(1.3124)	87066.65	1.260
EVAPOTRANSPIRATION	30.899	(2.7986)	3925722.50	56.810
LATERAL DRAINAGE COLLECTED FROM LAYER 4	22.37147	(5.99331)	2842295.250	41.13128
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.42462	(0.00521)	53947.691	0.78069
AVERAGE HEAD ON TOP OF LAYER 5	0.072	(0.019)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.42443	(0.00662)	53924.336	0.78035
AVERAGE HEAD ON TOP OF LAYER 10	0.002	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 11	**0.42443**	(0.00645)	53923.512	0.78034
CHANGE IN WATER STORAGE	0.010	(2.6927)	1291.82	0.019

****

3. PATHRAE MODEL

PATHRAE-RAD and PATHRAE-HAZ (Rogers and Associates Engineering, 1995a, b) models are used to calculate the arrival peak time and concentrations for the radioactive constituents and toxicological constituents at the hypothetical receptor surface water location, respectively. PATHRAE calculations are also performed to determine the equivalent annual water consumption per year for the creek (defined as the Equivalent Uptake).

Section 3.1 provides information about some of the PATHRAE input parameters. Section 3.2 provides a listing of PATHRAE modeling input and output files.

3.1 PATHRAE INPUT PARAMETERS

The solid-to-liquid partition coefficient (K_d) values used to develop the Environmental Management Waste Management Facility (EMWMF) waste acceptance criteria (WAC) were based on site-specific and generic K_d factors for soils and were also used to develop the PWAC for the proposed EMDF. These K_d values used in PATHRAE are provided below in Table 3-1 and Table 3-2.

Table 3-1. K_d Values for Radionuclide Constituents used in PATHRAE

RAD	K_d		
	Waste	Vadose zone	Aquifer
H-3	1.99E-01	0.00E+00	0.00E+00
C-14	1.09E+00	0.00E+00	0.00E+00
Tc-99	1.29E+00	0.00E+00	0.00E+00
U-233	4.00E+01	2.00E+01	7.00E-01
U-234	4.00E+01	2.00E+01	7.00E-01
U-235	4.00E+01	2.00E+01	7.00E-01
U-236	4.00E+01	2.00E+01	7.00E-01
U-238	4.00E+01	2.00E+01	7.00E-01
Np-237	5.56E+01	4.00E+01	4.00E+00
Pu-239	5.76E+01	4.00E+01	4.00E+00
Pu-240	5.76E+01	4.00E+01	4.00E+00
Am-241	5.76E+01	4.00E+01	4.00E+00
I-129	1.99E-01	1.99E-01	0.00E+00

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
Antimony	(7440-36-0)	1.90E+01	1.90E+01	1.90E+00
Barium	(7440-39-3)	5.50E+01	5.50E+01	5.50E+00
Boron	(7440-42-8)	3.00E+00	3.00E+00	3.00E-01
Chromium (Total)	(7440-47-3)	1.00E+01	1.00E+01	1.00E+00
Lead	(7439-92-1)	1.00E+02	1.00E+02	1.00E+01
Manganese	(7439-96-5)	2.00E+02	2.00E+02	2.00E+01
Molybdenum	(7439-98-7)	2.00E+01	2.00E+01	2.00E+00
Selenium	(7782-49-2)	1.50E+01	1.50E+01	1.50E+00
Strontium	(7440-24-6)	1.35E+01	1.35E+01	0.00E+00
Tin	(7440-31-5)	2.50E+00	2.50E+00	2.50E-01
Vanadium	(7440-62-2)	1.00E+02	1.00E+02	1.00E+01
U-233	(1-1)	4.00E+01	2.00E+01	7.00E-01
U-234	(1-2)	4.00E+01	2.00E+01	7.00E-01
U-235	(1-3)	4.00E+01	2.00E+01	7.00E-01
U-236	(1-4)	4.00E+01	2.00E+01	7.00E-01
U-238	(1-5)	4.00E+01	2.00E+01	7.00E-01
2,4-D	(94-75-7)	5.88E-02	5.88E-02	5.88E-03
2,4,5-T[Silvex]	(93-72-1)	1.61E-01	1.61E-01	1.61E-02
Acenaphthene	(83-32-9)	9.20E+01	9.20E+01	9.20E+00
Acenaphthylene	(208-96-8)	1.22E+01	1.22E+01	1.22E+00
Acetone	(67-64-1)	4.40E-02	4.40E-02	0.00E+00
Acetonitrile	(75-05-8)	1.54E-03	1.54E-03	1.54E-04
Acetophenone	(98-86-2)	9.24E-02	9.24E-02	9.24E-03
Acrolein	(107-02-8)	2.78E-03	2.78E-03	2.78E-04
Acrylonitrile	(107-13-1)	4.44E-03	4.44E-03	4.44E-04
Aldrin	(309-00-2)	9.74E+01	9.74E+01	9.74E+00
Aroclor-1221	(11104-28-2)	1.20E+02	1.20E+02	1.20E+02
Aroclor-1232	(11141-16-5)	1.50E+01	1.50E+01	1.50E+01
Benzene	(71-43-2)	1.70E+00	1.70E+00	0.00E+00
Benzoic Acid	(65-85-0)	1.20E-03	1.20E-03	1.20E-04

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
Benzyl Alcohol	(100-51-6)	3.13E-02	3.13E-02	3.13E-03
Benzidine	(92-87-5)	5.48E+00	5.48E+00	5.48E-01
alpha-BHC	(319-84-6)	3.52E+00	3.52E+00	3.52E-01
beta-BHC	(319-85-7)	4.28E+00	4.28E+00	4.28E-01
delta-BHC	(319-86-8)	4.28E+00	4.28E+00	4.28E-01
Bromodichloromethane	(75-27-4)	1.08E-02	1.08E-02	1.08E-03
Bromoform	(75-25-2)	2.52E-01	2.52E-01	2.52E-02
Bromomethane	(74-83-9)	2.83E-02	2.83E-02	2.83E-03
Butylbenzene	(104-51-8)	1.63E+00	1.63E+00	1.63E-01
Carbazole	(86-74-8)	6.78E+00	6.78E+00	6.78E-01
Carbon Tetrachloride	(56-23-5)	1.03E-01	1.03E-01	1.03E-02
Carbon Disulfide	(75-15-0)	2.20E+00	2.20E+00	0.00E+00
Chlordane	(57-74-9)	1.73E+02	1.73E+02	1.73E+01
Chlorobenzene	(108-90-7)	4.38E-01	4.38E-01	4.38E-02
Chloroform	(67-66-3)	6.20E-01	6.20E-01	0.00E+00
Chloromethane [Methyl Chloride]	(74-87-3)	2.86E-02	2.86E-02	2.86E-03
o-Chlorotoluene	(95-49-8)	8.86E-01	8.86E-01	8.86E-02
m-Cresol	(108-39-4)	9.56E-02	9.56E-02	9.56E-03
o-Cresol	(95-48-7)	1.82E-01	1.82E-01	1.82E-02
p-Cresol	(106-44-5)	9.22E-02	9.22E-02	9.22E-03
Cumene [Isopropylbenzene]	(98-82-8)	1.65E+00	1.65E+00	1.65E-01
Cyanide	(57-12-5)	9.90E+00	9.90E+00	9.90E-01
DDD	(72-54-8)	9.16E+01	9.16E+01	9.16E+00
DDE	(72-55-9)	1.73E+00	1.73E+00	1.73E-01
Di-n-butylphthalate	(84-74-2)	1.00E-06	1.00E-06	0.00E+00
Dibromochloromethane	(124-48-1)	1.41E-01	1.41E-01	1.41E-02
1,2-Dichlorobenzene	(95-50-1)	7.58E-01	7.58E-01	7.58E-02
1,3-Dichlorobenzene	(541-73-1)	1.61E+01	1.61E+01	1.61E+00
1,4-Dichlorobenzene	(106-46-7)	1.23E+00	1.23E+00	1.23E-01
1,2,-cis-Dichloroethylene	(156-59-2)	9.96E-01	9.96E-01	9.96E-02
1,2-trans-Dichloroethylene	(156-60-5)	7.60E-02	7.60E-02	7.60E-03

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
Dichlorodifluoromethane	(75-71-8)	1.37E-02	1.37E-02	1.37E-03
1,2-Dichloropropane	(78-87-5)	9.40E-02	9.40E-02	9.40E-03
Dieldrin	(60-57-1)	3.40E+01	3.40E+01	0.00E+00
Diethylphthalate	(84-66-2)	2.52E-01	2.52E-01	2.52E-02
1,2-Dimethylbenzene	(95-47-6)	4.80E-01	4.80E-01	4.80E-02
2,4-Dimethylphenol	(105-67-9)	2.52E+00	2.52E+00	2.52E-01
Dimethylphthalate	(131-11-3)	7.42E-02	7.42E-02	7.42E-03
2,4 Dinitrotoluene	(121-14-2)	1.02E-01	1.02E-01	1.02E-02
2,6 Dinitrotoluene	(606-20-2)	8.39E-02	8.39E-02	8.39E-03
Endosulfan plus metabolites****	(959-98-8)	4.08E+00	4.08E-01	4.08E+00
Endrin	(72-20-8)	2.16E+01	2.16E+01	2.16E+00
Endrin Aldehyde	(7421-93-4)	2.16E+01	2.16E+00	2.16E+01
Endrin Ketone	(53494-70-5)	2.16E+01	2.16E+00	2.16E+01
Ethylbenzene	(100-41-4)	4.08E-01	4.08E-01	4.08E-02
Ethylchloride	(75-00-3)	4.75E-02	4.75E-02	4.75E-03
Heptachlor	(76-44-8)	4.80E+01	4.80E+01	4.80E+00
Heptachlor Epoxide	(1024-57-3)	1.73E+01	1.73E+01	1.73E+00
Hexachlorobenzene	(118-74-1)	1.10E+02	1.10E+02	1.10E+01
Hexachloroethane	(67-72-1)	3.56E+00	3.56E+00	3.56E-01
n-Hexane	(110-54-3)	2.98E-01	2.98E-01	2.98E-02
1-Hexanol	(111-27-3)	2.60E-02	2.60E-02	2.60E-03
2-Hexanone	(591-78-6)	2.60E-02	2.60E-02	2.60E-03
Isophorone	(78-59-1)	1.70E+00	1.70E+00	0.00E+00
Lindane	(58-89-9)	6.76E+00	6.76E+00	6.76E-01
Methanol	(67-56-1)	2.00E-03	2.00E-03	2.00E-04
Methylene Chloride	(75-09-2)	4.34E-02	4.34E-02	4.34E-03
Methylcyclohexane	(108-87-2)	1.99E-01	0.00E+00	0.00E+00
Methyl Isobutyl Ketone	(108-10-1)	4.70E-03	4.70E-03	4.70E-04
Methyl Methacrylate	(80-62-6)	2.00E-02	2.00E-02	2.00E-03
1-Methyl-4-(1-methylethyl)-benzene	(99-87-6)	1.65E+00	1.65E+00	1.65E-01
2-Methylnapthalene	(91-57-6)	5.94E+00	5.94E+00	5.94E-01

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
(1-Methylpropyl)benzene	(135-98-8)	1.65E+00	1.65E+00	1.65E-01
Naphthalene	(91-20-3)	1.90E+01	1.90E+01	1.90E+00
4-Nitrobenzenamine [4-Nitroaniline]	(100-01-6)	3.44E-01	3.44E-01	3.44E-02
Nitrobenzene	(98-95-3)	1.29E-01	1.29E-01	1.29E-02
2-Nitrophenol	(88-75-5)	7.10E-01	7.10E-01	7.10E-02
4-Nitrophenol	(100-02-7)	8.74E-01	8.74E-01	8.74E-02
N-nitroso-di-n-propylamine	(621-64-7)	3.00E-01	3.00E-01	3.00E-02
N-Nitrosodiphenylamine	(86-30-6)	6.54E-01	6.54E-01	6.54E-02
Phenol	(108-95-2)	2.80E-01	2.80E-01	2.80E-02
Propylbenzene	(103-65-1)	1.65E+00	1.65E+00	1.65E-01
Propylene glycol	(57-55-6)	2.00E-03	2.00E-03	2.00E-04
Pyridine	(110-86-1)	1.38E-02	1.38E-02	1.38E-03
Styrene	(100-42-5)	1.82E+00	1.82E+00	1.82E-01
1,1,1,2-Tetrachloroethane	(630-20-6)	3.18E-01	3.18E-01	3.18E-02
1,1,2,2-Tetrachloroethane	(79-34-5)	1.58E-01	1.56E-01	1.56E-02
Tetrachloroethene	(127-18-4)	7.20E+00	7.20E+00	0.00E+00
2,3,4,6-Tetrachlorophenol	(58-90-2)	2.49E+02	2.49E+02	2.49E+01
Toluene	(108-88-3)	6.00E+00	6.00E+00	0.00E+00
1,2,4-Trichlorobenzene	(120-82-1)	1.44E+00	1.44E+00	1.44E-01
Trichloroethene	(79-01-6)	2.60E+00	2.60E+00	0.00E+00
Trichlorofluoromethane	(75-69-4)	2.68E-01	2.68E-01	2.68E-02
2,4,6-Trichlorophenol	(88-06-02)	6.36E-01	6.36E-01	6.36E-02
1,2,3-Trichloropropane	(96-18-4)	1.61E-01	1.61E-01	1.61E-02
Trimethylbenzene [mixture of isomers]	(25551-13-7)	1.44E+00	1.44E+00	1.44E-01
1,2,4-Trimethylbenzene	(95-63-6)	1.44E+00	1.44E+00	1.44E-01
1,3,5-Trimethylbenzene	(108-67-8)	3.34E+00	3.34E+00	3.34E-01
Vinyl Chloride	(75-01-4)	3.72E-01	3.72E-01	3.72E-02
Xylene [mixture of isomers]	(1330-20-7)	8.86E-01	8.86E-01	8.86E-02

Reference Dose (RD) and Slope Factor (SF) parameters based on updated values in U.S. Environmental Protection Agency (EPA) risk guidance (EPA 2012) are used to calculate the EMDF PWAC. Where no values are provided in the EPA risk guidance, values previously used to calculate the EMWMF WAC are used. Table 3-3 lists SF values for radioactive constituents. Table 3-4 lists SF and RD values for hazardous constituents.

Table 3-3. Slope Factor Values for Radioactive Constituents

Nuclide	Water Ingestion Slope Factor (1/pCi)
H-3	5.07E-14
C-14	1.55E-12
Tc-99	2.75E-12
I-129	1.48E-10
U-233	7.18E-11
U-234	7.07E-11
U-235	6.96E-11
U-236	6.70E-11
U-238	6.40E-11
Np-237	6.18E-11
Pu-239	1.35E-10
Pu-240	1.35E-10
Am-241	1.04E-10

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Antimony		4.00E-04
Barium		2.00E-01
Boron		2.00E-01
Chromium (Total)		1.00E+00
Lead		1.40E-03
Manganese		1.40E-01
Molybdenum		5.00E-03
Selenium		5.00E-03
Strontium		6.00E-01
Tin		6.00E-01
Vanadium		5.00E-03
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
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
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

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents (Continued)

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
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
Chloromethane [Methyl Chloride]	1.30E.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
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
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	6.80E-01	1.00E-03
Endosulfan plus metabolites		6.00E-03
Endrin		3.00E-04
Endrin Aldehyde		3.00E-04

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents (Continued)

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Endrin Ketone		3.00E-04
Ethylbenzene	1.10E-02	1.00E-01
Ethylchloride	2.90E-03	4.00E-01
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		5.00E-01
Methylene Chloride	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-nitroso-di-n-propylamine	7.00E+00	
N-Nitrosodiphenylamine	4.90E-03	2.00E-02
Phenol		3.00E-01
Propylbenzene		3.70E-02
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
Tetrachloroethene	2.10E-03	6.00E-03
2,3,4,6-Tetrachlorophenol		3.00E-02
Toluene		8.00E-02

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents (Continued)

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
1,2,4-Trichlorobenzene	2.90E-02	1.00E-02
Trichloroethene	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]		5.00E-02
1,2,4-Trimethylbenzene		5.00E-02
1,3,5-Trimethylbenzene		1.00E-02
Vinyl Chloride	7.20E-01	3.00E-03
Xylene [mixture of isomers]		2.00E-01

3.2 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 3.2.2 below, respectively. The output files contain a mirror image of the input files used to conduct PATHRAE model simulation.

3.2.1 PATHRAE-RAD

```
PATHRAE-RAD(PC)  Version 2.2d  February 1995
   Date:  9-11-2012
   Time: 20:22:17

 pWAC – July, 2012 New Proposed Cell in UBCV

 *****  Mirror Image of Input Files  *****

 -- Input File:  ABCDEF.DAT
 pWAC – July, 2012 New Proposed Cell in UBCV
 3,1000.,1200.,100000.
 13,0,5
 1,2,
 0.,486.0,243.0,4.91E+05,1.,476.,0.
 1800.,6.,0.,0.,0.,0.,0.315,0.
 20,2,0,1,1
 4.0,16.,1.91E+06,150.,450.,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
 0.010,4.2,0.25,7.0,0.025,24.,0.00001,1.,0.,0.25

 -- Input File:  BRCDCF.DAT
 101,H-3      1.55E-07,  6.40E-08,  0.00E+00,
 102,C-14     2.15E-06,  2.10E-06,  1.88E-09,
 108,Tc-99    2.37E-06,  7.50E-06,  6.30E-11,
 054,U-233    1.89E-04,  1.40E-01,  8.36E-08,
 038,U-234    1.81E-04,  1.30E-01,  8.74E-08,
 039,U-235    1.74E-04,  1.20E-01,  1.73E-05,
 040,U-236    1.74E-04,  1.30E-01,  7.59E-08,
 041,U-238    1.67E-04,  1.20E-01,  2.82E-06,
 042,Np-237   4.07E-04,  4.90E-01,  3.20E-06,
 044,Pu-239   9.25E-04,  4.30E-01,  4.29E-08,
 045,Pu-240   9.25E-04,  5.10E-01,  8.20E-08,
 048,Am-241   7.40E-04,  4.40E-01,  3.21E-06,
 020,I-129    4.07E-04,  1.80E-04,  2.20E-06,


 -- Input File:  INVNTRY.DAT
 101, 1.23E+01, 1.91E+06,    .0,  .000,      0., 0.,   1.,  H-3
 102, 5.73E+03, 1.91E+06,    .0,  .000,      0., 0.,   1.,  C-14
 108, 2.13E+05, 1.91E+06,  29.2,  .089,      0., 0.,   1.,  Tc-99
 054, 1.59E+05, 1.91E+06,  25.7,  .115,      0., 0.,   1.,  U-233
 038, 2.44E+05, 1.91E+06,  35.5,  .070,      0., 0.,   1.,  U-234
 039, 7.04E+08, 1.91E+06,  21.6,  .169,      0., 0.,   1.,  U-235
 040, 2.34E+07, 1.91E+06,  36.6,  .068,      0., 0.,   1.,  U-236
 041, 4.47E+09, 1.91E+06,  12.0,  .718,      0., 0.,   1.,  U-238
 042, 2.14E+06, 1.91E+06,  34.9,  .072,      0., 0.,   1.,  Np-237
 044, 2.41E+04, 1.91E+06,  25.8,  .113,      0., 0.,   1.,  Pu-239
 045, 6.54E+03, 1.91E+06,  46.3,  .054,      0., 0.,   1.,  Pu-240
 048, 4.32E+02, 1.91E+06,  43.5,  .057,      0., 0.,   1.,  Am-241
 020, 1.60E+07, 1.91E+06,  62.0,  .040, 1.0e-02, 0.,   1.,  I-129

 -- Input File:  RQSITE.DAT
 101,-1.99e-1, 0.00E+0, 0.00E+0,  H-3
 102,-1.09e+0, 0.00E+0, 0.00E+0,  C-14
 108,-1.29e+0, 0.00E+0, 0.00E+0,  Tc-99
 054,-4.00e+1, 7.00E-1, 2.00E+1,  U-233
 038,-4.00e+1, 7.00E-1, 2.00E+1,  U-234
 039,-4.00e+1, 7.00E-1, 2.00E+1,  U-235
 040,-4.00e+1, 7.00E-1, 2.00E+1,  U-236
 041,-4.00e+1, 7.00E-1, 2.00E+1,  U-238
 042,-5.56e+1, 4.00E+0, 4.00E+1,  Np-237
 044,-5.76e+1, 4.00E+0, 4.00E+1,  Pu-239
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 045,-5.76e+1, 4.00E+0, 4.00E+1,  Pu-240
 048,-5.76e+1, 4.00E+0, 4.00E+1,  Am-241
 020,-1.99E-1, 0.00E+0, 1.99E-1,  I-129


 -- 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., 6.9
 H-3              .25, 4.8E+0, 4.8E-1, 1.0E-2,   0., 1.2E-2, 9.0E-1
 C-14             .25, 5.5E+0, 5.5E-1, 1.2E-2,   0., 3.1E-2, 4.6E+3
 Tc-99            .25, 2.5E-1, 2.5E-2, 1.0E-3,   0., 1.0E-4, 1.5E+1
 U-233            .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
 U-234            .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
 U-235            .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
 U-236            .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
 U-238            .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
 Np-237           .25, 2.5E-3, 2.5E-4, 5.0E-6,   0., 2.0E-4, 1.0E+1
 Pu-239           .25, 2.5E-4, 2.5E-5, 2.0E-6,   0., 1.4E-5, 3.5E+0
 Pu-240           .25, 2.5E-4, 2.5E-5, 2.0E-6,   0., 1.4E-5, 3.5E+0
 Am-241           .25, 2.5E-4, 2.5E-5, 5.0E-6,   0., 2.0E-4, 2.5E+1
 I-129            .25, 2.0E-2, 2.0E-3, 7.0E-3,   0., 1.0E-2, 4.0E+1
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
H-3	1.166E+03	1.166E+03	1.172E+03	1.172E+03	1.172E+03	0.000E+00
C-14	9.564E+02	9.564E+02	3.270E+04	3.270E+04	3.270E+04	0.000E+00
Tc-99	7.403E+02	7.403E+02	8.438E+02	8.438E+02	8.438E+02	1.469E+00
I-129	8.327E+02	8.327E+02	1.109E+03	1.109E+03	1.109E+03	5.624E-01
U-234	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
U-235	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
U-236	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
U-238	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
Np-237	7.338E+02	7.338E+02	8.028E+02	8.028E+02	8.028E+02	1.122E-02
Pu-239	7.329E+02	7.329E+02	7.570E+02	7.570E+02	7.570E+02	1.059E-03
Pu-240	7.329E+02	7.329E+02	7.570E+02	7.570E+02	7.570E+02	1.059E-03
Am-241	7.338E+02	7.338E+02	9.063E+02	9.063E+02	9.063E+02	1.121E-03
U-233	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02

```
 **********  PATHRAE INPUT SUMMARY  **********

 THERE ARE 80 ISOTOPES IN THE DOSE FACTOR LIBRARY
 NUMBER OF TIMES FOR CALCULATION IS  3
 YEARS TO BE CALCULATED ARE ...

   1000.00  1200.00100000.00

 THERE ARE  13 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))        0
    0  3X,I2,2X,A22,6X,I2))        0
    0  3X,I2,2X,A22,6X,I2))        0
    0  3X,I2,2X,A22,6X,I2))        0

 TIME OF OPERATION OF WASTE FACILITY IN YEARS                    0.
 LENGTH OF REPOSITORY (M)                                      486.
 WIDTH OF REPOSITORY (M)                                       243.
 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)	4.00
THICKNESS OF WASTE IN PITS (M)	16.00
TOTAL WASTE VOLUME (M**3)	1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)	150.
DISTANCE TO WELL -- Y COORDINATE (M)	450.
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)	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
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)	1.00E-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)	4.2
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)
H-3	1.550E-07	6.400E-08	0.000E+00	1.230E+01
C-14	2.150E-06	2.100E-06	1.880E-09	5.730E+03
Tc-99	2.370E-06	7.500E-06	6.300E-11	2.130E+05
I-129	4.070E-04	1.800E-04	2.200E-06	1.600E+07
U-234	1.810E-04	1.300E-01	8.740E-08	2.440E+05
U-235	1.740E-04	1.200E-01	1.730E-05	7.040E+08
U-236	1.740E-04	1.300E-01	7.590E-08	2.340E+07
U-238	1.670E-04	1.200E-01	2.820E-06	4.470E+09
Np-237	4.070E-04	4.900E-01	3.200E-06	2.140E+06

Pu-239	9.250E-04	4.300E-01	4.290E-08	2.410E+04
Pu-240	9.250E-04	5.100E-01	8.200E-08	6.540E+03
Am-241	7.400E-04	4.400E-01	3.210E-06	4.320E+02
U-233	1.890E-04	1.400E-01	8.360E-08	1.590E+05

NUCLIDE	VOLATILITY FRACTION	GAMMA ENERGY (MEV)	GAMMA ATTENUATION (1/M)
H-3	0.000E+00	0.000E+00	0.000E+00
C-14	0.000E+00	0.000E+00	0.000E+00
Tc-99	0.000E+00	8.900E-02	2.920E+01
I-129	0.000E+00	4.000E-02	6.200E+01
U-234	0.000E+00	7.000E-02	3.550E+01
U-235	0.000E+00	1.690E-01	2.160E+01
U-236	0.000E+00	6.800E-02	3.660E+01
U-238	0.000E+00	7.180E-01	1.200E+01
Np-237	0.000E+00	7.200E-02	3.490E+01
Pu-239	0.000E+00	1.130E-01	2.580E+01
Pu-240	0.000E+00	5.400E-02	4.630E+01
Am-241	0.000E+00	5.700E-02	4.350E+01
U-233	0.000E+00	1.150E-01	2.570E+01

NUCLIDE	INPUT LEACH RATE (1/YR)	FINAL LEACH RATE (1/YR)	SOLUBILITY (MOLE/L)	INPUT INVENTORY (CI)
H-3	-1.990E-01	1.100E-03	0.000E+00	1.910E+06
C-14	-1.090E+00	3.134E-04	0.000E+00	1.910E+06
Tc-99	-1.290E+00	2.701E-04	0.000E+00	1.910E+06
I-129	-1.990E-01	1.381E-04	1.000E-02	1.910E+06
U-234	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
U-235	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
U-236	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
U-238	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
Np-237	-5.560E+01	7.006E-06	0.000E+00	1.910E+06
Pu-239	-5.760E+01	6.763E-06	0.000E+00	1.910E+06
Pu-240	-5.760E+01	6.763E-06	0.000E+00	1.910E+06
Am-241	-5.760E+01	6.763E-06	0.000E+00	1.910E+06
U-233	-4.000E+01	9.728E-06	0.000E+00	1.910E+06

NUCLIDE	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
H-3	0.000E+00	1.000E+00	0.000E+00	1.000E+00
C-14	0.000E+00	1.000E+00	0.000E+00	1.000E+00
Tc-99	0.000E+00	1.000E+00	0.000E+00	1.000E+00
I-129	0.000E+00	1.000E+00	1.990E-01	2.433E+00
U-234	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-235	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-236	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-238	7.000E-01	6.040E+00	2.000E+01	1.450E+02
Np-237	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
Am-241	4.000E+00	2.980E+01	4.000E+01	2.890E+02
U-233	7.000E-01	6.040E+00	2.000E+01	1.450E+02

	BIOACCUMULATION FACTORS			
NUCLIDE	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)
H-3	4.800E+00	4.800E-01	1.000E-02	1.200E-02
C-14	5.500E+00	5.500E-01	1.200E-02	3.100E-02
Tc-99	2.500E-01	2.500E-02	1.000E-03	1.000E-04
I-129	2.000E-02	2.000E-03	7.000E-03	1.000E-02
U-234	2.500E-03	2.500E-04	5.000E-04	3.400E-04
U-235	2.500E-03	2.500E-04	5.000E-04	3.400E-04
U-236	2.500E-03	2.500E-04	5.000E-04	3.400E-04
U-238	2.500E-03	2.500E-04	5.000E-04	3.400E-04
Np-237	2.500E-03	2.500E-04	5.000E-06	2.000E-04
Pu-239	2.500E-04	2.500E-05	2.000E-06	1.400E-05
Pu-240	2.500E-04	2.500E-05	2.000E-06	1.400E-05
Am-241	2.500E-04	2.500E-05	5.000E-06	2.000E-04
U-233	2.500E-03	2.500E-04	5.000E-04	3.400E-04

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***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY  1 *****
***** RIVER AT  476.0 M *****
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NUCLIDE	PEAK CONCENTRATION (CI/M**3)	PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MREM/YR)	AVERAGE RISK AT PEAK TIME (HE/YR)
H-3	7.23E-14	401.0	1.31E-08	3.66E-15
C-14	1.14E-03	569.6	2.34E+03	6.54E-04
Tc-99	1.05E-03	606.7	1.84E+03	5.15E-04
I-129	5.37E-04	1096.4	1.82E+05	5.10E-02
U-234	3.35E-05	42471.7	4.48E+03	1.25E-03
U-235	3.78E-05	51627.5	4.86E+03	1.36E-03
U-236	3.78E-05	42592.7	4.85E+03	1.36E-03
U-238	3.78E-05	51627.5	4.66E+03	1.31E-03
Np-237	2.65E-05	90316.8	7.90E+03	2.21E-03
Pu-239	2.03E-06	88714.0	1.37E+03	3.85E-04
Pu-240	2.22E-09	87960.1	1.50E+00	4.21E-07
U-233	3.14E-05	42451.5	4.39E+03	1.23E-03

3.2.2 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 99 COCs and the remaining COCs are provided in Section 3.2.2.1 and Section 3.2.2.2, respectively.

3.2.2.1 First 99 contaminants of concern

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PATHRAE-HAZ(PC)  Version 2.3d  January 1997
  Date:  8-22-2012
  Time: 14:54: 7

pWAC – July, 2012 New Proposed Cell in UBCV - HAZ
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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	1.423E+03	1.423E+03	1.423E+03	2.153E-01
Barium	7.372E+02	7.372E+02	7.648E+02	7.649E+02	7.649E+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	2.159E+03	2.159E+03	2.159E+03	6.445E-01
Lead	7.369E+02	7.369E+02	2.807E+03	2.807E+03	2.807E+03	4.682E-01
Manganese	7.355E+02	7.355E+02	3.496E+03	3.498E+03	3.498E+03	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	2.149E+04	2.149E+04	2.149E+04	1.895E+01
Vanadium	7.457E+02	7.457E+02	8.147E+02	8.147E+02	8.147E+02	4.151E-02
U-233	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-234	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-235	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-236	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-238	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
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	8.326E+03	8.327E+03	8.327E+03	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	7.340E+02	7.340E+02	2.940E+00
Aroclor1221	7.351E+02	7.351E+02	7.351E+02	7.354E+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	3.839E+03	3.839E+03	3.839E+03	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	7.908E+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	7.333E+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	7.570E+02	7.582E+02	7.582E+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	1.941E+03	1.955E+03	1.949E+03	1.255E+00
Dibenzofuran	7.352E+02	7.352E+02	7.352E+02	7.357E+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	7.333E+02	7.333E+02	1.334E+03	1.334E+03	1.334E+03	1.775E+00
13Dichloro	7.335E+02	7.335E+02	1.424E+03	1.424E+03	1.424E+03	1.362E+00
14Dichlorobenzen	7.332E+02	7.333E+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	8.284E+02	8.287E+02	8.287E+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	7.770E+02	7.770E+02	7.770E+02	1.097E+01
26Dinitrotoluene	7.328E+02	7.328E+02	7.756E+02	7.756E+02	7.756E+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	7.366E+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	7.696E+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	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.825E+01
Methylcyclo	7.329E+02	7.329E+02	1.561E+03	1.561E+03	1.561E+03	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	2.044E+03	2.044E+03	2.044E+03	1.981E+00
4Nitrobenzenamin	7.328E+02	7.328E+02	7.357E+03	7.357E+03	7.357E+03	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

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**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC – July, 2012 New Proposed Cell in UBCV - HAZ
3,1000.,1200.,100000.
99,0,2
1,2,
0.,486.0,243.0,4.91E+05,1.,476.,0.
1800.,6.,0.,0.,0.,0.,0.315,0.
20,2,0,1,1
4.0,16.,1.91E+06,150.,450.,1600.,.40,.705,0.90,1.
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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
0.010,4.2,0.25,7.0,0.025,24.,0.00001,1.,0.,0.25
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-- 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
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
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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
641,246-Trichlorphnl 1.10E-02,1.00E-03,0.00E+00,0.00E+00
642,123TriChlopr     3.00E+01,4.00E-03,0.00E+00,0.00E+00
643,Trimethbenz      0.00E+00,5.00E-02,0.00E+00,0.00E+00
644,124trimethylb    0.00E+00,0.00E+00,0.00E+00,0.00E+00
645,135Trimeth       0.00E+00,1.00E-02,0.00E+00,0.00E+00
646,Vinyl-Chloride   7.20E-01,3.00E-03,0.00E+00,0.00E+00
647,Xylene           0.00E+00,2.00E-01,0.00E+00,0.00E+00
122,Mercury          0.00E+00,3.00E-04,0.00E+00,0.00E+00
702,Endosulfan       0.00E+00,5.00E-02,0.00E+00,0.00E+00
703,14Dichloro       2.40E-02,6.00E-03,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
102,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Antimony
104,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Barium
106,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Boron
109,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Chromium
118,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Lead
121,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Manganese
123,  1.00E+10, 1.670E+06,         0,          0, 7.660E+04,         0,        Molybdenum
128,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Selenium
131,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Strontium
134,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Tin
136,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Vanadium
140,  1.59E+05, 1.670E+06,         0,          0, 0.000E+00,         0,        U-233
141,  2.44E+05, 1.670E+06,         0,          0, 0.000E+00,         0,        U-234
142,  7.04E+08, 1.670E+06,         0,          0, 0.000E+00,         0,        U-235
143,  2.34E+07, 1.670E+06,         0,          0, 0.000E+00,         0,        U-236
144,  4.47E+09, 1.670E+06,         0,          0, 0.000E+00,         0,        U-238
501,  1.00E+10, 1.670E+06,         0,          0, 6.820E+02,         0,        24-D
502,  1.00E+10, 1.670E+06,         0,          0, 2.000E+02,         0,        245-TP
503,  1.00E+10, 1.670E+06,         0,          0, 3.420E+00,         0,        Acenaphthene
504,  1.00E+10, 1.670E+06,         0,          0, 1.610E+01,         0,        Acenaphthylene
505,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Acetone
506,  1.00E+10, 1.670E+06,         0,          0, 1.000E+06,         0,        Acentonitrile
507,  1.00E+10, 1.670E+06,         0,          0, 6.130E+03,         0,        acetophenone
508,  1.00E+10, 1.670E+06,         0,          0, 1.200E+04,         0,        Acrolien
509,  1.00E+10, 1.670E+06,         0,          0, 7.450E+04,         0,        Acylonitrle
510,  1.00E+10, 1.670E+06,         0,          0, 1.700E-02,         0,        Aldrin
513,  1.00E+10, 1.670E+06,         0,          0, 4.830E+00,         0,        Aroclor1221
514,  1.00E+10, 1.670E+06,         0,          0, 4.830E+00,         0,        Aroclor1232
520,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Benzene
526,  1.00E+10, 1.670E+06,         0,          0, 3.400E+03,         0,        Benzolic
527,  1.00E+10, 1.670E+06,         0,          0, 4.290E+04,         0,        Benzyl
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528,	1.00E+10,	1.670E+06,	0,	0,	3.220E+02,	0,	benzidine
529,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Alpha-BHC
530,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Beta-BHC
531,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Delta-BHC
533,	1.00E+10,	1.670E+06,	0,	0,	3.030E+03,	0,	Bromodichloro
534,	1.00E+10,	1.670E+06,	0,	0,	1.000E+02,	0,	Bromoform
535,	1.00E+10,	1.670E+06,	0,	0,	5.200E+03,	0,	Bromometh
537,	1.00E+10,	1.670E+06,	0,	0,	6.130E+01,	0,	butylbenzene
539,	1.00E+10,	1.670E+06,	0,	0,	1.800E+00,	0,	Carbazole
540,	1.00E+10,	1.670E+06,	0,	0,	1.180E+03,	0,	CarbonDiS
541,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Carbontetchl
542,	1.00E+10,	1.670E+06,	0,	0,	5.600E-02,	0,	Chlordane
543,	1.00E+10,	1.670E+06,	0,	0,	4.980E+02,	0,	Chlorobenzene
544,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Chloroform
545,	1.00E+10,	1.670E+06,	0,	0,	5.320E+03,	0,	Chlorometh
548,	1.00E+10,	1.670E+06,	0,	0,	3.740E+02,	0,	0-ChloroTu
550,	1.00E+10,	1.670E+06,	0,	0,	2.270E+04,	0,	m-cresol
551,	1.00E+10,	1.670E+06,	0,	0,	2.590E+04,	0,	o-cresol
552,	1.00E+10,	1.670E+06,	0,	0,	2.150E+04,	0,	p-cresol
553,	1.00E+10,	1.670E+06,	0,	0,	6.130E+01,	0,	Cumene
554,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	Cyanide
555,	1.00E+10,	1.670E+06,	0,	0,	9.000E-02,	0,	DDD
556,	1.00E+10,	1.670E+06,	0,	0,	4.000E-02,	0,	DDE
558,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Dinbutylphthalat
560,	1.00E+10,	1.670E+06,	0,	0,	1.030E-03,	0,	Dibenz[ah]
561,	1.00E+10,	1.670E+06,	0,	0,	3.100E+00,	0,	Dibenzofuran
562,	1.00E+10,	1.670E+06,	0,	0,	2.700E+03,	0,	Dibromochloro
563,	1.00E+10,	1.670E+06,	0,	0,	8.000E+01,	0,	12Dichloro
564,	1.00E+10,	1.670E+06,	0,	0,	1.250E+02,	0,	13Dichloro
565,	1.00E+10,	1.670E+06,	0,	0,	8.130E+01,	0,	14Dichlorobenzen
571,	1.00E+10,	1.670E+06,	0,	0,	3.500E+03,	0,	12cisDichloro
572,	1.00E+10,	1.670E+06,	0,	0,	3.500E+03,	0,	12transDichl
573,	1.00E+10,	1.670E+06,	0,	0,	2.800E+02,	0,	Dichlorodiflo
574,	1.00E+10,	1.670E+06,	0,	0,	2.800E+03,	0,	12Dichlprop
575,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Dieldrin
576,	1.00E+10,	1.670E+06,	0,	0,	1.080E+03,	0,	Diethylphth
577,	1.00E+10,	1.670E+06,	0,	0,	2.200E+02,	0,	12DiMethylB
579,	1.00E+10,	1.670E+06,	0,	0,	7.870E+03,	0,	24-Dimethylphe
580,	1.00E+10,	1.670E+06,	0,	0,	4.000E+03,	0,	Dimethylphth
582,	1.00E+10,	1.670E+06,	0,	0,	2.700E+02,	0,	24Dinitrotoluene
583,	1.00E+10,	1.670E+06,	0,	0,	3.520E+02,	0,	26Dinitrotoluene
585,	1.00E+10,	1.670E+06,	0,	0,	4.500E-01,	0,	EndosufanII
586,	1.00E+10,	1.670E+06,	0,	0,	2.500E-01,	0,	Endrin
587,	1.00E+10,	1.670E+06,	0,	0,	2.500E-01,	0,	Aldehyde
588,	1.00E+10,	1.670E+06,	0,	0,	2.500E-01,	0,	Ketone
589,	1.00E+10,	1.670E+06,	0,	0,	1.690E+02,	0,	Ethylbenz
590,	1.00E+10,	1.670E+06,	0,	0,	6.700E+03,	0,	Ethylchlorid
593,	1.00E+10,	1.670E+06,	0,	0,	1.800E-01,	0,	Heptachlor
594,	1.00E+10,	1.670E+06,	0,	0,	2.000E-01,	0,	Heptachlor
595,	1.00E+10,	1.670E+06,	0,	0,	6.200E-03,	0,	Hexachlorobenzen
596,	1.00E+10,	1.670E+06,	0,	0,	5.000E+01,	0,	Hexachloroethane
597,	1.00E+10,	1.670E+06,	0,	0,	9.500E+00,	0,	Nhexane
598,	1.00E+10,	1.670E+06,	0,	0,	5.900E+03,	0,	1hexanol
599,	1.00E+10,	1.670E+06,	0,	0,	5.900E+03,	0,	2hexanone
601,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Isophorone
602,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Lindane
603,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	Methonal
605,	1.00E+10,	1.670E+06,	0,	0,	1.300E+04,	0,	Methchloride
606,	1.00E+10,	1.670E+06,	0,	0,	1.400E+01,	0,	Methylcyclo
607,	1.00E+10,	1.670E+06,	0,	0,	1.900E+04,	0,	MethylIso
608,	1.00E+10,	1.670E+06,	0,	0,	1.500E+04,	0,	MMetacrylate
609,	1.00E+10,	1.670E+06,	0,	0,	6.100E+01,	0,	MethylEthylB
610,	1.00E+10,	1.670E+06,	0,	0,	2.460E+01,	0,	2Methylnaptha
611,	1.00E+10,	1.670E+06,	0,	0,	6.100E+01,	0,	MethylPropylB
612,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Naphthalene
614,	1.00E+10,	1.670E+06,	0,	0,	1.070E-05,	0,	4Nitrobenzenamin
615,	1.00E+10,	1.670E+06,	0,	0,	2.090E+03,	0,	Nitrobenzene
616,	1.00E+10,	1.670E+06,	0,	0,	2.500E+03,	0,	2Nitrophenol
617,	1.00E+10,	1.670E+06,	0,	0,	1.160E+04,	0,	4Nitrophenol
618,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	NnitroNpropyl
619,	1.00E+10,	1.670E+06,	0,	0,	3.500E+01,	0,	NNitrosodiphen
622,	1.00E+10,	1.670E+06,	0,	0,	9.300E+04,	0,	Phenol
623,	1.00E+10,	1.670E+06,	0,	0,	6.100E+01,	0,	PropylB
624,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	PropGlycol
626,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	Pyridine
627,	1.00E+10,	1.670E+06,	0,	0,	3.100E+02,	0,	Styrene
628,	1.00E+10,	1.670E+06,	0,	0,	1.070E+03,	0,	1112Tetra
629,	1.00E+10,	1.670E+06,	0,	0,	2.870E+03,	0,	1122Tetra
630,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Tetrachloroethen
631,	1.00E+10,	1.670E+06,	0,	0,	2.300E+01,	0,	2346Tetrachlor

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632,  1.00E+10, 1.670E+06,         0,         0, 0.000E+00,        0,        Toluene
634,  1.00E+10, 1.670E+06,         0,         0, 5.700E+01,        0,        124Trichlorb
637,  1.00E+10, 1.670E+06,         0,         0, 0.000E+00,        0,        Trichloroethene
639,  1.00E+10, 1.670E+06,         0,         0, 1.100E+03,        0,        TriChloFlo
641,  1.00E+10, 1.670E+06,         0,         0, 8.000E+02,        0,        246-Trichlorophnl
642,  1.00E+10, 1.670E+06,         0,         0, 1.750E+03,        0,        123TriChlopr
643,  1.00E+10, 1.670E+06,         0,         0, 5.700E+01,        0,        Trimethbenz
644,  1.00E+10, 1.670E+06,         0,         0, 5.700E+01,        0,        124trimethylb
645,  1.00E+10, 1.670E+06,         0,         0, 4.820E+01,        0,        135Trimeth
646,  1.00E+10, 1.670E+06,         0,         0, 8.800E+03,        0,        Vinyl
647,  1.00E+10, 1.670E+06,         0,         0, 1.060E+02,        0,        Xylene
122,  1.00E+10, 1.670E+06,         0,         0, 0.000E+00,        0,        Mercury
702,  1.00E+10, 1.670E+06,         0,         0, 4.500E-01,        0,        Endosulfan
703,  1.00E+10, 1.670E+06,         0,         0, 8.130E+01,        0,        14Dichloro

-- 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
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,-4.000E+01, 7.000E-01, 2.000E+01,       U-233
141,-4.000E+01, 7.000E-01, 2.000E+01,       U-234
142,-4.000E+01, 7.000E-01, 2.000E+01,       U-235
143,-4.000E+01, 7.000E-01, 2.000E+01,       U-236
144,-4.000E+01, 7.000E-01, 2.000E+01,       U-238
501,-5.880E-02, 5.880E-03, 5.880E-02,       24-D
502,-1.608E-01, 1.608E-02, 1.608E-01,       245-TP
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
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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,-4.340E-02, 4.340E-03, 4.340E-02,       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
641,-6.360E-01, 6.360E-02, 6.360E-01,       246-Trichlorophnl
642,-1.610E-01, 1.610E-02, 1.610E-01,       123TriChlopr
643,-1.440E+00, 1.440E-01, 1.440E+00,       Trimethbenz
644,-1.440E+00, 1.440E-01, 1.440E+00,       124trimethylb
645,-3.340E+00, 3.340E-01, 3.340E+00,       135Trimeth
646,-3.720E-01, 3.720E-02, 3.720E-01,       Vinyl
647,-8.860E-01, 8.860E-02, 8.860E-01,       Xylene
122,-5.800E+02, 5.800E+01, 5.800E+02,       Mercury
702,-4.080E+00, 4.080E-01, 4.080E+00,       Endosulfan
703,-1.232E+00, 1.232E-01, 1.232E+00,       14DiChloro


-- 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., 6.9


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
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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
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

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Methchloride        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
246-Trichlorphnl    0.25,  2.70E-01,  2.70E-02,  4.00E-05,         0,  1.30E-04,  0.00E+00,         641
123TriChlopr        0.25,  8.20E-02,  8.20E-03,  3.10E-04,         0,  1.00E-03,  0.00E+00,         642
Trimethbenz         0.25,  2.40E-01,  2.40E-02,  4.80E-05,         0,  1.50E-04,  0.00E+00,         643
124trimethylb       0.25,  2.40E-01,  2.40E-02,  4.80E-05,         0,  1.50E-04,  0.00E+00,         644
135Trimeth          0.25,  3.90E-01,  3.90E-02,  2.10E-05,         0,  6.60E-05,  0.00E+00,         645
Vinyl chloride      0.25,  5.90E+00,  5.90E-01,  2.00E-07,         0,  6.30E-07,  0.00E+00,         646
Xylene              0.25,  4.60E-01,  4.60E-02,  1.60E-05,         0,  5.00E-05,  5.50E+01,         647
Mercury             0.25,  1.00E+00,  1.00E-01,  4.70E-04,         0,  1.00E-02,  1.00E+03,         122
Endosulfan          0.25,  3.30E-01,  3.30E-02,  2.80E-05,         0,  8.90E-05,  5.20E+03,         702
14Dichloro          0.25,  4.10E-01,  4.10E-02,  2.00E-05,         0,  6.30E-05,  8.90E+01,         703
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**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  3
YEARS TO BE CALCULATED ARE ...

  1000.00  1200.00100000.00

THERE ARE  99 CONTAMINANTS 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
   0  3X,I2,2X,A22,6X,I2))         0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                     0.
LENGTH OF REPOSITORY (M) 486.
WIDTH OF REPOSITORY (M)  243.
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)                                   4.00
THICKNESS OF WASTE IN PITS (M)                                  16.00
TOTAL WASTE VOLUME (M**3)  1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)                           150.
DISTANCE TO WELL -- Y COORDINATE (M)                           450.
DENSITY OF WASTE (KG/M**3)                                    1600.

FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE                   .400
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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 CLASS4
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)            1.00E-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)                             4.20E+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
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CONTAMINANT	INGESTION UNIT RISK FACTORS (KG-DAY/MG)	INGESTION ALLOWABLE DAILY INTAKES (MG/KG-DAY)	INHALATION UNIT RISK FACTORS (KG-DAY/MG)	INHALATION ALLOWABLE DAILY INTAKES (MG/KG-DAY)	HALF 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
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

VAPORIZATION	SKIN		
	VOLATILITY	RATE	ABSORPTION
CONTAMINANT	FRACTION	(1/S)	(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
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

CONTAMINANT	INPUT LEACH (1/YR)	FINAL LEACH (1/YR)	SOLUBILITY (MG/L)	INPUT INVENTORY (KG)
Antimony	-1.900E+01	2.039E-05	0.000E+00	1.670E+06
Barium	-5.500E+01	7.082E-06	0.000E+00	1.670E+06
Boron	-3.000E+00	1.238E-04	0.000E+00	1.670E+06
Chromium-III	-1.000E+01	3.846E-05	0.000E+00	1.670E+06
Lead	-1.000E+02	3.900E-06	0.000E+00	1.670E+06
Manganese	-2.000E+02	1.952E-06	0.000E+00	1.670E+06
Molybdenum	-2.000E+01	1.938E-05	7.660E+04	1.670E+06
Selenium	-1.500E+01	2.577E-05	0.000E+00	1.670E+06
Strontium	-1.350E+01	2.860E-05	0.000E+00	1.670E+06
Tin	-2.500E+00	1.471E-04	0.000E+00	1.670E+06
Vanadium	-1.000E+02	3.900E-06	0.000E+00	1.670E+06
U-233	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-234	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-235	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-236	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-238	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
24-D	-5.880E-02	4.823E-04	6.820E+02	1.670E+06
245-TP(Silvex)	-1.608E-01	1.414E-04	2.000E+02	1.670E+06
Acenaphthene	-9.200E+01	2.419E-06	3.420E+00	1.670E+06
Acenaphthylene	-1.220E+01	1.139E-05	1.610E+01	1.670E+06
Acetone	-4.400E-02	1.951E-03	0.000E+00	1.670E+06
Acentonitrile	-1.540E-03	2.476E-03	1.000E+06	1.670E+06
acetophenone	-9.240E-02	1.571E-03	6.130E+03	1.670E+06
Acrolien	-2.780E-03	2.456E-03	1.200E+04	1.670E+06
Acylonitrle	-4.440E-03	2.431E-03	7.450E+04	1.670E+06
Aldrin	-9.740E+01	1.202E-08	1.700E-02	1.670E+06
Aroclor1221	-1.200E+02	3.251E-06	4.830E+00	1.670E+06
Aroclor1232	-1.500E+01	3.416E-06	4.830E+00	1.670E+06
Benzene	-1.700E+00	2.104E-04	0.000E+00	1.670E+06
Benzoic-Acid	-1.200E-03	2.404E-03	3.400E+03	1.670E+06
Benzyl-Alcohol	-3.130E-02	2.083E-03	4.290E+04	1.670E+06
benzidine	-5.480E+00	6.931E-05	3.220E+02	1.670E+06
Alpha-BHC	-3.520E+00	5.657E-06	8.000E+00	1.670E+06
Beta-BHC	-4.280E+00	5.657E-06	8.000E+00	1.670E+06
Delta-BHC	-4.280E+00	5.657E-06	8.000E+00	1.670E+06
Bromodichloro	-1.080E-02	2.143E-03	3.030E+03	1.670E+06
Bromoform	-2.520E-01	7.072E-05	1.000E+02	1.670E+06
Bromometh	-2.830E-02	2.117E-03	5.200E+03	1.670E+06
butylbenzene	-1.630E+00	4.335E-05	6.130E+01	1.670E+06
Carbazole	-6.780E+00	1.273E-06	1.800E+00	1.670E+06
CarbonDiS	-1.030E-01	8.345E-04	1.180E+03	1.670E+06
Carbontetchl	-2.200E+00	1.658E-04	0.000E+00	1.670E+06
Chlordane	-1.730E+02	3.960E-08	5.600E-02	1.670E+06
Chlorobenzene	-4.380E-01	3.522E-04	4.980E+02	1.670E+06
Chloroform	-6.200E-01	5.032E-04	0.000E+00	1.670E+06
Chlorometh	-2.860E-02	2.113E-03	5.320E+03	1.670E+06
0-ChloroTu	-8.860E-01	2.645E-04	3.740E+02	1.670E+06
m-cresol	-9.560E-02	1.551E-03	2.270E+04	1.670E+06
o-cresol	-1.820E-01	1.155E-03	2.590E+04	1.670E+06
p-cresol	-9.220E-02	1.572E-03	2.150E+04	1.670E+06
Cumene	-1.650E+00	4.335E-05	6.130E+01	1.670E+06
Cyanide	-9.900E+00	3.884E-05	1.000E+06	1.670E+06
DDD	-9.160E+01	6.365E-08	9.000E-02	1.670E+06
DDE	-1.730E+00	2.829E-08	4.000E-02	1.670E+06
Dinbutylphthalat	-1.000E-06	2.500E-03	0.000E+00	1.670E+06
Dibenz[ah]	-3.580E+03	7.284E-10	1.030E-03	1.670E+06
Dibenzofuran	-2.260E+02	1.727E-06	3.100E+00	1.670E+06
Dibromochloro	-1.410E-01	1.314E-03	2.700E+03	1.670E+06

12Dichloro	-7.580E-01	5.657E-05	8.000E+01	1.670E+06
13Dichloro	-1.606E+01	2.409E-05	1.250E+02	1.670E+06
14Dichlorobenzen	-1.232E+00	5.749E-05	8.130E+01	1.670E+06
12cisDichloro	-9.960E-01	3.390E-04	3.500E+03	1.670E+06
12transDichl	-7.600E-02	1.682E-03	3.500E+03	1.670E+06
Dichlorodiflo	-1.370E-02	1.980E-04	2.800E+02	1.670E+06
12Dichlprop	-9.400E-02	1.561E-03	2.800E+03	1.670E+06
Dieldrin	-3.400E+01	1.144E-05	0.000E+00	1.670E+06
Diethylphth	-2.520E-01	7.637E-04	1.080E+03	1.670E+06
12DiMethylB	-4.800E-01	1.556E-04	2.200E+02	1.670E+06
24-Dimethylphe	-2.520E+00	1.460E-04	7.870E+03	1.670E+06
Dimethylphth	-7.420E-02	1.695E-03	4.000E+03	1.670E+06
24Dinitrotoluene	-1.020E-01	1.909E-04	2.700E+02	1.670E+06
26Dinitrotoluene	-8.390E-02	2.489E-04	3.520E+02	1.670E+06
EndosulfanII	-4.080E+00	3.182E-07	4.500E-01	1.670E+06
Endrin	-2.160E+01	1.768E-07	2.500E-01	1.670E+06
Aldehyde	-2.160E+01	1.768E-07	2.500E-01	1.670E+06
Ketone	-2.160E+01	1.768E-07	2.500E-01	1.670E+06
Ethylbenz	-4.080E-01	1.195E-04	1.690E+02	1.670E+06
Ethylchlorid	-4.750E-02	1.917E-03	6.700E+03	1.670E+06
Heptachlor	-4.800E+01	1.273E-07	1.800E-01	1.670E+06
Heptachlor-epoxd	-1.730E+01	1.414E-07	2.000E-01	1.670E+06
Hexachlorobenzen	-1.100E+02	4.384E-09	6.200E-03	1.670E+06
Hexachloroethane	-3.560E+00	3.536E-05	5.000E+01	1.670E+06
Nhexane	-2.980E-01	6.718E-06	9.500E+00	1.670E+06
1hexanol	-2.600E-02	2.143E-03	5.900E+03	1.670E+06
2hexanone	-2.600E-02	2.143E-03	5.900E+03	1.670E+06
Isophorone	-1.700E+00	2.104E-04	0.000E+00	1.670E+06
Lindane	-6.760E+00	5.657E-06	8.000E+00	1.670E+06
Methonal	-2.000E-03	2.468E-03	1.000E+06	1.670E+06
Methchloride	-4.340E-02	1.957E-03	1.300E+04	1.670E+06
Methylcyclo	-1.990E-01	9.900E-06	1.400E+01	1.670E+06
MethylIso	-4.700E-03	2.427E-03	1.900E+04	1.670E+06
MMetacrylate	-2.000E-02	2.216E-03	1.500E+04	1.670E+06
MethylEthylB	-1.650E+00	4.314E-05	6.100E+01	1.670E+06
2Methylnaptha	-5.940E+00	1.740E-05	2.460E+01	1.670E+06
MethylPropylB	-1.650E+00	4.314E-05	6.100E+01	1.670E+06
Naphthalene	-1.900E+01	2.039E-05	0.000E+00	1.670E+06
4Nitrobenzenamin	-3.440E-01	7.567E-12	1.070E-05	1.670E+06
Nitrobenzene	-1.290E-01	1.369E-03	2.090E+03	1.670E+06
2Nitrophenol	-7.100E-01	4.509E-04	2.500E+03	1.670E+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	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-234	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-235	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-236	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-238	7.000E-01	6.040E+00	2.000E+01	1.450E+02
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	4.340E-03	1.031E+00	4.340E-02	1.312E+00
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

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
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	6.700E+00	6.700E-01	1.600E-07	5.000E-07

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

***** 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	6.94E-02	50362.8	1.99E-03		4.98E+00
Barium	2.41E-02	144848.5	6.95E-04		3.47E-03
Boron	4.21E-01	8369.1	1.23E-02		6.16E-02
Chromium-III	1.31E-01	26741.3	3.99E-03		
Lead	1.33E-02	262955.7	3.83E-04		
Manganese	6.64E-03	525416.0	1.91E-04		1.36E-03
Molybdenum	6.59E-02	52987.4	1.93E-03		3.87E-01
Selenium	8.77E-02	39864.3	4.50E-03		9.00E-01
Strontium	9.73E-02	34515.3	3.02E-03		5.04E-03
Tin	5.00E-01	7056.8	1.55E-02		2.58E-02
Vanadium	1.33E-02	262955.7	3.87E-04		7.74E-02
U-233	2.75E-02	42451.5	7.93E-04		2.64E-01
U-234	2.93E-02	42471.7	8.46E-04		2.82E-01
U-235	3.31E-02	51627.5	9.54E-04		3.18E-01
U-236	3.30E-02	42592.7	9.53E-04		3.18E-01
U-238	3.31E-02	51627.5	9.55E-04		3.18E-01
24-D	1.64E+00	1039.4	4.71E-02		4.71E+00
245-TP(Silvex)	4.81E-01	1100.8	1.38E-02		1.73E+00
Acenaphthene	8.23E-03	241958.8	2.37E-04		3.95E-03
Acenaphthylene	3.87E-02	32515.4	1.11E-03		1.85E-02
Acetone	6.63E+00	848.6	1.90E-01		2.11E-01
Acentonitrile	8.42E+00	699.1	2.42E-01		
acetophenone	5.34E+00	885.4	1.53E-01		1.53E+00
Acrolien	8.35E+00	703.6	2.40E-01		4.79E+02
Acylonitrle	8.27E+00	709.7	2.37E-01	1.28E-01	5.93E+00
Aldrin	4.09E-05	256131.7	1.17E-06	1.99E-05	3.91E-02
Aroclor1221	1.11E-02	556945.5	3.18E-04	6.36E-04	
Aroclor1232	1.16E-02	75580.1	3.33E-04	6.67E-04	
Benzene	7.16E-01	4779.3	2.05E-02	1.13E-03	5.13E+00
Benzoic-Acid	8.18E+00	697.8	2.35E-01		5.86E-02
Benzyl-Alcohol	7.08E+00	808.4	2.03E-01		2.03E+00
benzidine	2.36E-01	14878.1	6.76E-03	1.55E+00	2.25E+00
Alpha-BHC	1.92E-02	9733.9	5.53E-04	3.48E-03	6.91E-02
Beta-BHC	1.92E-02	11728.6	5.53E-04	9.96E-04	
Delta-BHC	1.92E-02	11728.6	5.52E-04	9.94E-04	
Bromodichloro	7.29E+00	733.1	2.09E-01	1.30E-02	1.05E+01
Bromoform	2.41E-01	1388.0	6.90E-03	5.45E-05	3.45E-01
Bromometh	7.20E+00	797.4	2.06E-01		1.47E+02
butylbenzene	1.47E-01	5728.1	4.23E-03		8.46E-02
Carbazole	4.33E-03	18290.1	1.24E-04	2.49E-06	
CarbonDiS	2.84E+00	918.7	8.14E-02		8.14E-01
Carbontetchl	5.64E-01	6039.3	1.62E-02	1.13E-03	4.04E+00
Chlordane	1.35E-04	454551.7	4.17E-06	1.46E-06	8.33E-03
Chlorobenzene	1.20E+00	1973.8	3.44E-02		1.72E+00
Chloroform	1.71E+00	2057.7	4.91E-02	1.52E-03	4.91E+00
Chlorometh	7.19E+00	798.5	2.06E-01		
0-ChloroTu	9.00E-01	3384.8	2.58E-02		1.29E+00
m-cresol	5.28E+00	895.4	1.51E-01		3.03E+00
o-cresol	3.93E+00	1167.6	1.13E-01		2.25E+00
p-cresol	5.35E+00	884.7	1.53E-01		1.53E+00
Cumene	1.47E-01	5791.1	4.23E-03		4.23E-02
Cyanide	1.32E-01	26478.9	3.79E-03		6.32E+00
DDD	2.16E-04	240909.0	7.20E-06	1.73E-06	
DDE	9.62E-05	6043.0	3.11E-06	1.06E-06	
Dinbutylphthalat	8.50E+00	693.4	2.68E-01		2.68E+00
Dibenz[ah]		> 1000000.0			
Dibenzofuran	5.87E-03	593655.7	1.69E-04		1.69E-01
Dibromochloro	4.47E+00	1038.4	1.28E-01	1.08E-02	6.41E+00

12Dichloro	1.92E-01	2981.7	5.52E-03		6.14E-02
13Dichloro	8.19E-02	42646.4	2.35E-03		2.64E-02
14Dichlorobenzen	1.96E-01	4474.6	5.61E-03	3.03E-05	8.02E-02
12cisDichloro	1.15E+00	3731.3	3.31E-02		1.65E+01
12transDichl	5.72E+00	972.7	1.64E-01		8.20E+00
Dichlorodiflo	6.73E-01	850.0	1.93E-02		9.66E-02
12Dichlprop	5.31E+00	890.4	1.52E-01	5.48E-03	1.69E+00
Dieldrin	3.89E-02	86175.3	1.26E-03	2.02E-02	2.52E+01
Diethylphth	2.60E+00	1388.0	7.45E-02		9.31E-02
12DiMethylB	5.29E-01	2106.1	1.52E-02		7.59E-02
24-Dimethylphe	4.96E-01	8531.1	1.42E-02		7.12E-01
Dimethylphth	5.77E+00	966.0	1.65E-01		1.65E-02
24Dinitrotoluene	6.49E-01	915.6	1.86E-02	5.77E-03	9.31E+00
26Dinitrotoluene	8.47E-01	858.6	2.43E-02		2.43E+01
EndosulfanII	1.08E-03	13899.0	3.11E-05		5.18E-03
Endrin	6.01E-04	57186.7	1.74E-05		5.81E-02
Aldehyde	6.01E-04	62772.3	1.74E-05		5.81E-02
Ketone	6.01E-04	62772.3	1.74E-05		5.81E-02
Ethylbenz	4.06E-01	1879.3	1.17E-02	1.28E-04	1.17E-01
Ethylchlorid	6.52E+00	867.9	1.87E-01		
Heptachlor	4.33E-04	126476.3	1.25E-05	5.62E-05	2.50E-02
Heptachlor-epoxd	4.81E-04	45900.9	1.47E-05	1.33E-04	1.13E+00
Hexachlorobenzen	1.49E-05	289201.7	4.49E-07	7.19E-07	5.61E-04
Hexachloroethane	1.20E-01	9838.9	3.46E-03	1.38E-04	4.94E+00
Nhexane	2.28E-02	1532.9	6.57E-04		1.09E-02
1hexanol	7.29E+00	788.9	2.09E-01		5.23E+00
2hexanone	7.29E+00	788.9	2.09E-01		4.18E+01
Isophorone	7.16E-01	4779.3	2.05E-02	1.95E-05	1.03E-01
Lindane	1.92E-02	18237.6	5.53E-04	6.08E-04	1.84E+00
Methonal	8.40E+00	700.7	2.41E-01		4.82E-01
Methchloride	6.65E+00	852.9	1.91E-01	3.82E-04	3.18E+01
Methylcyclo	3.37E-02	792.5	9.66E-04		1.61E-02
MethylIso	8.25E+00	710.7	2.37E-01		2.96E+00
MMetacrylate	7.54E+00	766.9	2.16E-01		1.54E-01
MethylEthylB	1.47E-01	4825.9	4.21E-03		1.14E-01
2Methylnaptha	5.92E-02	16085.4	1.70E-03		4.25E-01
MethylPropylB	1.47E-01	4825.9	4.21E-03		1.14E-01
Naphthalene	6.94E-02	50362.8	1.99E-03		9.95E-02
4Nitrobenzenamin	2.57E-08	1677.8	7.38E-10	1.48E-11	1.85E-07
Nitrobenzene	4.66E+00	1000.6	1.34E-01		6.68E+01
2Nitrophenol	1.53E+00	2830.5	4.40E-02		7.10E-01

3.2.2.2 Remaining contaminants of concern

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PATHRAE-HAZ(PC)  Version 2.3d  January 1997
  Date:  9-11-2012
  Time: 20: 7:14

pWAC – July, 2012 New Proposed Cell in UBCV - HAZ
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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
4Nitrophenol	7.328E+02	7.328E+02	2.872E+03	2.872E+03	2.872E+03	1.266E+01
NnitroNpropyl	7.328E+02	7.328E+02	7.797E+02	7.797E+02	7.797E+02	2.488E+01
NNitrosodiphen	7.330E+02	7.330E+02	7.696E+02	7.696E+02	7.696E+02	2.605E+00
Phenol	7.328E+02	7.328E+02	7.887E+02	7.887E+02	7.887E+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	7.357E+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	7.343E+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
246-Trichlorphnl	7.337E+02	7.337E+02	7.337E+02	7.337E+02	7.337E+02	1.201E+00
123TriChlopr	7.400E+02	7.400E+02	7.400E+02	7.400E+02	7.400E+02	4.928E-01

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  Trimethbenz         7.339E+02 7.339E+02 7.339E+02 7.339E+02 7.339E+02 1.077E+00
  124trimethylb       7.339E+02 7.339E+02 7.339E+02 7.339E+02 7.339E+02 1.077E+00
  135Trimeth          7.333E+02 7.333E+02 7.333E+02 7.333E+02 7.333E+02 1.690E+00
  Vinyl-Chloride      7.328E+02 7.328E+02 7.328E+02 7.328E+02 7.328E+02 2.488E+01
  Xylene              7.332E+02 7.332E+02 1.113E+03 1.113E+03 1.113E+03 1.981E+00

**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC – July, 2012 New Proposed Cell in UBCV - HAZ
3,1000.,1200.,100000.
23,0,2
1,2,
0.,486.0,243.0,4.91E+05,1.,476.,0.
1800.,6.,0.,0.,0.,0.,0.315,0.
20,2,0,1,1
4.0,16.,1.91E+06,150.,450.,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
0.010,4.2,0.25,7.0,0.025,24.,0.00001,1.,0.,0.25


-- Input File:  BRCDCF.DAT
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
641,246-Trichlorphnl 1.10E-02,1.00E-03,0.00E+00,0.00E+00
642,123TriChlopr     3.00E+01,4.00E-03,0.00E+00,0.00E+00
643,Trimethbenz      0.00E+00,5.00E-02,0.00E+00,0.00E+00
644,124trimethylb    0.00E+00,0.00E+00,0.00E+00,0.00E+00
645,135Trimeth       0.00E+00,1.00E-02,0.00E+00,0.00E+00
646,Vinyl-Chloride   7.20E-01,3.00E-03,0.00E+00,0.00E+00
647,Xylene           0.00E+00,2.00E-01,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
617,  1.00E+10, 1.670E+06,         0,          0, 1.160E+04,         0,        4Nitrophenol
618,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        NnitroNpropyl
619,  1.00E+10, 1.670E+06,         0,          0, 3.500E+01,         0,        NNitrosodiphen
622,  1.00E+10, 1.670E+06,         0,          0, 9.300E+04,         0,        Phenol
623,  1.00E+10, 1.670E+06,         0,          0, 6.100E+01,         0,        PropylB
624,  1.00E+10, 1.670E+06,         0,          0, 1.000E+06,         0,        PropGlycol
626,  1.00E+10, 1.670E+06,         0,          0, 1.000E+06,         0,        Pyridine
627,  1.00E+10, 1.670E+06,         0,          0, 3.100E+02,         0,        Styrene
628,  1.00E+10, 1.670E+06,         0,          0, 1.070E+03,         0,        1112Tetra
629,  1.00E+10, 1.670E+06,         0,          0, 2.870E+03,         0,        1122Tetra
630,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Tetrachloroethen
631,  1.00E+10, 1.670E+06,         0,          0, 2.300E+01,         0,        2346Tetrachlor
632,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Toluene
634,  1.00E+10, 1.670E+06,         0,          0, 5.700E+01,         0,        124Trichlorb
637,  1.00E+10, 1.670E+06,         0,          0, 0.000E+00,         0,        Trichloroethene
639,  1.00E+10, 1.670E+06,         0,          0, 1.100E+03,         0,        TriChloFlo
641,  1.00E+10, 1.670E+06,         0,          0, 8.000E+02,         0,        246-Trichlorophnl
642,  1.00E+10, 1.670E+06,         0,          0, 1.750E+03,         0,        123TriChlopr
643,  1.00E+10, 1.670E+06,         0,          0, 5.700E+01,         0,        Trimethbenz
644,  1.00E+10, 1.670E+06,         0,          0, 5.700E+01,         0,        124trimethylb
645,  1.00E+10, 1.670E+06,         0,          0, 4.820E+01,         0,        135Trimeth
646,  1.00E+10, 1.670E+06,         0,          0, 8.800E+03,         0,        Vinyl
647,  1.00E+10, 1.670E+06,         0,          0, 1.060E+02,         0,        Xylene

-- Input File:  RQSITE.DAT
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
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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
641,-6.360E-01, 6.360E-02, 6.360E-01,       246-Trichlorophnl
642,-1.610E-01, 1.610E-02, 1.610E-01,       123TriChlopr
643,-1.440E+00, 1.440E-01, 1.440E+00,       Trimethbenz
644,-1.440E+00, 1.440E-01, 1.440E+00,       124trimethylb
645,-3.340E+00, 3.340E-01, 3.340E+00,       135Trimeth
646,-3.720E-01, 3.720E-02, 3.720E-01,       Vinyl
647,-8.860E-01, 8.860E-02, 8.860E-01,       Xylene

-- 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., 6.9
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
246-Trichlorphnl      0.25,  2.70E-01,  2.70E-02,  4.00E-05,         0,  1.30E-04,  0.00E+00,        641
123TriChlopr          0.25,  8.20E-02,  8.20E-03,  3.10E-04,         0,  1.00E-03,  0.00E+00,        642
Trimethbenz           0.25,  2.40E-01,  2.40E-02,  4.80E-05,         0,  1.50E-04,  0.00E+00,        643
124trimethylb         0.25,  2.40E-01,  2.40E-02,  4.80E-05,         0,  1.50E-04,  0.00E+00,        644
135Trimeth            0.25,  3.90E-01,  3.90E-02,  2.10E-05,         0,  6.60E-05,  0.00E+00,        645
Vinyl-Chloride        0.25,  5.90E+00,  5.90E-01,  2.00E-07,         0,  6.30E-07,  0.00E+00,        646
Xylene                0.25,  4.60E-01,  4.60E-02,  1.60E-05,         0,  5.00E-05,  5.50E+01,        647
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 ...

  1000.00  1200.00100000.00

THERE ARE  23 CONTAMINANTS 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
   0  3X,I2,2X,A22,6X,I2))         0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                         0.
LENGTH OF REPOSITORY (M)                                           486.
WIDTH OF REPOSITORY (M)                                            243.
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)	4.00
THICKNESS OF WASTE IN PITS (M)	16.00
TOTAL WASTE VOLUME (M**3)	1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)	150.
DISTANCE TO WELL -- Y COORDINATE (M)	450.
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)	1.00E-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)	4.20E+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)
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
246-Trichlorphnl	1.100E-02	1.000E-03	0.000E+00	0.000E+00	1.000E+10
123TriChlopr	3.000E+01	4.000E-03	0.000E+00	0.000E+00	1.000E+10
Trimethbenz	0.000E+00	5.000E-02	0.000E+00	0.000E+00	1.000E+10
124trimethylb	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
135Trimeth	0.000E+00	1.000E-02	0.000E+00	0.000E+00	1.000E+10
Vinyl-Chloride	7.200E-01	3.000E-03	0.000E+00	0.000E+00	1.000E+10
Xylene	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10

CONTAMINANT	VOLATILITY FRACTION	VAPORIZATION RATE (1/S)	SKIN ABSORPTION (M/HR)
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
246-Trichlorphnl	0.000E+00	0.000E+00	0.000E+00
123TriChlopr	0.000E+00	0.000E+00	0.000E+00
Trimethbenz	0.000E+00	0.000E+00	0.000E+00
124trimethylb	0.000E+00	0.000E+00	0.000E+00
135Trimeth	0.000E+00	0.000E+00	0.000E+00
Vinyl-Chloride	0.000E+00	0.000E+00	0.000E+00
Xylene	0.000E+00	0.000E+00	0.000E+00

CONTAMINANT	INPUT LEACH (1/YR)	FINAL LEACH (1/YR)	SOLUBILITY (MG/L)	INPUT INVENTORY (KG)
4Nitrophenol	-8.740E-01	3.792E-04	1.160E+04	1.670E+06
NnitroNpropyl	-3.000E-01	8.562E-04	0.000E+00	1.670E+06
NNitrosodiphen	-6.540E-01	2.475E-05	3.500E+01	1.670E+06
Phenol	-2.800E-01	8.954E-04	9.300E+04	1.670E+06
PropylB	-1.650E+00	4.314E-05	6.100E+01	1.670E+06
PropGlycol	-2.000E-03	2.468E-03	1.000E+06	1.670E+06
Pyridine	-1.380E-02	2.297E-03	1.000E+06	1.670E+06
Styrene	-1.820E+00	1.977E-04	3.100E+02	1.670E+06
1112Tetra	-3.180E-01	7.567E-04	1.070E+03	1.670E+06
1122Tetra	-1.580E-01	1.243E-03	2.870E+03	1.670E+06
Tetrachloroethen	-7.200E+00	5.310E-05	0.000E+00	1.670E+06
2346Tetrachlor	-2.490E+02	1.568E-06	2.300E+01	1.670E+06
Toluene	-6.000E+00	6.345E-05	0.000E+00	1.670E+06
124Trichlorb	-1.440E+00	4.031E-05	5.700E+01	1.670E+06
Trichloroethene	-2.600E+00	1.417E-04	0.000E+00	1.670E+06
TriChloFlo	-2.680E-01	7.779E-04	1.100E+03	1.670E+06
246-Trichlorphnl	-6.360E-01	4.931E-04	8.000E+02	1.670E+06
123TriChlopr	-1.610E-01	1.231E-03	1.750E+03	1.670E+06
Trimethbenz	-1.440E+00	4.031E-05	5.700E+01	1.670E+06
124trimethylb	-1.440E+00	4.031E-05	5.700E+01	1.670E+06
135Trimeth	-3.340E+00	3.409E-05	4.820E+01	1.670E+06
Vinyl-Chloride	-3.720E-01	7.395E-04	8.800E+03	1.670E+06
Xylene	-8.860E-01	7.496E-05	1.060E+02	1.670E+06

CONTAMINANT	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
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
246-Trichlorphnl	6.360E-02	1.458E+00	6.360E-01	5.579E+00
123TriChlopr	1.610E-02	1.116E+00	1.610E-01	2.159E+00
Trimethbenz	1.440E-01	2.037E+00	1.440E+00	1.137E+01
124trimethylb	1.440E-01	2.037E+00	1.440E+00	1.137E+01
135Trimeth	3.340E-01	3.405E+00	3.340E+00	2.505E+01
Vinyl-Chloride	3.720E-02	1.268E+00	3.720E-01	3.678E+00
Xylene	8.860E-02	1.638E+00	8.860E-01	7.379E+00

	BIOACCUMULATION FACTORS			
CONTAMINANT	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)
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
246-Trichlorphnl	2.700E-01	2.700E-02	4.000E-05	1.300E-04
123TriChlopr	8.200E-02	8.200E-03	3.100E-04	1.000E-03
Trimethbenz	2.400E-01	2.400E-02	4.800E-05	1.500E-04
124trimethylb	2.400E-01	2.400E-02	4.800E-05	1.500E-04
135Trimeth	3.900E-01	3.900E-02	2.100E-05	6.600E-05
Vinyl-Chloride	5.900E+00	5.900E-01	2.000E-07	6.300E-07
Xylene	4.600E-01	4.600E-02	1.600E-05	5.000E-05

***** 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
4Nitrophenol	1.29E+00	2789.2	3.70E-02		5.97E-01
NnitroNpropyl	2.91E+00	1539.2	8.35E-02	5.85E-01	
NNitrosodiphen	8.42E-02	2654.1	2.42E-03	1.18E-05	
Phenol	3.05E+00	1476.2	8.74E-02		2.91E-01
PropylB	1.47E-01	4825.9	4.21E-03		1.14E-01
PropGlycol	8.40E+00	700.7	2.41E-01		1.20E-02
Pyridine	7.81E+00	744.1	2.24E-01		2.24E+02
Styrene	6.72E-01	5272.1	1.93E-02		9.64E-02
1112Tetra	2.57E+00	1595.9	7.38E-02	1.92E-03	2.46E+00
1122Tetra	4.23E+00	1085.7	1.21E-01	2.43E-02	6.06E+00
Tetrachloroethen	1.81E-01	18639.3	5.18E-03	1.09E-05	8.64E-01
2346Tetrachlor	5.33E-03	654021.6	1.53E-04		5.11E-03
Toluene	2.16E-01	15615.3	6.19E-03		7.74E-02
124Trichlorb	1.37E-01	5129.7	3.94E-03	1.14E-04	3.94E-01
Trichloroethene	4.82E-01	7047.3	1.38E-02	6.36E-04	2.77E+01
TriChloFlo	2.65E+00	1438.4	7.59E-02		2.53E-01
246-Trichlorphnl	1.68E+00	2164.5	4.82E-02	5.30E-04	4.82E+01
123TriChlopr	4.19E+00	1101.4	1.21E-01	3.64E+00	3.03E+01
Trimethbenz	1.37E-01	5129.7	3.94E-03		7.88E-02
124trimethylb	1.37E-01	5129.7	3.94E-03		
135Trimeth	1.16E-01	9261.5	3.33E-03		3.33E-01
Vinyl-Chloride	2.52E+00	1766.0	7.21E-02	5.19E-02	2.40E+01
Xylene	2.55E-01	3384.8	7.32E-03		3.66E-02

APPENDIX G:

COST ESTIMATES FOR ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES

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CONTENTS

FIGURES

TABLES

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
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
ETTP	East Tennessee Technology Park
FY	Fiscal Year
LLW	low-level waste
M	million
NNSS	Nevada National Security Site
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
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
U.S.	United States
WAC	waste acceptance criteria
WBS	Work Breakdown Structure

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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.

CERCLA waste will be generated from environmental restoration activities on the ORR and associated sites. Separate 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.

Candidate waste streams addressed under these disposal alternatives are low-level waste (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 Toxic Substances Control Act of 1976 (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 disposal cells and supporting infrastructure, operation and management of the disposal cells, capping and closure, and post-closure monitoring and maintenance. Major cost elements of the Off-site Disposal Alternative are transportation of waste to the off-site facilities and fees for disposal. Waste volumes estimated to be generated and disposed are key to 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.

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. For the On-site cost estimate a 25% contingency was applied, 10% for scope contingency, and 15% for bid contingency. The lower end of the EPA recommended range was selected for the scope contingency based on the fact that needed design considerations have been readily available from the existing EMWMF design. An average value was selected for the bid contingency portion of the On-site estimate. For the Off-site estimate, a contingency value of 20% was applied due to the 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. Further uncertainties regarding waste volume estimates, technologies, and process options that will be used for final designs; unknowns that could pose risks that would increase costs; or opportunities that could decrease costs are accounted for in the cost accuracy range for CERCLA feasibility studies of -30% to +50% of the calculated estimate.

For the On-site Disposal Alternative, a cost estimate was developed for construction of the EMDF on the ORR at a site in East Bear Creek Valley near EMWMF.

Table G-1 summarizes the cost in 2012 dollars and present worth project cost (including contingency) for the On-site and Off-site Disposal Alternatives.

Table G-1. On-site and Off-site Disposal Alternatives Cost Estimates with Contingency

Alternative	Cost in 2012 Dollars ($ Ms)	Present Worth Cost* ($ Ms)
On-site Disposal		
EMDF	817	547
Off-site Disposal		
Existing Off-site Facilities	2,356	1,556
*Based on real discount rate of 2.0%		

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 ORR. The scope of actions for this alternative includes early actions (i.e., pre-design investigations); design and construction of all facilities; design support during construction, quality assurance, quality controls, 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. The EMDF is estimated to receive waste for approximately 21 years (i.e., early Fiscal Year [FY] 2023 through FY 2043) and be operational for 22 years (through FY 2044). Support facilities required for initial operations would include those needed for staging of waste, receiving and unloading waste, and decontamination of equipment. Siting near the EMWMF would allow many of the support facilities already constructed for the EMWMF to be shared with the EMDF (see Section 6.2.2.5 of the RI/FS). The conceptual design of the EMDF would provide a disposal capacity of approximately 2.5 million[1] (M) yd^3.

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 implementing long-term institutional controls for this EMDF. Key elements of the proposed disposal facility include a dike constructed of clean fill material to contain the waste laterally; a multilayer liner with a double leachate collection detection system to isolate the waste from groundwater; a facility underdrain beneath the landfill to intercept and drain upwelling groundwater; upgradient geomembrane-lined diversion ditch with shallow French drain to divert upgradient surface water and shallow perched groundwater 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 the EMDF is shown on Figure G-1.

[1] A projected disposal capacity need of approximately 2.5M 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.

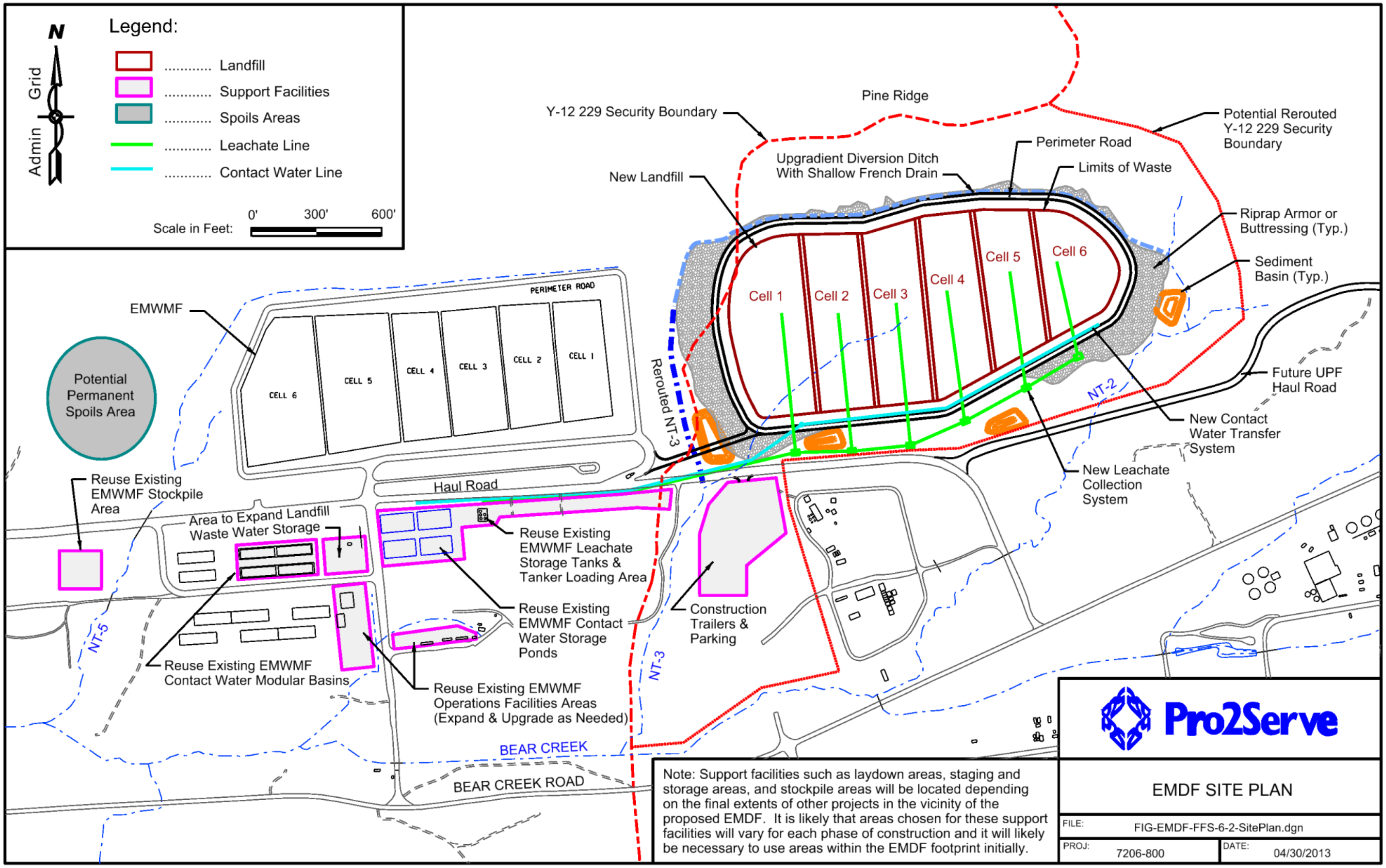


Figure G-1. On-site EMDF Conceptual Site Layout Plan

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 estimates, it is assumed that all non-classified LLW and LLW/TSCA waste and classified LLW waste would be shipped to Nevada National Security Site (NNSS) in Nye County, Nevada. Any unclassified LLW/RCRA (mixed) waste would be shipped for treatment and disposal at Energy*Solutions*, in Clive, Utah. Classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS. 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 rail followed by truck transport to NNSS (transload facility in Kingman, AZ). All classified waste shipments to NNSS would be by truck transport. The waste volume estimates (including 25% uncertainty) for the Off-site Disposal Alternative are approximately 1,966,713 yd^3 destined for NNSS and 73,544 yd^3 destined for Energy*Solutions*. For purposes of the cost estimate, it is assumed that all waste and material types would be placed into intermodal containers before shipment.

2. PROJECT SCHEDULES

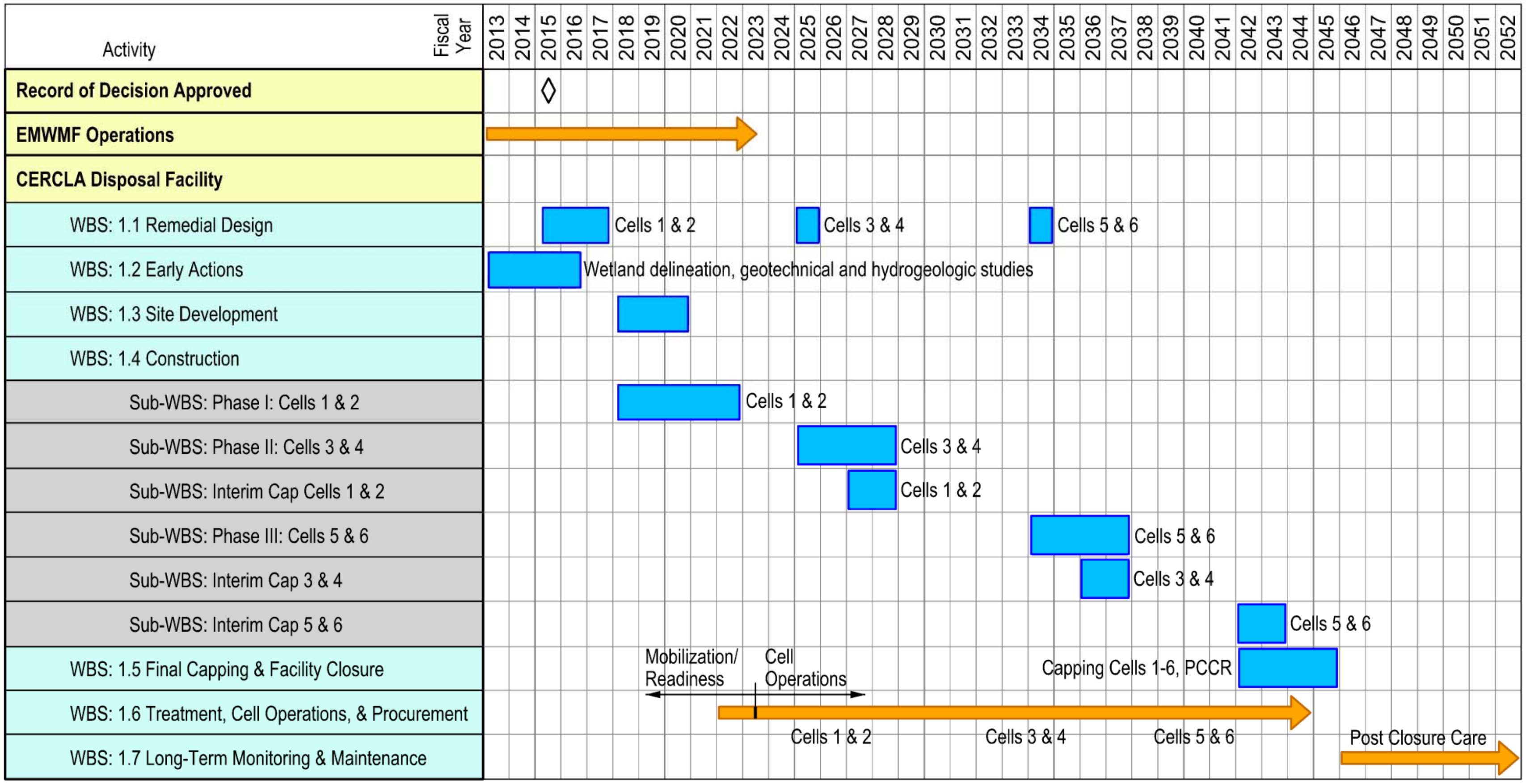
Project schedules for the On- and Off-site Disposal Alternatives are based on the estimated future waste-generation rates. It is assumed that waste would be disposed of on-site or off-site in the same year it is generated. The schedule for the Off-site Disposal Alternative is directly linked to the as-generated waste volume estimate.

Figure G-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 2044 with closure activities completed in FY 2046. Long-term surveillance and maintenance (S&M) and monitoring would continue after facility closure.

3. ELEMENTS COMMON TO THE ON- AND OFF-SITE DISPOSAL ALTERNATIVES

Key elements common to the On- and Off-site Disposal Alternatives affecting cost estimates include contractual mechanism, assumption about no costs for involvement of an integrating contractor, assumption about excluding cost of the U.S. Department of Energy (DOE) activities, and assumptions regarding responsibilities of the waste generators. Costs for off-site shipment of waste not meeting the 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 cost estimates for both alternatives, it is assumed that integrating contractor overhead costs would not be applicable for the design, construction, operation, or management of the project. Costs for DOE activities are excluded from the cost estimates for both disposal alternatives. Cost contingency was added to both the On-site or Off-site Disposal Alternative cost estimates, 25% for the On-site estimate and 20% for the Off-site estimate.



WBS = Work Breakdown Structure

Figure G-2. On-site Disposal Alternative Schedule

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; 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 the East Tennessee Technology Park (ETTP) rail siding for off-site shipment; and interim storage, if required, for waste not meeting the disposal facilities' WAC. Because these costs are not within the scope of the disposal alternatives, and would not represent a discriminating element between the alternatives because of comparable expense, costs associated with these activities and materials are not included in the cost estimates, except for purchase and loading waste containers for transport to off-site facilities. For classified waste and hazardous waste to be treated at the disposal facility, purchase and single use of containers is assumed. Costs for purchase of containers for shipment to off-site disposal facilities are included in the off-site disposal cost estimate because the costs are a discriminator between the On-site and Off-site Disposal Alternatives.

4. 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.

4.1 ON-SITE DISPOSAL ALTERNATIVE COST-ESTIMATE 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 G-1). This section provides the conditions and assumptions for the on-site EMDF. Elements common to both the On-site and Off-site Disposal Alternative (see Section 3 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; 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, leachate and contact water management, 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 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.
- All costs are presented in 2012 dollars and present worth.
- Assumed EMWMF capacity is filled in early FY 2023. The EMDF would have an operational lifespan of approximately 22 years from early FY 2023 through FY 2044 and waste would be generated during 21 of the 22 years of operation.
- 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 the 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 4.2.3. 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 at least one year prior to reaching capacity at EMWMF.
- Phase II construction would include the construction of two waste disposal cells (Cells 3 and 4) and the interim capping of Cells 1 and 2. This construction would occur simultaneously with the operation of the existing disposal cells.
- Phase III construction would include the construction of two waste disposal cells (Cells 5 and 6) and the interim capping of Cells 3 and 4. This construction would occur simultaneously with the operation of the existing disposal cells. The Phase III construction cost estimate also includes interim capping of Cells 5 and 6 after the cells are filled.
- 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 on Cells 5 and 6 placed as part of Phase III construction. (Cells 5 and 6 may not require the geomembrane portion of the interim cap if the landfill is closed shortly after operations cease, but the vent layer and associated geotextile would be required regardless of schedule. All layers of the interim cap are included in the Phase III construction cost estimate.)
- The new disposal facility would be a stand-alone facility. Complete self-supporting infrastructure (e.g., access roads, utilities, disposal cells, leachate collection, decontamination 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 to the EMDF on a dedicated Haul Road and not over state maintained roadways.
- All on-site waste shipments would satisfy U.S. Department of Transportation (DOT) requirements.
- The 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.
- Leachate and contact water would be managed by collecting in existing or updated leachate collection tanks and contact water basins located at the EMWMF site. Current practices of leachate and contact water management (direct discharge that meets appropriate discharge criteria) and/or transport to the Oak Ridge National Laboratory (ORNL) wastewater treatment systems for treatment would be performed. Existing collection systems would be maintained as necessary for EMDF utilization. Operation of the leachate collection system would continue 10 years after disposal operations cease.

- Waste would not be highly radioactive and; 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 the 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 the EMDF (e.g., 22 years) would be paid into an escrow account to be used for long-term monitoring and maintenance.

4.2 BASIS OF ESTIMATE FOR THE ON-SITE DISPOSAL ALTERNATIVE

The key components of the On-site Disposal Alternative cost estimate are early actions; remedial design; site development and construction; operations; final capping and facility closure; and long-term monitoring and maintenance.

4.2.1 Early Actions

Early actions to support remedial design include construction of new groundwater monitoring wells and surface water weirs, upgrading existing down-gradient groundwater monitoring wells (if required), groundwater monitoring, hydrogeological and geotechnical investigation, and wetland delineation activities. These early actions would be completed prior to issuance of the draft Remedial Design Report (RDR)/ Remedial Action Work Plan (RAWP).

4.2.2 Remedial Design

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, etc., required to construct and operate the new disposal facility. In addition, remedial design includes preparation of design documents for site development activities. Procurement activities (captured in Work Breakdown Structure (WBS) 1.8, Project Management) include development and issuance of Request for Proposals for the different phases of facility design and construction.

4.2.3 Site Development and Construction

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 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; relocating the Y-12 National Security Complex 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.

Construction activities would include construction of the disposal facility and construction of a leachate/contact water collection system described in Section 6.2.2.4, Section 6.2.2.6, and Section 6.2.2.7 of the RI/FS. Construction of six disposal cells of the facility would be in three phases (two cells in each phase - Phases I, II, and III). An interim cover system (interim cap) would be installed for all Phases of the cells construction.

4.2.3.1 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.

4.2.3.2 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.

4.2.3.3 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 cost 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.

4.2.3.4 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, General and Administrative 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.

4.2.4 Operations

It is assumed that all operations activities would be performed by a prime contractor to DOE. Operations activities would consist of waste receipt and inspection, 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, leachate collection and management, equipment maintenance, support facility (e.g., roads and buildings) maintenance, and record keeping. Treatment of waste to meet the disposal-facility WAC would remain the responsibility of the waste generator and is not included in this alternative. Disposal facility operations costs are based on actual EMWMF operations cost data.

Collected wastewater from the leachate and contact water collection systems would be stored in the existing EMWMF leachate storage tanks and contact water collection basins/modular tanks. The leachate and contact water will be sampled and characterized to determine if it is acceptable for direct discharge. If the water does not meet direct discharge criteria, it will be transported to an existing, permitted wastewater treatment system on the ORR (currently the ORNL Process Waste Treatment Complex).

4.2.5 Final Capping and Facility Closure

Final capping and facility closure would include placement of the final cover system, removal of support facilities, and site restoration (see Section 6.2.8 of the RI/FS).

4.2.6 Long-term Monitoring and Maintenance

Long-term monitoring and maintenance would include post-closure operation of the leachate collection system for 10 years following closure of the disposal facility. Also included in the estimate is a perpetual care fund ($22M or $1M per year of facility operation) that would be paid into an escrow account during active operation of the facility, to be used for long-term facility S&M and monitoring after the facility is closed.

4.2.7 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 in 2012 dollars over the period of activity as determined by the project schedule.

4.3 PROJECT WORK BREAKDOWN STRUCTURE

The project WBS for the On-site Disposal Alternative is presented in Figure G-3.

4.4 SUMMARY COST DATA

Table G-2 provides summary project cost estimates for the On-site Disposal Alternative for the proposed EMDF site. Examples of items included in the Capital Cost portion of the table are listed below. The items listed below are not intended to be an exhaustive list of every line of the cost estimate, but just demonstrate that this RI/FS has adequately considered the On-site option’s costs. These costs include labor, material, and equipment costs and all the necessary plans and reports associated with the activities listed.

<u>Early Actions and Site Characterization</u> - Surveys (topographic, wetland, threatened and endangered species, and as-built surveys of installed monitoring devices), mobilization and installation for access roads, weir installation, groundwater monitoring well installation, installation reports, geotechnical investigation (including field, laboratory, and engineering efforts), weir and groundwater well monitoring and reporting, and project oversight (engineering, health and safety, regulatory review, field services, document control, and project management).

<u>Remedial Design</u> - Preparation of design drawings, design specifications, design calculations, final WAC, and the RDR/RAWP; regulatory review; and project management.

<u>Site Development</u> - Work packages and lift plan; mobilization and rental of construction equipment; wetlands/stream replacement; clearing, grubbing, topsoil removal, excavating, off-site borrow, and grading for site development activities; installation of sediment controls; construction of access roads and laydown areas; relocation of the 229 Boundary; utility installation and distribution; installation of personnel facilities and parking; installation of truck scales; installation of guard stations; and project oversight and reporting (engineering, health and safety, regulatory review, field services, document control, and project management).

<u>Project Phase Oversight and Management</u> - Project oversight reporting (engineering, health and safety, regulatory review, field services, document control, and project management); quality control subcontractor (mobilization, supplies and equipment, vehicles, home office support, on-site labor, field and lab testing, surveying, certification reports, and demobilization); and construction management.

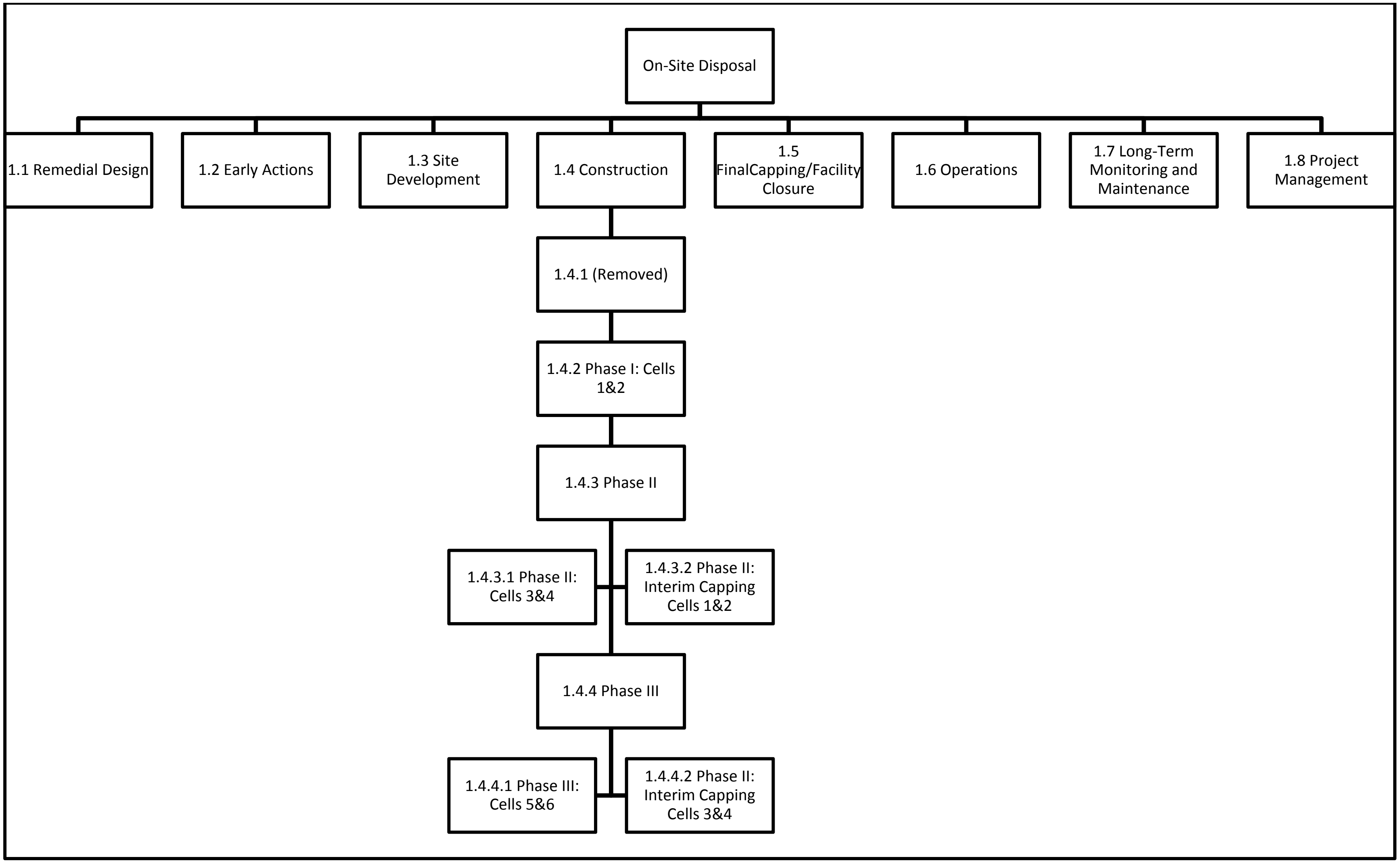


Figure G-3. On-site Disposal Alternative Work Breakdown Structure

Table G-2. On-site Disposal Alternative Cost Elements, Estimate Summary

Cost Element	Cost in 2012 Dollars ($ Ms)
Capital Cost	
Early Actions and Site Characterization	3.5
Remedial Design	5.5
Site Development	6.0
Phase 1 Oversight and Management	4.8
Phase 1 Support Construction	7.9
Phase 1 Landfill Construction (Cells 1 and 2)	52
Phase 2 Oversight and Management	4.4
Phase 2 Support Construction	3.7
Phase 2 Landfill Construction (Cells 3 and 4)	19
Interim Capping Cells 1 and 2	2.2
Phase 3 Oversight and Management	6.1
Phase 3 Support Construction	2.4
Phase 3 Landfill Construction (Cells 5 and 6)	25
Interim Capping Cells 3 and 4	2.0
Interim Capping Cells 5 and 6	1.7
Capping and Closure Oversight and Management	11
Capping and Closure Support Construction	4.4
Capping Construction	43
Project Management (includes construction management and procurement)	20
Total Capital Cost	**225**
Operations Cost	
Disposal Facility Operations (includes security)	391
Long-Term Monitoring and Maintenance (Includes Periodic Cost Elements)	38
Total Operations Cost	**429**
Total Cost	
Total Project Cost Before 25% Contingency	**654**
25% Contingency	**163**
Total Project Cost with Contingency	**817**
Total Project Cost (present worth)*	**547**

***Present Worth calculated at 2.0% real discount rate.

Project Phase Support Construction - Pre-mobilization submittals (includes development of contracts); work packages and lift plan; personnel training; construction of temporary trailers and parking; mobilization of staff and equipment; clearing, grubbing, topsoil removal, excavating, off-site borrow, and grading for site development activities; installation of sediment controls; installation of security fencing, lighting, and alarms; site restoration; engineering and testing; support equipment services; operations transition, readiness, and startup; demobilization.

Project Phase Landfill Construction - Contractor mobilization and demobilization; 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 piping and contact water piping and equipment; and installation of landfill waste water manholes.

Interim Capping - Pre-mobilization submittals; construction of temporary facilities; personnel training; mobilization and demobilization of staff and equipment; construction of cover; equipment decontamination; anchor trenching; storm runoff management; support equipment and services; and subcontractor project management.

Capping and Closure Support Construction - Pre-mobilization submittals; construction of temporary facilities; personnel training; mobilization and demobilization of staff and equipment; support equipment and services; erosion control; site restoration; and field engineering and quality control testing.

Final Capping Construction - Construction of the cap layers; construction of test pads; and seeding and mulching.

Capping and Closure Oversight and Management - Contractor management; subcontractor project management staff; post construction reports; construction quality assurance subcontract; and project oversight reporting (engineering, health and safety, regulatory review, field services, document control, and project management).

Landfill Construction Project Management - 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.

Operations and maintenance costs were divided into the costs to operate the facility while it is receiving waste and then costs associated with monitoring and maintaining the facility once it is closed.

Disposal Facility Operations - Costs were calculated based on EMWMF actual costs. Activities include all daily operations receiving and managing waste and waste documentation; equipment maintenance; equipment replacement; personnel; security; engineering; monitoring, reporting; stormwater management; landfill wastewater management; and miscellaneous expenditures.

Long-Term Monitoring and Maintenance - Perpetual Care Fee for post-closure care; leachate collection and shipment for treatment; monitoring; reporting; maintenance; and demolition and disposal of landfill wastewater storage areas.

Contingency - 10% scope contingency and 15% bid contingency was added to the final total estimated project cost.

5. 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.

5.1 OFF-SITE DISPOSAL ALTERNATIVE COST-ESTIMATE CONDITIONS AND ASSUMPTIONS

A cost estimate was conducted 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.

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 3 of this Appendix).

Figures G-4 and G-5 show the off-site disposal activities and responsible entities for waste shipments to NNSS and Energy*Solutions*.

Table G-3 shows the estimated volumes expected to be disposed of at NNSS and Energy*Solutions*. Transportation and treatment/disposal costs are based on these estimated volumes.

The key assumptions for the Off-site Disposal Alternative cost estimate are as follows:

- All non-classified LLW and LLW/TSCA waste, and all classified LLW would be disposed at the NNSS facility in Nye County, NV.
- The NNSS WAC allows for the use of returnable intermodal containers.
- All LLW/RCRA (mixed) waste would be treated and disposed at the Energy*Solutions* facility in Clive, Utah.
- All classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS.
- All non-classified waste shipped to NNSS or Energy*Solutions* would be transported in intermodal containers from the individual remedial sites to the Technology Park rail siding, loaded onto railcars, and shipped by :
  - Rail to Kingman, AZ transload facility followed by truck transport to NNSS (two intermodal containers per truckload for debris and one intermodal container per truckload for soil), or
  - Rail to Energy*Solutions.*
- Each intermodal would contain approximately 11 yd^3 of debris waste or 15 yd^3 of soil waste and each railcar will carry eight intermodal debris containers or six intermodal soil containers.
- Intermodal containers would be purchased and reused for all non-classified, non-RCRA hazardous waste shipment.
- All intermodal containers would include a plastic liner for each shipment.
- Intermodal container design life is 10 years.

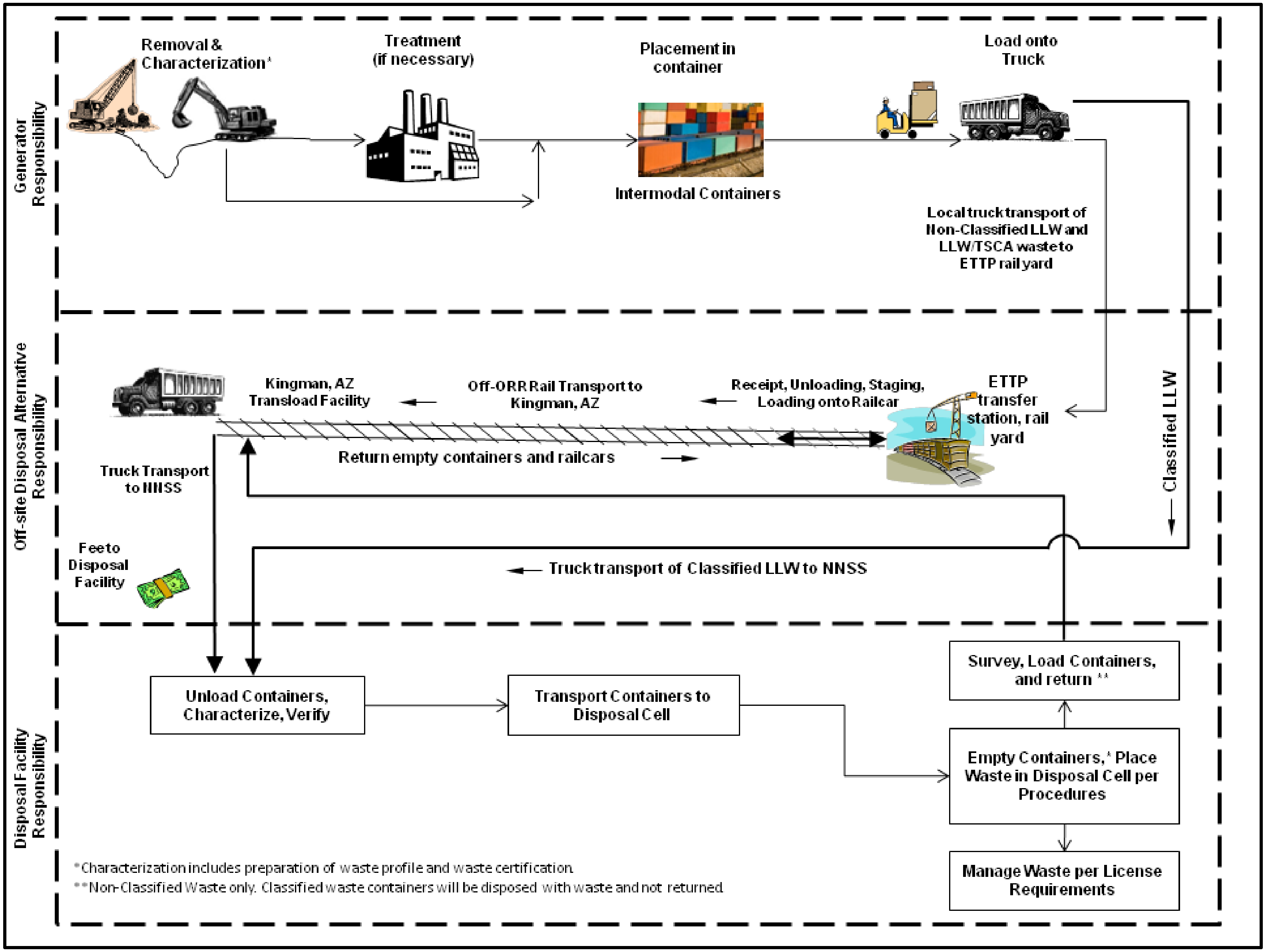


Figure G-4. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative

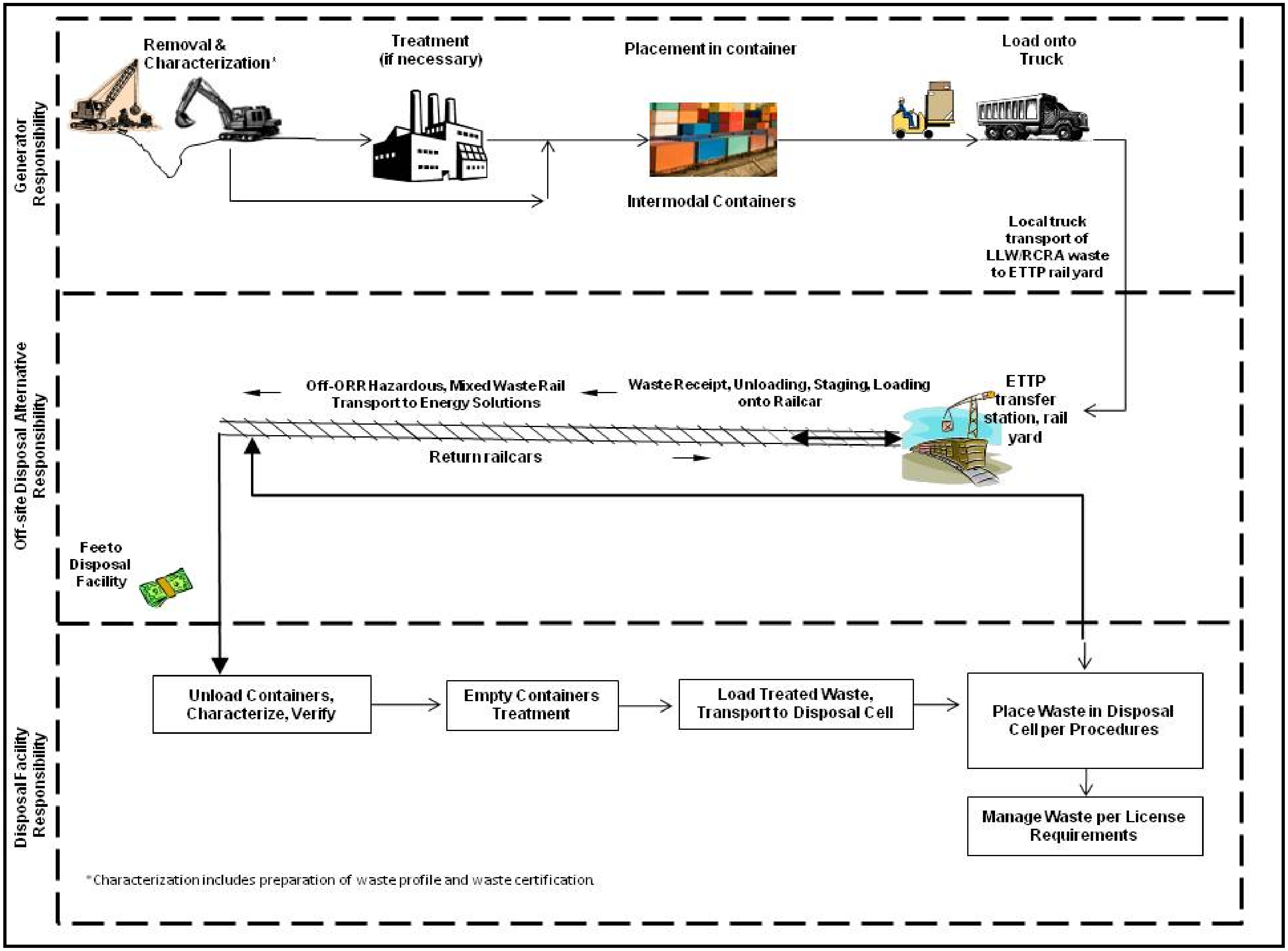


Figure G-5.Schematic of Responsibilities for Waste Shipments to EnergySolutions for Off-site Disposal Alternative

- Intermodal containers would be purchased for all classified and LLW/RCRA (mixed) waste shipments (non-returnable containers).
- Macroencapsulation is the assumed waste treatment for LLW/RCRA (mixed) waste disposed at Energy*Solutions*. The waste treatment fee for macroencapsulation includes waste disposal.
- Waste treatment/disposal fees for Energy*Solutions* are based on the actual volume shipped in the container and·not on the total container volume.
- 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.
- All shipments will satisfy DOT requirements.

  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.)

Table G-3. As-generated Waste Volume Estimate (FY 2023 - FY 2043) 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)	LLW	Debris	1,479,503
	LLW and LLW/TSCA	Soil	487,210
		NNSS (Non-Classified) SUBTOTAL	**1,966,713**
NNSS (Classified)	LLW	Debris	0
NNSS (Classified, Mixed)	LLW	Debris	1,469
		NNSS (Classified) SUBTOTAL	**1,469**
Energy*Solutions*	LLW/RCRA	Debris	57,107
		Soil	14,969
		Energy*Solutions* SUBTOTAL	**72,076**
		TOTAL	**2,040,257**

5.2 BASIS OF ESTIMATE FOR THE OFF-SITE DISPOSAL ALTERNATIVE

The key components of the Off-site Disposal Alternative cost estimate are those costs associated with transportation and treatment/disposal. Costs calculated for the Off-site Disposal Alternative estimates are situation-specific rates based on privatized cost estimates, and include no allowance for involvement of an integrating contractor. Table G-4 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. Transportation costs include purchase cost for intermodal containers for all waste shipments. Intermodal containers used for LLW would be reused as many times as possible during an assumed design life of 10 years. Intermodal containers for classified and mixed low-level (radioactive) waste are considered single use. Treatment/disposal fees used in the cost estimate for macroencapsulation of LLW/RCRA waste are based on the fee structure of an existing mixed waste disposal contract between DOE and Energy*Solutions*.

Fuel surcharges that may be incurred during transportation of the waste to the disposal facilities are not included in the estimate. 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 G-4. Transportation and Treatment/Disposal Costs Used for Off-site Disposal Alternative

Transportation Costs*		
Rail from ETTP Railyard to Kingman, AZ or Clive, UT	$25,440	Per railcar (8 debris intermodals per railcar)
Rail from ETTP Railyard to Kingman, AZ or Clive, UT	$22,482	Per railcar (6 soil intermodals per railcar)
Truck transport from Kingman, AZ to NNSS	$1,000	Per truckload for soil waste (1 intermodal per truckload)
	$2,000	Per truckload for debris waste (2 intermodals per truckload)
Rail loading/unloading for truck transport and return of empty containers (Kingman, AZ)	$370	Per intermodal
Container purchase (classified and LLW/RCRA waste shipments)	$6,300	Per intermodal
Container liner purchase	$545	Per intermodal per trip
Truck transport to NNSS for classified waste	$15,887	Per truckload (2 intermodals per truckload for classified debris waste)
Treatment/Disposal Costs*		
Treatment and Disposal of LLW/RCRA (mixed waste) (macroencapsulation)	$3,406	Per yd^3
Surcharge of 4% on waste received during winter months (Dec - Feb)	$136	Per yd^3
NNSS disposal access fee rate	$391.77	Per yd^3

**All rates are in 2012 dollars*

5.3 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.

5.4 SUMMARY COST DATA

Table G-5 provides the summary cost estimates for the Off-site Disposal Alternative.

Table G-5. Summary Cost Estimate for the Off-site Disposal Alternative

Project Cost Item	Cost in 2012 Dollars ($ Ms)
Capital Cost	
Total Capital Cost	**0**
Operations Cost	
Transportation and Packaging	944
Treatment/Disposal	1,019
Long-Term Monitoring and Maintenance	0
Total Operations Cost	**1,963**
20% Contingency	**393**
Total Project Cost	**2,356**
Total Project Cost (present worth)*	**1,556**

Note: All costs are in 2012 dollars unless otherwise noted and all costs are rounded.
*Present worth based on real discount rate of 2.0%

6. REFERENCES

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.

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.

CERCLA D1 RI/FS COMMENT AND RESPONSE SUMMARY

Comments by: **U.S. EPA Region 4**

Comments Received: January 25, 2013

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

Revision No.: D1

Document No: DOE/OR/01-2535&D1

Date: September 2012

No.	Reference	Comment	Response
1)	General	A thorough evaluation of volume reduction has been presented in Appendix B. Section 6.2.2.8 includes volume reduction via mechanical debris size reduction as a $38 M Process Modification that could save up to $72 M in the final cost of the response action. Section 9 "Conclusions and Recommendations" of Appendix B states, "This study indicates substantial benefits are possible if VR efforts are pursued." Including VR process options as process modifications in this FS is not appropriate. Revise Section 6.2 and Section 7 to include a detailed analysis of two on-site and two off-site disposal alternatives, the current alternatives and the current alternatives that include waste treatment via on-site mechanical size reduction. The alternatives that include VR can consider VR process options in the detailed analysis. This will enable a thorough evaluation of volume size reduction, as a treatment component of the alternatives against the nine criteria. This will enable a definitive remedial decision on whether to select VR as a component of the selected remedy, rather than the current approach to consider VR as a process option that may or may not be deployed as part of the remedy.	The evaluation of volume reduction (VR) given in Appendix B was completed at the request of the regulators, and while it uses volumes and cost data based on the two alternatives, it can be considered almost a stand-alone study. The majority of the evaluated VR technologies apply to, or would be implemented at, the program or project level, which is outside the scope of the RI/FS alternatives analysis. The remedy for management of CERCLA wastes, which is the subject of this RI/FS and eventual alternative selection process, applies *after* the wastes have been generated and managed by the projects, to a point at which the wastes *then* become a subject for this document. The majority of the VR technologies discussed in Appendix B are applicable to the waste streams prior to them becoming a subject for this remedy selection process. Most especially, this is the case for the off-site disposal alternative, therefore it is inappropriate to consider a combination of VR and off-site disposal as a valid alternative. [Any programmatic or multi-project treatment by VR of an "off-site"-destined waste stream would become an "on-site" action.] In terms of on-site disposal, only one VR technology has been identified as a possible activity that would be applicable to the waste stream as it "enters" this analysis and can be combined with the on-site alternative. It is presented correctly in Section 6.2.2.9 as a process modification. This technology would employ a type of on-site crusher for debris, to be used at the on-site disposal cell. It is appropriately treated as a process modification, however, not part of an alternative, for several reasons. First, while the waste type and volume estimates that are presented in Section 2 of the RI/FS represent the best currently available data,

No.	Reference	Comment	Response
			they are necessarily based on a number of parametric assumptions, particularly for those projects scheduled for out-years. This introduces uncertainty that cannot be removed without first performing extensive characterization and planning. A more detailed analysis (waste profiles. cost, operating parameters) would need to be completed, with more defensible data, to determine if a cost savings is realizable. Second, the VR operation is not applicable to all debris waste streams. The screening of which wastes would be treatable, and which would not, is far beyond the scope of the available data and would introduce much more uncertainty. Lastly, it is believed that considering VR on-site as part of an on-site alternative would not change the outcome of the alternative analysis and would not result in significant changes to the evaluation criteria for the on-site alternative. The RI/FS has therefore not been revised to add VR as an alternative.
2)	General	The Y-12 permitted landfills are considered by DOE ORR to be a portion of its onsite remedial actions for the on-site disposal of CERCLA waste as specified in various decision documents. The Y-12 permitted landfills have not been requested by DOE to be evaluated under the Off-Site Rule for acceptability. To date, it does not appear that a ROD has specifically selected the Y-12 landfills as part of the on-site remedy. Rather, the RODs simply state that disposal will occur at "another suitable facility" (e.g., BV ROD, Section 1.4, p. 1-8). Furthermore, the on-site disposal at "another suitable facility" is not documented in much greater detail in post-ROD documentation and has not yet been documented in an annual Remedial Effectiveness Report or a Five Year Review. The current lack of documentation regarding the use of the Y-12 landfills as a component of on-site remedial and removal actions may be in part due to its use in a programmatic nature and not as a specific portion of any operable unit decision. Since DOE has not requested an Off-Site Rule acceptability determination for the Y-12 landfills, DOE should consider including the Y-12 landfills in this programmatic on-site /off-site waste disposition remedial evaluation/remedy selection process.	The purpose of this RI/FS is to document alternatives for disposition of radioactively-contaminated CERCLA waste, as stated in the second paragraph of the EXECUTIVE SUMMARY and the first paragraph of Section 1.2 PURPOSE. This document does not address the waste management activities and decisions that must occur at the project level prior to the selection of waste disposition pathways for the project waste streams. This comment addresses concerns that are related to waste management and disposal that are project-specific, and outside the scope of this RI/FS. The RI/FS has not been revised in response to this comment.

No.	Reference	Comment	Response
3)	General	It appears the applicable or relevant and appropriate requirements (ARARs) for groundwater monitoring programs for the On-site Disposal Alternative are not complete and implied to only be applicable after operations and during post closure. Appendix E does not address RCRA Subpart F requirements in Section 6.5 of Appendix E and Table E-3 includes RCRA Subpart F under the Post Closure subheading. RCRA groundwater monitoring program regulatory requirements are applicable during the landfill's active operational period. Further, it is not clear why certain portions of 40 CFR 264 Subpart F and Subpart N are not included as ARARs. In addition to other Specific Comments below, the following ARARs should be added:	ARARs for groundwater detection and compliance monitoring in substantive accord with 40 CFR 264, Subpart F, have been added to the Table E-3, Action-Specific ARARs. Table E-3 has been reorganized to collect all groundwater monitoring ARARs in a subsection entitled *Environmental Monitoring and Corrective Action During Operations, Closure, and Post-Closure Care*. Baseline groundwater conditions will be measured, and groundwater detection monitoring will be carried out during operations, closure, and post-closure periods. If a release is detected, it will be remediated within the CERCLA framework because this is a CERCLA action. Appropriate remediation monitoring will be carried out under CERCLA.
		a. 40 CFR 264.97(h), (i) and (j)	a. Accepted, with exception that data reporting under 40 CFR 264.97(j) will be as required by the Oak Ridge FFA.
		b. 40 CFR 264.100	b. Not applicable; corrective action program substantively consistent with Subpart F requirements would be carried out pursuant to CERCLA requirements, not with a permit issued by the Administrator as identified in the regulations
		c. 40 CFR 264.302	c. Accepted
		d. 40 CFR 264.316	d. Not appropriate or relevant: Lab-packs will be excluded from disposal at the EMDF
		e. 40 CFR 264.317	e. Not appropriate or relevant: Listed wastes will be excluded from disposal at the EMDF.
4)	General	Explain why the EMWMF required a Preliminary Waste Acceptance Criteria (WAC) and the process for finalizing/documenting the final EMWMF WAC. Explain why the final EMWMF WAC is insufficient for the EMDF WAC and what significant changes are likely in the EMDF PWAC and final WAC.	Explanation of the process used by EMWMF to define the WAC is adequately explained in EMWMF documentation. The EMWMF WAC may be adequate for use at EMDF; however, a final decision on the EMDF WAC is beyond the scope of this RI/FS. The purpose of preparing a preliminary WAC for the EMDF was to determine whether the conditions at the proposed site would result in PWAC values that are consistent with/within the bounds of the EMWMF WAC.
5)	General	Provide a summary description in Section 6.2 of the lessons learned from the EMWMF design, construction and operations. Include a summary of the following topics:	Section 6 of the RI/FS has been expanded where appropriate to include a summary description of the lessons learned from the EMWMF and other DOE CERCLA landfills relative to design, construction, and operations, including a summary of the requested topics. A new Section 6.2.10 has been added to summarize lessons learned.
		a. Underdrain Retrofitting and Underdrain monitoring	a, Discussed in Section 6.2.2.4, "Facility Underdrain" paragraphs.

No.	Reference	Comment	Response
		b. Primary line protective soil layer's design permeability affect on decreasing leachate collection and increasing contact storm water collection c. Post-ROD decision to design for Contact Storm Water handling, monitoring and treatment d. Leachate storage and shipment to permitted facilities on the ORR in lieu of this remedy's plan for construction of an on-site water treatment plant e. Action Leakage Rate f. Operations decision to preclude RCRA Listed Waste even though the remedy was based disposal of listed wastes g. Other	b. Discussed in Section 6.2.2.4, "Protective Soil Layer" paragraphs. c. Discussed in Section 6.2.2.4, "Protective Soil Layer" paragraphs. d. The on-site treatment plant has been removed. e. Discussed in Section 6.2.2.1, "Remedial Design" paragraphs f. Listed waste will not be accepted in the new On-Site disposal facility, and this remedy is NOT based on disposal of listed wastes. See Section 6.2.3 for the discussion on this subject. g. Discussed where applicable throughout Chapter 6. See Section 6.2.10, Table 6-2for summary of lessons learned that are discussed.
6)	General	ARARs for discharge of wastewaters for the On-site Disposal alternative discussed as part of Appendix E, do not include the discharge requirements set forth in 40 CFR Part 445 Subpart A (RCRA Subtitle C Hazardous Waste Landfill). These are applicable to wastewater discharged during the landfill's active operational period and relevant and appropriate during the closure/post-closure period. Revise the RI/FS to include these Clean Water Act requirements.	40 CFR 445 is applicable to wastewater discharged from permitted landfills during operations; however, the requirements are less restrictive, in general, than the TDEC water quality criteria at 1200-04-03-.03. Further, the TDEC analyte list is more appropriate to the EMDF wastes than is 40 CFR 445 Subpart A.
7)	General	The executive summary states, "The advantages and disadvantages of On-site and Off-site Disposal Alternatives are highlighted 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." This discussion is expanded on in Section7 (Detailed Analysis of Alternatives), which identifies the criteria listed above as the "Primary Balancing Criteria" (identified as "key criteria" in the Executive Summary) and adds two Threshold Criteria and two Modifying Criteria. The RI/FS should consistently apply the nine criteria set forth in The Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA/540/G-89/004), dated October 1988 (RI/FS Guidance) to evaluate the remedial	The executive summary has been revised to list the nine criteria and discuss them consistent with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA/540/G-89/004). Chapter 5 uses three of the nine criteria (effectiveness, implementability, and cost) as tools to screen a larger number of alternatives and process options for the short list of alternatives to be examined in detail. The screening process follows the RI/FS Guidance (see Chapter 4 of EPA/540/G-89/004). All nine CERCLA criteria are used in Chapter 7, Detailed Analysis of Alternatives. The terms threshold criteria and primary criteria are from CERCLA RI/FS Guidance (see Section 6.2.2 of EPA/540/G-89/004); the term modifying criteria is used

No.	Reference	Comment	Response
		alternatives. Revise the RI/FS to evaluate the remedial alternatives against the nine criteria included in the NCP and RI/FS Guidance. All discussions of the evaluation criteria should address all nine criteria, and the names used for the three categories of criteria should be consistently applied to avoid confusion.	here to indicate that state and community input may modify the remedy. These "modifying" criteria are not addressed, since state review and comment on the RI/FS should lead to state acceptance of the remedy, and because community acceptance will not be known until after the public has the opportunity to comment on the Proposed Plan.
8)	General	Two of the remedial action objectives (RAOs) included in the RI/FS are as follows: a) Prevent exposure to future-generated CERCLA waste that exceeds a human health risk of 1×10^{-5} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1. b) Prevent releases of future-generated CERCLA waste or waste constituents that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or ARARs for environmental media. The basis for the 1 x 10^{-5} ELCR as point of departure is not clear and does not appear to be consistent with the EPA's stated point of departure as presented in the National Contingency Plan (NCP), 40 CFR 300 and Preamble at 55 FR 8866 (Preamble). The Preamble indicates remediation goals should be set for total risk due to carcinogens that represent an excess upper bound lifetime cancer risk to an individual between 1 x 10^{-4} to 1 x 10^{-6} and that a cancer risk of 1 x 10^{-6} should serve as the point of departure for these remediation goals. Further, factors related to exposure, uncertainty and technical limitations may justify modification of initial cleanup levels that are based on the 1 x 10^{-6} risk level or risk management decisions, but that the ultimate decision of the appropriate level of protection depends on the selected remedy and the results of the associated FS screening process. Revise the RI/FS to clarify that the risk point of departure is 1 x10^{-6} or, alternatively, provide additional justification for the proposed 1 x 10^{-5} value.	EPA defined a range of 10^{-4} – 10^{-6} for the excess lifetime cancer risk for CERCLA actions. In the Preamble to the 1988 NCP (see 53 FR 51426), EPA invited comment on changing the risk range from 10^{-4} – 10^{-7} to 10^{-4} – 10^{-6}, on the basis that this is the risk range used in other EPA programs. In summarizing and responding to commenters (see 55 FR 8666), EPA notes that while it's preference, and hence, point of departure, is at the low end of the range (10^{-6}), CERCLA Section 121 directs that remedies be protective, permanent, and cost-effective. The 121 directives are met, in EPA's opinion, with a risk range of 10^{-4} to 10^{-6}. Further, the preamble (55 FR 8717) states "While the 10^{-6} starting point expresses EPA's preference for setting cleanup levels at the more protective end of the risk range, it is not a presumption that the final Superfund cleanup will attain that risk level." East Bear Creek Valley, with its several legacy, current, and future waste management facilities is to meet the 10^{-5} ILCR at the Zone 3 Integration Point, by agreement among the regulators and DOE. This should apply as well to EMDF. The EMWMF ROD (DOE 1999, see pp. B-5 and B-6) documents the use of a 10^{-5} ILCR and HI ≤1 to model concentration limits for the first 1,000 yrs post-closure; 10^{-4} ILCR and HI ≤ 3 were selected for the period after 1,000 yrs. Further, the Bear Creek Valley Phase I ROD (DOE 2000; please see pp. 2-76) set the RAOs at 1 x 10^{-5} ILCR relative to uranium and attainment of applicable TDEC AWQC for the Land Use Zone 3 Integration Point. Land use Zone 3 is designated for industrial use, with the further expectation that it will remain in DOE control for the foreseeable future. No residential use would occur within Zone 3. EPA policy (see OSWER Directive 9355.7-04) notes that RAOs should be consistent with reasonably anticipated future land use. The use of 10^{-5} ELCR is consistent with this policy.

No.	Reference	Comment	Response
9)	General	Describe how the RAOs apply to discharges from cell operations, including contact water and leachate.	Discharges from cell operations (e.g. leachate, contact water) will comply with the ARARs described in Appendix E (see Table E-1 and E-3) during active operations, closure, and post-closure. In order to be released/discharged to surface water, the water must meet the state ambient water quality criteria and TDEC 0400-20-11.16 as referenced in the ARAR Tables. RAOs are risk-based objectives for cleanup of a site. Concentrations/activities of discharges (leachate and contact water) must be converted through detailed calculations to result in a risk-based value that is a comparable measurement to an RAO; however, that calculation will include all pathways, which are site-specific and may incorporate land use restrictions. Therefore, a dose calculation at the point of discharge may result in a much lower dose at the point of exposure taking into account land use restrictions.
10)	General	The last paragraph of Section [5]4.1.2.1 (Development and Screening of Alternatives) of the RI/FS Guidance states that a comparative assessment of assembled alternatives should be conducted based on effectiveness, implementability, and cost before conducting the detailed analysis of alternatives based on the nine NCP evaluation criteria. While this comparative assessment is referenced in Section 5.1 (Identification, Screening, and Selection of Technologies and Process Options), which states, “In the following step, 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,” the RI/FS does not clearly indicate whether or not the comparative assessment was completed or discuss the results. Revise the feasibility study (FS) to provide an initial comparative assessment of assembled alternatives by screening assembled alternatives on only short-and long-term aspects of three criteria (i.e., effectiveness, implementability, and cost), prior to performing a detailed assessment of the assembled alternatives against the nine screening criteria.	Table 5-1 has been extensively revised to provide information and rationale on effectiveness, implementability, and cost for each alternative process option considered, as well as to indicate selection or elimination. Minor changes to the text in Section 5.1 were also made to reflect the changes made to Table 5-1.
11)	General	Revise Section 6.2.2 to include action and chemical specific ARARs related to each of the design components in the remainder of the subsections.	Action and chemical specific ARARS are discussed in Appendix E. Detailed lists of all ARARS are included in Tables E-1 through E-4 of Appendix E.

No.	Reference	Comment	Response
12)	General	The environmental conditions at the selected site for the Environmental Management Disposal Facility (EMDF) are unclear. For example, Section 6.2.2.6 (EMDF Conceptual Design Approach) indicates that the site is located in a historical waste management (brownfield) area; however, Section 7.2.2.8 [NEPA Considerations (On-site)] indicates that the proposed EMDF location is forested and undeveloped and adjacent to brownfields. Revise the RI/FS to clarify the existing environmental conditions at the site selected for the EMDF.	Section 6.2.2.6, paragraph 3 was revised to state ". . . including its location adjacent to an historical waste management (brownfield) area . . ."
13)	General	The summary of the comparative analysis presented in Table 7-2 (Comparative Analysis Summary for Disposal of ORR CERCLA Waste) does not include a rating system used to rank the alternatives. Without any ranking system, the RI/FS does not allow for development of discriminating factors to aid in the selection of a preferred alternative. Page 55 FR 8719 of the Preamble, Section 300.430(e)(9), Detailed analysis of alternatives, states: The purpose of the detailed analysis is to objectively assess the alternatives with respect to nine evaluation criteria that encompass statutory requirements and include other gauges of the overall feasibility and acceptability of remedial alternatives (53 FR 51428). This analysis is comprised of an individual assessment of the alternatives against each criterion and a comparative analysis designed to determine the relative performance of the alternatives and identify major trade-offs (i.e., relative advantages and disadvantages) among them. The decision-maker uses information assembled and evaluated during the detailed analysis in selecting a remedial action. Section 6.2.5 (Comparative Analysis of Alternatives) in the RI/FS Guidance states, "[a]n effective way of organizing this section is, under each individual criterion, to discuss the alternative(s) that performs the best overall in that category, with other alternatives discussed in the relative order in which they perform [emphasis added] . . . . the presentation of differences among alternatives can be measured either qualitatively or quantitatively, as appropriate, and should identify substantive differences." Further discrimination between factors is needed to make this process transparent to the public and Regulatory Agencies. Revise the FS to provide a system of rating using a ranking scale that allows for differentiation (i.e., use a range of	Table 7-2 has been revised to (a) provide a numeric-adjectival rating for each of the seven CERCLA criteria discussed for each alternative, and a summation of ratings for each alternative, and (b) to remove the table row that addressed NEPA values, since NEPA is not one of the seven CERCLA criteria addressed in this document. Sections (7.2.1.8, 7.2.2.8, & 7.2.3.8) that discuss alternative-specific NEPA values remain unchanged. Text has been added to Section 7.1 to explain the rating system employed.

No.	Reference	Comment	Response
		terminology and identify the differentiating features) so that a straightforward determination of the relative performance of the alternatives and identification of major trade-offs can be made. Ensure the assessment clearly indicates the alternative(s) that rank highest overall in each category.	
14)	General	Appendix F, Section 5.2 (Pathrae Model Output and Risk/Dose Calculations) on page F-48 states "PATHRAE calculations were performed to determine the equivalent annual water consumption per year for the creek (defined as the Equivalent Uptake [EU])". The use of the term 'equivalent uptake' is confusing since radiological dose is calculated by determining the uptake of a radiological constituent that occurs as a result of ingestion or 'intake'; that is, when referring to radiological exposure and dose, intake does not necessarily result in an 'uptake' as some radiological constituents will be eliminated from the body without resulting in a dose. Provide a response and/or text revisions which explain the intended meaning of 'uptake' relative to intake or consumption, or provide alternative terminology which more clearly explains the intended meaning for EU.	The PATHRAE model was one of the PRESTON-EPA code family that EPA developed to estimate the environmental impact from the disposal of Low Level Waste (EPA, 1987). Doses from all environmental food chain pathways are considered in the PATHRAE model. The complete food chain calculations included transfer factors to vegetation and animals as well as consumption rates for water, vegetation, meat, and milk on a nuclide specific basis. The PATHRAE model uses equivalent total uptake factors (EU) to quantify the annual amount of nuclide consumed by a individual from all potential pathways. For the ingestion pathway, it 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, milk and drinking water. Thus, the specific pathways by which contaminants are ingested and the quantities of the contaminated foods ingested are built into the uptake factors. Text in Section 5.2 has been revised
15)	General	Appendix F Section 5.2 (Pathrae Model Output and Risk/Dose Calculations) states that the PATHRAE-RAD and PATHRAE-HAZ models were used to calculate the arrival and peak time for the radioactive constituents and toxicological constituents at the surface water receptor location. However, the text does not explain whether a composite analysis which considered all potential source terms was completed to determine potential peak contaminant concentrations in the surface water originating from both the EMWMF and the EMDF or other potential on-site sources, or whether modeling was conducted only for constituents projected to leach from the EMDF. Provide a response and/or text revision to address this concern.	A Composite Analysis will be completed as required by DOE Order 435.1 at a later date and as a separate document. The Composite Analysis will be reviewed and approved by the Low-Level Waste Disposal Facility Federal Review Group (LFRG) as part of the Disposal Authorization Statement (DAS) process. A DAS must be approved and issued by a cognizant Deputy Assistant Secretary prior to the start of landfill operations.
16)	General	The components and assumptions provided in Tables G – 3 (Summary Cost Estimate for the On-site Disposal Alternative) and G – 6 (Summary Cost Estimate for the Off-site Disposal	The cost estimates presented in this RI/FS are based on commonly available commercial rate tables (e.g., R.S. Means), material quotes (if available), available disposal rate tables,

No.	Reference	Comment	Response
		Alternative) in Appendix G (Cost Estimates for On-Site and Off-Site Disposal Alternatives) are insufficient to demonstrate an understanding of the level of effort necessary to implement each of the alternatives. For example, Table G – 3 on Page G-12 indicates that the construction will cost a lump sum value of $147 million; however, this line item aggregates the construction costs associated with the cells, interim capping, and leachate/contact water treatment facility without providing the estimated costs for the individual activities. As such, it is unclear if remedial alternatives were appropriately scoped and costed to reflect a -30%/+50% margin as allowed for in the FS process. Given the lack of costing details, the FS does not demonstrate an understanding of the level of rigor that would be necessary to design and implement the remedial alternatives evaluated. Revise the FS to include the detail and specificity requested in order to demonstrate an understanding of the complexity of the proposed remedial alternatives. Further, provide vendor quotes and engineer's estimates of the costs for individual activities.	experience, and labor rate tables for the ORR. This has been expanded upon within Appendix G.
17)	General	No contingencies were added to either the On-site of Off-site Disposal Alternative cost estimates included in Appendix G (Cost Estimates for On-Site and Off-Site Disposal Alternatives). According to A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, EPA 540-R-00-002, dated July 2000, scope contingency typically ranges from 10 to 25 percent and bid contingency typically ranges from 10 to 20 percent. Revise the RI/FS to provide a detailed justification for not adding a contingency into the cost estimates for the On-site and Off-site Disposal Alternatives.	Contingencies have been applied to overall alternative costs, rather than separately to scope and bid, because the EMDF design is conceptual, both alternatives have long durations, and the acquisition strategy has not been developed. A total contingency of 20% has been applied to the Off-site Alternative, and a 25% contingency has been applied to the On-site Alternative, in accordance with EPA guidance. The cost estimates provided in this document have been cited as accurate within -30% to +50% due to the fact that there are unforeseen risks, again in accordance with EPA guidance.
18)	General	It is unclear whether the cost estimates included in Appendix G (Cost Estimates for On-Site and Off-Site Disposal Alternatives) for the future construction of the On-site Disposal alternative have been properly reported since construction begins in 2020, but costs are reported in 2012 dollars. Revise the RI/FS to include a more detailed explanation of construction costs and include present and future cost calculations/considerations.	The 2012 dollars are the base dollars the estimate was generated in. The purpose of the estimate is to be able to compare alternatives. The off-site alternative is also presented in 2012 dollars. An escalation factor can be applied for both alternatives to give future dollars, but it will not change the comparison of the two costs. As well, the estimated costs of the two alternatives are presented in terms of present worth, another comparison of the two alternatives given on equal footing.
19)	General	It is unclear how the cost of the new leachate/contact water facility has been estimated. Specifically, an assumption in Section 4.1 (On-site Disposal Alternative Cost-estimate Assumptions) of Appendix G (Cost Estimates for On-Site and	The treatment facility has been removed from the RIFS. Leachate will be managed in the same fashion as the EMWMF and will utilize the same facilities with maintenance upgrades as necessary.

No.	Reference	Comment	Response
		Off-Site Disposal Alternatives) states that, "Operations costs (except for treatment plant operations are based on actual EMWMF [Environmental Management Waste Management Facility] operations data;" however, the leachate/contact water facility does not already exist. As such, it is unclear how the cost estimates for this facility have been estimated. Revise the RI/FS to include justification for the cost estimate of the new leachate/contact water facility for the on-site disposal alternative.	
1)	Executive Summary, Page ES-5	Under the heading, Differentiating Criteria, and the subheading, No Action Alternative, the Executive Summary states, "The No Action Alternative may not support the RAO of facilitating the timely cleanup or release of portions of ORR [Oak Ridge Reservation] and associated facilities for beneficial use." The release of portions of ORR and associated facilities for beneficial use is not included as a RAO in this RI/FS; therefore, it is not clear why this is discussed as a differentiating criterion for comparing the alternatives. Revise the Executive Summary to address this issue and evaluate this alternative against overall protection of human health and environment in accordance with the RAOs.	Text has been revised. This issue has been addressed through the revisions requested by General Comment no. 7.
2)	Section 1.1, Page 1-3, Final paragraph	Include the original waste-only volume estimate for the EMWMF at the time of the ROD, and the projected total waste volume estimates in the closed EMWMF and the remaining left to be closed in the new EMDF at this time. These waste-only volumes will clearly show the history and projections in the context of this summary for both on-site CERCLA landfill operations.	The original waste-only volume estimate for the EMWMF at the time of the ROD was a large range, 223,000 to 1,100,000 yd^3. Volume estimates made within this RI/FS document take pages to explain (see chapter 2). A comparison of volumes assumed for EMWMF during its RI/FS phase and those presented in this RI/FS would also take a significant amount of explanation. In addition, Section 1.1 is the Background section, it is not a summary that would include any discussion of future situations. A sentence was added to the section to give an idea of the growth of the EM scope by adding the statement, "Current waste volume estimates detailed within this RI/FS are approximately three times higher than the largest estimates made during the EMWMF RI/FS development."
3)	Section 1.2, Purpose, Page 1-3	Section 1.2 indicates the purpose of the RI/FS is to evaluate alternatives for disposal of low-level waste (LLW), hazardous wastes regulated under RCRA, mixed waste, and certain classified waste. In contrast, the Executive Summary (Page ES-1) and Section 2.1.2 (Page 2-3) appear to indicate only LLW, mixed waste, and classified waste will be considered for disposal at the Environmental Management Disposal Facility (EMDF).	Section 1.2 has been revised to read "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

No.	Reference	Comment	Response
		Revise the RI/FS to address this apparent discrepancy and clearly indicate whether or not RCRA hazardous waste that does not include a radiological component will be considered for disposal at the EMDF.	certain classified waste." The facility will not accept hazardous waste that does not include a radiological component.
4)	Section 2.1.1, Exclusions, Page 2-3	Section 2.1.1 summarizes several wastes types that will be excluded from consideration in the RI/FS; however, a discussion of the waste types specifically prohibited by the Waste Acceptance Criteria (WAC) (i.e. neutron moderators such as graphite) is not provided. Revise the RI/FS to provide a comprehensive discussion of all wastes that will not be considered for disposal at the proposed EMDF based on guidelines set forth in the Administrative WAC. Include a discussion of RCRA listed wastes to confirm whether such wastes will include design features for leachate treatment and discharge.	Additional detail was added regarding excluded materials based on EMWMF Waste Acceptance Criteria including administrative criteria. Detailed waste acceptance criteria for the EMDF will be developed prior to construction, and will be subject to regulatory review. RCRA listed waste will not be accepted at the EMDF. The treatment facility for leachate has been removed from the design and the current EMWMF approach for transportation of contaminated leachate to the ORNL PWTC will be continued for the EMDF.
5)	Section 2.1.2, Page 2-3, Table 2-3	The discussion states "mixed waste" is LLW mixed with TSCA or RCRA waste. Table 2-3 refers to "mixed waste" as LLW mixed with RCRA.	The reason the Tables 2-2 and 2-3 (2-3 has now been removed from the document) separate LLW/TSCA into the LLW category and not the mixed category, is because, for the off-site alternative analysis, LLW and LLW/TSCA are sent to Nevada National Security Site for disposal, while the remaining mixed waste is sent to Energy*Solutions* for disposal. A sentence was added to explain this segregation in Section 2.2.1, "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 is LLW, while mixed waste that may require treatment is disposed at Energy*Solutions*."
6)	Section 2.2, Pages 2-5 & 2-6	This introduction to the capacity needs for the EMDF should state up front the clean fill aspect of as-disposed waste volume (i.e., where contaminated fill cannot fill voids and clean fill is required) as well as the clean fill necessary for operations.	Wording was revised in the description of "as-disposed" waste to stress the addition of "clean fill" needed to fill voids that also includes clean fill necessary for operations. See page 2-5, "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 for On-site Disposal Alternative)."

No.	Reference	Comment	Response
7)	Section 2.2.1, Pages 2-5 – 2-7	***"As-generated Waste Volume Estimate"*** Figure 2-1 (As-generated Waste Volume Estimate) projects highly variable annual as-generated waste volumes over the next 30 years. Section 2.2.1 does not clearly indicate the reason(s) for this high degree of variability or include a discussion of how the uncertainty associated with the projected annual volumes will be managed. Revise the RI/FS to address these concerns. Specifically, include a discussion of the possible effects higher than anticipated annual waste volumes over the next five years might have on the construction and implementation of the remedial actions assessed in the RI/FS (i.e., if the EMWMF reaches capacity sooner than anticipated).	A discussion of the variability in annual waste generation estimate was included. It reads, "*These projected volumes are quite variable, especially in out-years, 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 figure. A calculated annual average of 70,034 yd^3 of waste per year is well within the EMWMF annual operational range of waste processed thus far (approximately 40,000 up to 133,000 yd^3 per year, which is rather variable).*" Wording was added, following Figure 2-1, to address the possibility (very slim) of higher than anticipated annual waste generation over the next 5-7 years as given here in italics, "*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 the EMWMF will be filled to capacity in FY 2023. Any accelerated waste generation during the FY 2013 to FY2023 time frame would require a significantly large increase in funding, and while this is highly unlikely given 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.*"
8)	Section 2.2.2, Pages 2-7 – 2-9	***"As-disposed Waste Volume Estimate"*** Section 2.2.2 summarizes the approach used to estimate the as-disposed waste volumes used in the RI/FS.; however, the discussion provides insufficient detail regarding the specifics of these calculations. Revise the RI/FS to provide a detailed discussion of the calculations used to determine the as-disposed waste volumes so that the approach as well as the results can be easily assessed. Specifically, provide example calculations which include the density conversion factors used for the various waste material types and refer to the Section in the CARAR where this is described in detail.	The RI/FS has been revised to include a more detailed discussion of the calculations used to determine as-disposed waste volumes. Specific calculations and density factors are provided. Appendix A was revised to include a description of the calculations used to estimate the CERCLA as-disposed volumes along with PCCR references. Reference to the detailed calculations in Appendix A is given in Section 2.2.2.
9)	Tables 2-2 & 2-3	Include in the table headings "with uncertainty" and "without uncertainty", respectively. Table 2-3 includes uncertainty in the total column whereas all columns include uncertainty. Include a brief discussion why uncertainty estimates include only an increase in volume.	Table titles have been revised. The third paragraph in Chapter 2 (page 2-1) was modified to include, "*Uncertainty is accounted for in the waste volume estimates based on the same approach taken in the 2013 PCCR. Uncertainty is added as a percentage (increase only, to be*

No.	Reference	Comment	Response
			conservative) to the annual predicted volumes. Uncertainty/ sensitivity is not applied to characterization since characterization used in this RI/FS serves mainly to identify risk for on-site versus off-site alternatives (refer to Table 2-1), and that comparison may be made using a single data set; looking at variability in that data set would not alter the comparison conclusions."
10)	Section 2.2, Pages 2-8 & 2-9	Many volume types and uncertainties are described and the final summary on page 2-9 should provide a clear summary of the previous discussions. It would be helpful if the final paragraph of this section clearly discusses the total EMDF volume needs based on the following specific assumptions, including uncertainty and operations experience. A suggested summary paragraph could be structured as follows to assist the reader in understanding how estimates are determined and adjusted for a final EMDF volume estimate:	This section has been revised in a manner that loosely follows the suggested structure. A new table (new Table 2-3) has been added that summarizes the key calculations necessary to obtain the as-disposed waste volume from the as-generated WGF. These calculations have been expanded and described in detail in Appendix A with PCCR references.
		a. Current estimate of as-generated WGF volume needs for both soil and debris after EMWMF termination of waste receipt (EMDF WGF); i. Contingency EMDF as-generated WGF uncertainty/contingency correction in the WGF (an increase of x% based on...) [Explain if this contingency built into WGF as-generated volumes]	a.) Table 2-2 provides a summary of as-generated debris and soil for the EMDF without uncertainty. The explanation for the 25% contingency is provided following this table. Note that the 25% uncertainty/contingency is not added to the As-Disposed numbers until the very end (e.g., 25% is NOT added to the As-Generated numbers that are subsequently used in calculations to eventually get to the As-Disposed numbers.)
		b. EMDF waste placement and operations corrections to the EMDF volume capacity estimate in a) i) above: i. As-disposed WGF volume adjusted for waste placement debris and soil compaction (a decrease of x% due to compaction) ii. As-disposed WGF volume adjusted for waste placement contaminated soil used as void space fill (a decrease of x% due to debris void space fill with contaminated fill) iii. As-placed clean fill necessary for void spaces due to unavailability of waste fill (an increase of x% based on debris/soil project sequencing) iv. As-placed clean fill necessary for cell operations (an increase of x% based on EMWF experience	b.) Table 2-3 (new) provides a summary of the calculations used to determine as-disposed volumes from the as-generated volumes provided in Table 2-2. See the expanded description of calculations given in Appendix A for the step-by-step process of adjusting for compaction and addition of clean fill, etc.
		c. Final corrected total EMDF volume a) above and	The explanation for the 25% contingency is provided following

No.	Reference	Comment	Response
		adjustments in b) above. Use the same units for all. It appears the correction factors above have been combined into a 28% increase. This should be clarified.	Table 2-3. Table 2-4 shows the projected capacity need with and without uncertainty. The 25% uncertainty is applied at the end of all calculations, and only applied once.
11)	Figure 2-2	Excess Waste Fill and Uncertainty cannot be differentiated. Excess waste fill should not be within the uncertainty band. Rather, excess clean fill should be represented as an uncertainty affecting the total volume.	Volume estimates have been rerun based on the most recent Waste Generation Forecast. As it happens, in this rerun, there is no "Excess Waste Fill" and the comment is no longer applicable.
12)	Table 2-5, Page 2-11	***"Estimate of CERCLA Waste Disposal Capacity Needed Post-EMWMF with 28% Uncertainty"*** See Specific Comment 10. It would be helpful if the tables focus solely on volumes and adjustment factors based on the expected post EMWF WGF.	Table 2-5 was replaced with a new table showing the projected as-generated waste volume for the Off-site Disposal Alternative with the new 25% uncertainty. See new Table 2-3 for volumes and adjustment factors for the EMDF as-disposed capacity need. .
13)	Section 2.3, Page 2-11, Table 2-6	Explain why chemical risk is not a relevant transportation or natural phenomenon risk.	This explanation is in the Appendix D. Added the explanation to the end of the 1st paragraph in Section 2.3: "*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 the assessment."*
14)	Section 2.3, Pages 2-12 – 2-13	***"RI/FS Waste Characterization"*** Radionuclide concentration data derived from waste lots (WLs) disposed of at the EMWMF were used to develop the data set for risk evaluation presented in the RI/FS. The average activity per unit mass (pCi/g) for each radionuclide included in this data set is presented in Table 2-6. Several transuranic (TRU) isotopes are included in the data set with mass-weighted concentrations greater than 100 nanocuries per gram (100 nCi/g), indicating that TRU waste may be disposed of at the EMDF even though the RI/FS indicates that TRU waste will not be disposed of at the EMDF. Revise the RI/FS to clarify why these TRU waste data values were included in Table 2-6. If these data are inappropriate for use in the RI/FS risk evaluation, they should be removed and all related risk calculations revised.	There are no TRU isotopes in this table (2-6) that exceed the transuranic "waste" limit of 100nCi/g. Adding all the TRU isotopes together does not exceed the 100 nCi/g limit. Reviewer either misread the table (which is in pCi/g) or miscalculated something.
15)	Table 3-1, Page 3-6	The BCV Burial Grounds future ROD is missing.	Table 3-1 has been revised to include BCV Burial Grounds future ROD and project.

No.	Reference	Comment	Response
16)	Section 6.2.1.1	The site characteristics are not based on site specific data within the footprint of expected construction. DOE should consider a small scale pre-ROD investigation to confirm lack of contamination that could complicate performance monitoring and the lack of elevated bedrock which could significantly increase cost of any cut operations. Alternatively, the potential groundwater contamination and costly site preparation activities due to elevated bedrock should be described as critical uncertainties and contingency plans discussed.	Wording was added to Section 6.2.1.1 to convey the following discussion: It is agreed site-specific characterization data are lacking within the footprint of expected construction. Site characterization studies will be performed as part of the early actions described in Section 6.2.2.2. It is anticipated that initial geologic, hydrogeologic, and geotechnical data resulting from characterizations will be available prior to ROD issuance. Baseline monitoring data will not be available for approximately 14 months from initiation of monitoring. All results will be used as appropriate in formulating the landfill design. Regulators will review and approve characterization reports. The lack of site–specific characterization data was recognized and factored into the conceptual design by selecting conservatively high approximations for the seasonal high groundwater table 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 Bear Creek Valley. These conservative assumptions resulted in the bottom of the landfill being higher in elevation, thus requiring larger volumes of structural fill under and around the landfill. These larger quantities of structural fill were costed and assumed to be purchased from an off-site borrow source to be further conservative (as opposed to obtaining from on-site borrow areas). The cost estimate makes conservative assumptions regarding the percentages of excavated materials requiring rock excavation techniques. The conceptual design does not take credit for the lowering of the groundwater table that will occur through construction of the facility underdrain, upgradient storm water diversion ditches, and shallow French drain. Process knowledge and previous groundwater 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 groundwater plumes.
17)	Sections 6.2.1.1 and 6.2.2.2, Pages 6-4, 6-7, & 6-8	Page 6-4 states there are no known endangered species. Page 6-7 states that a field survey of endangered species would be performed. Page 6-8 states that field surveys of endangered species would be performed as necessary. Together these statements are ambiguous.	The text in these sections has been revised to consistently state that no known endangered species have been identified in this area during previous studies; however, a field survey for endangered species would be performed during pre-design site characterization efforts to confirm previous findings.

No.	Reference	Comment	Response
18)	Section 6.2.2, Page 6-8	The subheading *Construct New Groundwater Monitoring Wells and Surface Water Weirs* indicates that new groundwater monitoring wells and surface water weirs will be installed as part of the EMDF; however, the number of wells or weirs is not identified. It appears that given the knowledge of the existing EMWMF, the number of wells and weirs could be estimated for the RI/FS. In addition, it is not clear how the cost estimates for monitoring included as Appendix G (Cost Estimates for On-Site and Off-Site Disposal Alternatives) were developed without this information. Revise the RI/FS to include an estimated number of groundwater monitoring wells and weirs and include these as part of the cost estimate for the On-site Disposal alternative.	Estimated numbers of new groundwater monitoring wells (19) and surface water monitoring weirs (6) have been added to Section 6.2.2 of the RI/FS. These are estimates that have not been through the DQO process, 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.
19)	Figure 6-3, Page 6-11	Is the figure to scale or does it include vertical exaggeration? Upon observation of this figure, the risk of clean fill dike toe failure or excessive pressure and liner slip failure on the upslope liner system is a concern. The FS should address potential for any significant failure scenarios.	Figure 6-3 is not to scale and includes vertical exaggeration to better illustrate the structural components of the landfill. The slope ratios are depicted on the figure. When drawn to scale, it is apparent the slopes are quite flat, particularly the liner slopes. A note was added to the figure to clarify the figure is not to scale and the vertical scale is exaggerated. The design is very similar to the EMWMF, which has undergone rigorous slope stability analyses demonstrating the landfill's stability.
20)	Figure 6-5, Page 6-13	The thick crusher run gravel layer is likely not 6 feet.	The crusher run gravel layer is 6 inches thick. The typographical error was corrected within the figure.
21)	Section 6.2.2.4, Page 6-14	It states in the Protective Soil Layer that lower permeability soils is desirable to maximize contact water. Lessons learned from current landfill operations has identified significant issues that should be the basis of an exact opposite design standard to that contact time of rainwater and waste minimized. One of the objectives of the construction of an on-site waste water treatment plant is to minimize contact water that may then be discharged without treatment and maximize leachate that will be capable of effective and efficient on-site treatment.	Based on EMWMF experience, the on-site leachate/contact water treatment plant will not be needed since the landfill will not receive RCRA-listed waste. This treatment plant was deleted from the On-Site Disposal Alternative. The text in Section 6.2.2.4 was revised. Also, Section 6.2.2.9, Process Modifications has been expanded to include the option of eliminating separate handling of contact water by designing and constructing small "windows" through the protective soil layer within the floor of the landfill cell to allow rapid drainage of contact water into the granular leachate collection drainage layer of the leachate collection and removal system (LCRS). With this option, the LCRS and temporary leachate storage system would be designed to accommodate this additional volume of fluids. The pros and cons of this process modification are cited.

No.	Reference	Comment	Response
22)	Section 6.2.2.4, Page 6-15	The conceptual design discussion appears to be missing a discussion of the structural fill component. Refer to Figure 6-12 in this discussion.	A brief discussion of the structural fill component was added to Section 6.2.2.4
23)	Section 6.2.2.4, Page 6-15	Include Footnote 13 as an ARAR.	Accepted. Text in Section 6.2.2.4 was revised to indicate TDEC Rule 0400-11-01-.04(a)(2) is an ARAR. This requirement was added to Table E-3 in Appendix E.
24)	Section 6.2.2.4, Page 6-17	Include "daily cover" and "enhanced operations cover" as part of the Interim Cover discussion.	"Daily cover" and "enhanced operations cover" were added to the cover system discussion under the heading "operational cover" since these temporary covers are part of landfill operations and are independent of the interim cover.
25)	Section 6.2.2.4, Page 6-18	The final cover discussion includes benching. Consider showing this feature in a cross-section schematic.	The benches are shown in a cross-sectional view on Figure 6-3. Text was added to Section 6.2.2.4 referencing Figure 6-3.
26)	Section 6.2.2.4, Page 6-18	The final sentence of the first paragraph should consider starting "from the top of the temporary liner" rather than the "top of waste."	The final sentence of the first paragraph was revised to indicate the final cover begins at the top of the geotextile separator layer of the interim cover system since the temporary geomembrane liner of the interim cover system is removed prior to construction of the final cover system.
27)	Section 6.2.2.4, Page 6-18	Identify in the bullets which layer represents the gas collection layer.	For clarity a bullet was added for this layer since it is part of the 13-ft thick final cover. The function of this layer is dual and is also described in two other areas: 1) previously in the second bulleted item under "Interim Cover System" and 2) later in the "Landfill Gas Collection and Venting System" section.
28)	Section 6.2.2.5, Page 6-19	The list of new support facilities does not include the waste water treatment plant.	Based on EMWMF experience, the on-site leachate/contact water treatment plant will not be needed since the landfill will not receive RCRA-listed waste. This treatment plant was deleted from the On-Site Disposal Alternative.
29)	Section 6.2.2.6, Page 6-26	***"EMDF conceptual Design Approach"*** The subheading *Layout Approach* indicates there will be a 200 foot buffer between the waste and NT-2; however, it is not clear how this buffer distance was determined. Revise the RI/FS to clarify how this distance was determined and whether it is appropriate to protect human health and the environment.	The text in Section 6.2.2.6 was revised to indicate this preliminary 200-ft buffer 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 groundwater modeling. Design groundwater modeling will demonstrate the landfill is sited a sufficient distance away from NT-2 to protect human health and the environment. Post-construction groundwater and surface water monitoring will confirm the design is protective of human health and the environment.

No.	Reference	Comment	Response
30)	Section 6.2.2.7, page 6-28	The first sentence is ambiguous. Confirm that the waste water treatment is part of the alternative.	Based on EMWMF experience, the on-site leachate/contact water treatment plant will not be needed since the landfill will not receive RCRA-listed waste. This treatment plant was deleted from the On-Site disposal Alternative.
31)	Section 6.2.2.7, Page 6-28	***"Leachate/Contact Water"*** Include a new subsection for site stormwater that does not come into contact with waste.	A new subsection (6.2.2.8) was added for site storm water that does not come into contact with waste.
32)	Section 6.2.2.7, Page 6-28	***"Leachate/Contact Water"*** Section 6.2.2.7 states, "The portion of precipitation that falls within an open, active cell potentially coming in contact with the waste materials and collecting on the floor of the cell (referred to as "contact water") would be pumped out of the active cells and stored temporarily in lined basins located near the landfill." There does not appear to be an ARAR (e.g., RCRA) definition of "contact water"; rather, it appears most of the "contact water" would meet the RCRA definition of leachate, since it percolates though some of the waste. As such, it is not clear why all wastewater is not classified as leachate. Revise the RI/FS to address this issue.	It is recognized that "contact water" could be defined as leachate in some instances where the storm water comes into contact with waste. There are however other instances where the water collected within a cell above the liner system has not been in contact with the waste. "Contact water" is tested and monitored in similar fashion to the water collected from within the liner system to ensure that it meets discharge requirements prior to being discharged. If contaminated, the contact water could not be released as storm water and would be transferred to one of the two tanker truck loading stations for transporting to the PWTC. This discussion has been added to Section 6.2.2.7.
33)	Section 6.2.2.7, Page 6-28	***"Leachate/Contact Water"*** Section 6.2.2.7 states, "If the results of the analytical tests indicate the contact water is free of contamination, it would be released to the stormwater detention basin." The RI/FS does not appear to clearly indicate the criteria that would be used to determine whether or not the contact water is free of contamination. Revise the RI/FS to clearly indicate what criteria will be used to determine whether or not the contact water is contaminated.	Discharge criteria for contact water are defined by the relevant subsections within DOE Order 458.1(4) and TDEC Rule 1200-04-03. These are listed in detail in Appendix E within Table E-3 under the Wastewater Discharge section. This statement has been added to Section 6.2.2.7. The TDEC ambient water quality criteria (AWQC) that are applicable are those for recreational use under TDEC Rule 1200-04-03-.03(4). A waiver is being requested (See Appendix E of the RI/FS) to apply the fish and aquatic life AWQC under TDEC 1200-04-03-.03(3). This is clearly indicated throughout the document.
34)	Section 6.2.2.7, Page 6-28	***"Treatment Facility Conceptual Design"*** The 100 mrem per year standard cited is not protective of human health and the environment. Release standards must be set in compliance with ARARs and not be inconsistent with EPA OSWER Directive 9200.4-18, August 22 1997. The chemical specific ARAR cited in Table E-1, "TDEC 1200-2-11-.16(2)" is not protective. Release standards must be demonstrated to be within the risk range. It is noted that the PWAC is based on use of the risk range where sufficiently protective chemical -specific	See response to EPA General Comment 9 above, and Specific Comment 56 below.

No.	Reference	Comment	Response
		ARARs do not exist. A similar approach should be taken for the releases of wastewater from cell operations and closure/post-closure.	
35)	Section 6.2.2.7, Page 6-29	The final sentence of this section "...to an appropriate facility on the ORR" is ambiguous and inappropriate. If waste remains on-site it must be addressed in this ROD (e.g., ARARs, design, implementation, construction, RER, FYR). If waste is sent off-site, the Off-Site Rule must be followed.	The final sentence in Section 6.2.2.7 was revised as follows: "If contaminated, the contact water could not be released as storm water and would be transferred to one of the two tanker truck loading stations for transporting to the PWTC."
36)	Section 6.2.2.8, Page 6-30	***"Process Modification, Volume Reduction Processing"*** Project sequencing is discussed in the context of a process modification that could save $65.4 M in total costs. The final sentence states, "The planning of EMDF disposal capacity assumes that this effective sequencing of projects will occur." If it will occur, then this is a part of the remedy and should be factored into the remedy conceptual design, implementation and cost (i.e, not a process modification or cost savings) for the detailed analysis.	Agree that the assumption of efficient project sequencing is part of the remedy and not a process modification. References to sequencing were removed from this section.
37)	Section 6.2.2.8, Page 6-30	***"Process Modification, Volume Reduction Processing"*** The discussion on Waste Segregation as a process modification is vague. Under what conditions would waste segregation as a process modification be deployed or not deployed? What are the estimated efficiencies for this process and resulting impacts on total cost? See General Comment 2 above regarding appropriate documentation for use of the Y-12 landfills.	Some additional detail was added for the Waste Segregation discussion. Segregation of clean and contaminated materials is routinely performed if it is safe and cost effective. ORR landfill disposal costs less than EMWMF disposal and should be utilized to the maximum extent possible. However, additional spending for characterization efforts are necessary to employ segregation and the overall costs need to be considered. Since segregation must be conducted at the project-level, both On-site and Off-site Alternatives are effected equally by implementation of segregation, and segregation estimates require characterization data. Segregation is not considered as a process modification and any reference as such has been removed.
38)	Section 6.2.2.8, Page 6-30	***"Process Modification, Volume Reduction Processing"*** The final sentence includes changing limits for the Subtitle D landfills. The discussion of this action is vague and not clear as to how it supports the evaluation of the three alternatives.	Wording was removed. We acknowledge it is not within the scope of this document to discuss other landfill WAC or changes to those limits.
39)	Section 6.2.4, Page 6-31	***"Construction Activities and Schedule"*** This section references Figure 6-9 for the conceptual sequence of design, construction, operations and closure; however, it appear the correct reference is Figure 6-13. Revise the RI/FS to address this issue.	Figure number was corrected to Fig. 6-13.

No.	Reference	Comment	Response
40)	Section 6.2.7, Page 6-37	Specify in this section that decisions to manage waste that do not meet the remedial action criteria for on-site disposal under this ROD will be documented and managed in project specific schedules and documentation.	Accepted. Text in Section 6.2.7 has been revised as requested.
41)	Section 6.2.8, Page 6-38	***"Closure"*** This section indicates that deed restrictions would be implemented as part of the On-site Disposal alternative; however, Appendix G (Cost Estimates for On-Site and Off-Site Disposal Alternatives) does not discuss these deed restrictions and therefore it is unclear if these costs have been captured as part of the cost estimate for the On-site Disposal alternative. Revise the RI/FS to include these costs or alternatively revise Appendix G to include a description of these costs.	DOE or its successor agency intends to retain ownership and control of the EMDF for the foreseeable future. Existing and future RODs will specify land use restrictions for the EMDF and surrounding areas. If required, fees for adding an environmental notation to an existing deed are negligible. In the unlikely event the land is transferred from federal ownership, DOE will comply with CERCLA Section 120(h) notification and deed requirements. Fees and other costs (taxes) for recording deeds would be included in any real estate transaction. These fees are unknown because they depend on the acreage, sale price and tax rate at the time of transfer, and are beyond the scope of this RI/FS. RI/FS Section 6.2.8 has been modified for clarity.
42)	Section 6.2.9, Page 6-38	Briefly state in this subsection how indefinite period action costs were determined.	This discussion has been added.
43)	Section 6.3, Page 6-39	This section should discuss CERCLA Section 121 bias against off-site disposal of untreated wastes.	The Off-site Rule is discussed in Section 6.3. An additional statement was added regarding the need for off-site TSDs to have the required licenses and permits to receive untreated wastes.
44)	Section 6.3.1, Table 6-2, Page 6-40	Consistent with earlier comments on WGF as-generated and as-disposed uncertainty, these waste volumes include the same uncertainty inflation of waste volumes. It appears for off-site, the only WGF uncertainty is whether the forecast is likely to forecast too low or too high. This same WGF uncertainty should apply for both on and off-site. Clarify the WGF uncertainty.	The WGF uncertainty given in Section 6.3.1, Table 6-2, is the same uncertainty given in Chapter 2 (approximately 25%). In the RI/FS, no uncertainty values predicting a low forecast are used. The 25% uncertainty is applied in both the on-site and off-site alternatives.
45)	Section 7.2.2.3, Page 7-8	The discussion on engineering controls provides specific expectations for design life for certain components and then includes ambiguous statements like "effective for the period of active institutional controls" and "at least their design live." Clarify these statements.	These statements have been clarified.
46)	Section 7.2.2.3, Page 7-8	The discussion on sinkhole challenges should be tied to specific sections in this FS and the Appendices that affirm this site and its underlying formations are not prone to development of karst features that could impact the long-term integrity of the landfill.	This discussion was expanded and Appendix C was referenced as discussing the topic of karst challenges.

No.	Reference	Comment	Response
47)	Section 7.2.2.6, Page 7-15	Delete the discussion regarding implementability challenges in the remedial evaluation and decision process and limit the discussion to implementability of the response action if selected.	Accepted.
48)	Section 7.2.2.6, Page 7-15	The discussion on DOE Order 435.1 does not clearly state whether this applies as a TBC. Explain this and the "LFROG" as appropriate.	O 435.1 is TBC. A brief explanation of LFRG's mission and purpose has been added to Section 7.2.2.6.
49)	Section 7.2.2.7, Page 7-16	The discussion of institutional controls in Section 7.2.2.3 states "Active institutional controls would continue for an indefinite period." This discussion should briefly summarize how costs were determined for the indefinite period of active controls.	This discussion has been added.
50)	Table 7-2	***"Long-term Effectiveness"*** The final sentence for the On-site alternative states that loss of habitat may be partially offset by cleanup at contaminated sites. Cleanup will be performed at other sites. Include a sentence explaining or clarifying how this benefit will be realized at the other cleanup sites by selecting this alternative.	The sentence was revised as follows: [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, while also better containing, ORR "brownfield" areas.]
51)	Section 7.3.3	This section should include a discussion of future costs that may be incurred for waste remaining on-site. If there is a reasonable expectation that any major component of the on-site disposal facility may fail, Section 7.3.7 should address this future cost possibility.	This comment is not entirely clear: are the wastes remaining on-site those that have been placed in the landfill, or those that may remain at the project sites? If the former, the costs for surveillance, monitoring, and maintenance are provided for through a perpetual care fee. If the latter, those costs (if any) would be dealt with separately and are outside the scope of this RI/FS. The EMDF will be designed to meet the specific challenges of the EMDF site. Potential failures are analyzed and the design or operating requirements are modified to limit mitigate the potential. For example, cap failure as a result of subsidence is prevented by ensuring that the allowable settlement remains within liner tolerances, and by operating the landfill to prevent settlement of the wastes. Even though the risk model assumes, for the sake of conservancy, that all synthetic liners fail, the expectation is that there will not be a major component failure, and that redundant systems will act to limit the impacts of single component failure. This is adequately explained in section 7.3.3.
52)	Section 7.3.3	There is no discussion of sensitivity analyses for cost factors that may be highly uncertain. Explain whether any sensitive cost parameters vary between the EMDF and the off-site facility and if these parameters are sufficiently certain and thereby do not warrant cost sensitivity analyses.	The conceptual landfill design is very conservative. The cost estimate is within a range of -30% to +50%, reflecting uncertainties.

No.	Reference	Comment	Response
53)	Appendix B, Section 5.2.2, Page B-15	This section does not clearly provide an overview of Scenarios A and B. Paragraph two should explain why the two scenarios were developed and the key differences between the scenarios.	An explanation for the two scenarios was added to paragraph two of Section 5.2.2.
54)	Appendix B, Section 5.2.3, Page B-17	The second to the last paragraph is not clearly written. It would help if the information for each scenario were described in summary bullets or a summary table.	Table B-4 was added that provides summary cost information for the VR processing. The paragraph was also revised to support the table data.
55)	Appendix B, Section 5.4	The body of the FS implies that project sequencing to use all waste as fill is assumed. Clarify the purpose of this section in support of the FS (See Section 6 specific comments).	Wording was added to point out the cost impact of poor sequencing or the inability to stockpile waste soil that can be used to replace clean fill.
56)	Appendix E, Section 4.1	In addition to compliance with this ARAR, confirm that chemical specific action levels (e.g., surface water discharges, groundwater modeling) will be protective of human health and the environment and consistent with EPA OSWER Directive 9200.4-18, August 22 1997. Include a statement that all radionuclide release standards will be demonstrated to be within the NCP risk range and reference the policy.	Statement has been added to Appendix E, Section 4.1 to read "*EPA OSWER Directive 9200.4-18 (EPA 1997) establishes cleanup levels for CERCLA sites with radioactive contamination. Responses to radionuclide releases will be consistent with this 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)].*" It should be noted that, as specified in footnotes within the guidance itself, the risk (dose) is to the public and may take into account land use restrictions that will "ensure no unacceptable exposures." The OSWER guidance allows for site specific considerations in meeting the NCP risk range. Additionally, the directive notes that the 25/75/25 mrem/yr standard (which is the standard presented in TDEC 0400-20-11.16 and is an ARAR in the RI/FS) on average "corresponds to approximately 10 mrem/yr EDE." The directive notes that 15 mrem/yr is approximately $3x10^{-4}$ lifetime cancer risk, therefore the 10 mrem/yr corresponds to approximately $2x10^{-4}$ lifetime cancer risk. With land use restrictions taken into account, the public risk would fall within the NCP risk range. [Note also, that the directive states EPA concluded in a CAA rulemaking establishing NESHAPs for NRC licensees,…that a risk level of "$3x10^{-4}$ is essentially equivalent to the presumptively safe level of $1x10^{-4}$". Groundwater modeling is discussed in Appendix F. Preliminary Waste Acceptance Criteria for the site are calculated to ensure

No.	Reference	Comment	Response
			that the Remedial Action Objectives for the site are met. They are therefore consistent with EPA OSWER Directive 9200.4-18 and are demonstrated to be within the NCP risk range as discussed in App. F.
57)	Appendix E, Section 2, Page E-3	The final sentence of the first paragraph should state "For purposes of not requiring a permit for the EMDF and the identification of ARARs…"	Sentence has been revised as requested.
58)	Appendix E, Section 5.1, Page E-5	It is stated that compensatory mitigation for wetlands may be required however it appears to be known and described in other portions of the FS, including the final sentence of Section 5.1 that some wetlands damages will occur. Is compensation known to be required and if not, what site conditions may require compensation and this will be determined.	Sentence was modified to read, "Compensatory mitigation in the form of wetland restoration, creation, or enhancement would be carried out as required." The final sentence in Section 5.1 was modified to read, "Construction activities at the EMDF site would involve some disturbance of wetlands and aquatic resources; mitigation activities are therefore assumed in the on-site cost estimate."
59)	Appendix E, Section 6.4, Page E-9	The final sentence of this section identifies an aspect of the alternative for onsite disposal that suggest wastewater after cell construction and during waste disposal operations will be generated and shipped to another on-site wastewater treatment plant. This raises two issues: a. First, why would the EMDF wastewater treatment plant not be constructed prior to generation of EMDF leachate? All components of the remedy must be constructed, including the waste water treatment plant, before initiation of cell disposal operations. b. Second, the vague reference to some other on-site aspect of this remedy is not sufficient. All on-site actions required for this operable unit must be included in this FS.	The last sentence was removed. Construction of a leachate treatment plant in EBVC is not included in this scope. Wastewaters (leachate) will be treated, if and as necessary, at the ORNL Process Waste Treatment Complex, just as leachate from EMWMF is currently treated.
60)	Appendix E, Section 6.5, Page E-9	The second paragraph of this section states that some ARARs are for administrative requirements that are necessary to meet substantive requirements. Clarify this statement.	Wording was modified with additional text in red. Sentence was revised to read, "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."
61)	Appendix E,	The RCRA requirements do not include a summary discussion of 40 CFR Subpart F during cell operations.	A statement regarding compliance with the substantive requirements of 40 CFR 264 Subpart F, as appropriate, has been

No.	Reference	Comment	Response
	Section 6.5, Page E-10		added to Section 6.5. Sections 6.6 (Closure) and 6.7 (Post-Closure) have been slightly modified as well.
62)	Appendix E, Sections 6.5, 6.6, & 6.7	Include a summary discussion of wastewater requirements during cell operations, closure and post closure.	Discussion has been added to Section 6.5 of Appendix E.
63)	Appendix E, Table E-1	The following comments are added directly to the table in the form of redline / strikeout text. See Attachment 1 to Specific Comments	See separate App. E table
64)	Appendix E, Table E-2	The following comments are added directly to the table in the form of redline / strikeout text. See Attachment 1 to Specific Comments	See separate App. E table
65)	Appendix E, Table E-3	The following comments are added directly to the table in the form of redline / strikeout text. See Attachment 1 to Specific Comments	See separate App. E table
66)	Appendix E, Tables E-1, E-2, & E-3	The following table was generated from the EMWMF draft ARARs Compliance Matrix that will be included in the EMWMF annual remediation report. This table lists EMWMF ARARs that are missing or not cited consistently in the EMDF ARARs. Describe why these EMWMF ARARs differ from the EMDF ARARs and include or correct discrepancies.	Comments from the table incorporated below have been addressed as appropriate in Appendix E and Tables E-1 through E-3. Several of the differences between the EMWMF and EMDF ARARs are due to change in applicable rules: • In reference to EMWMF Index numbers 33 through 54, TDEC Rule 1200-4-10 has been repealed. The only guiding document now is the TN General Permit No.TNR10-0000, which is cited in the Appendix E tables. • DOE O 5400.5 has been canceled and replaced with DOE O 458.1. Citations were updated for the Appendix E tables, as noted below. • TWRCP 94-16 and TWRCP 94-17 have been superseded by TWRCP 00-14 and 00-15. The remainder of the differences/inconsistencies are addressed individually below, in red text.
67)	Appendix F, Section 4.2, Pages F-	The approach used in modeling groundwater flow and contaminant transport at the proposed EMDF appears reasonable and appropriate considering the geology and structural setting in Bear Creek Valley, as well as the fact that the modeled domain is a smaller, sub-area of the larger Bear Creek regional groundwater	

No.	Reference	Comment	Response
	20 – F-46	flow model with boundary conditions established through telescopic mesh refinement of the larger regional flow model. However, several inconsistencies were observed between the tables and figures in Section 4.2. These are presented below: a. Table F-4 [UBCV Groundwater Model Parameter Summary (Future Condition)], Page F-30, indicates in the last row of the "Grid Information" section that there are 78.67% inactive cells in the model domain. Considering the number of total cells and total active cells presented in the two previous rows, it would appear that the 78.67% refers to the percentage of active cells in the model instead of inactive cells. The table should be corrected accordingly. b. Table F-4 [UBCV Groundwater Model Parameter Summary (Future Condition)], Page F-31, indicates in the first row of the "Recharge" section that the recharge rate for the Closed Landfill/Paved Park Area is 2.28E-04 feet per day (ft/day). However, Figure F-9 (Model Recharge Distribution), Page F-28, indicates that the recharge rate in these areas is 2.28E-03 ft/day. The table or figure should be corrected accordingly. c. Table F-4 [UBCV Groundwater Model Parameter Summary (Future Condition)], Page F-31, indicates in the second row of the "Recharge" section that the recharge rate for the Rome formation is 2.00E-03 ft/day. However, Figure F-9 (Model Recharge Distribution), Page F-28, indicates that the recharge rate for the Rome formation is 5.00E-03 ft/day. The table or figure should be corrected accordingly.	Table has been corrected to state that 78.67% are active cells. Table lists the correct value (2.28E-04 feet per day (ft/day)). The typo in Figure F-9 has been corrected to 0.000228. Table lists the correct value (2.00E-03 ft/day). The typo in Figure F-9 will be corrected to 0.002.
68)	Appendix F, Section 4.2.4, Page F-28	***"Hydraulic Conductivity Field"*** The text in the first paragraph states that anisotropy ratios of five to one (for the weathered bedrock zone) and ten to one (for the fractured bedrock zone) were used to represent the preferred fracture/bedding orientation of the natural units. The text should discuss if hydraulic conductivity anisotropy ratios of this magnitude have been measured in the weathered bedrock and fractured bedrock zones in the field. If these values have not been physically measured in the field, the text should indicate how these values were derived for the modeling simulations (e.g., previous calibration of the regional groundwater flow model).	Text was revised to include references and backup information: "Both field data and previous modeling sensitivity analyses have supported the anisotropic ratios used in the model. Field data included analytical plume distribution and aquifer test data within Bear Creek Valley (Geraghty & Miller, 1987, 1989; Law Engineering, 1983; Lee et al., 1992; and Golder & Associates, 1988). Extensive modeling sensitivity analyses were conducted during the Bear Creek model development in the Bear Creek FS report (DOE, 1997). A summary was also presented in a publication (Evans et al., 1996). All these data indicated the anisotropy nature in the aquifer of Bear Creek and the anisotropic relationship with depth. Attachment F.1 of the modeling A detailed summary of the aquifer test data is provided

No.	Reference	Comment	Response
			in the Bear Creek FS, Appendix F (DOE 1997)."
69)	Appendix G, Section 4.2.3.4, Table G-2, Page G-9	This table provides the breakdown of the 28% indirect markup prior to compounding; however, the sum of the markups in Table G – 2 only adds up to 26% (10% overhead, 10% profit, 1% bond, and 5% general contractor's markup for work performed by subcontractors). Revise the RI/FS to report the same percentage of markup in the table as in the text.	This table was removed. A 28% indirect markup is added in the estimate, and the text states what is included in the markup (e.g., overhead, profit, bond, etc.) but the breakdown is not necessary, so it was removed.
70)	Appendix G, Section 5.2, Table G-5, Page G-17	This table reports the Treatment/Disposal Costs of Nevada National Security Site (NNSS) disposal access fee rate as $14.51 per cubic foot ($ft^3$); whereas, the Treatment/Disposal Costs for treatment and disposal of LLW/RCRA (mixed waste) (macroencapsulation) and surcharge of 4% on waste received during winter months (Dec – Feb) are reported in dollars per yd^3. Revise the RI/FS to use consistent units in Table G – 5.	Revised NNSS access fee to $/yd3.

CERCLA D1 RI/FS COMMENT AND RESPONSE SUMMARY

Comments by: **TDEC Division of DOE Oversight**
Comments Received: February 19, 2013
Title of Document: Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee
Revision No.: D1
Document No: DOE/OR/01-2535&D1
Date: September 2012

No.	Reference	Comment	Response Approach/Comment
1)	General	The approach to development of a preliminary WAC taken in this document does not address cumulative effects due to the EMWMF and the proposed EMDF, as required by DOE M 435.1-1 (*Radioactive Waste Management Manual*). TDEC has concerns as to whether the proposed approach is adequate for WAC development or to assure future compliance with the performance objectives required by DOE Order 435.1 and TN Rule 0400-20-11-.16. Below are listed concerns TDEC has with the risk based modeling employed in this document.	DOE Order 435.1 Chg 1 requirements are To Be Considered materials subject to review and approval by the DOE Low-Level Waste Disposal Facility Federal Review Group (LFRG). A Performance Assessment and Composite Analysis will be prepared under separate cover and submitted to LFRG at a later date. The PA, CA and a PA/CA Maintenance Plan are among the requirements for LFRG to approve a Disposal Authorization Statement pursuant to O435.1. A brief explanation of the mission and purpose of LFRG has been added to RI/FS Section 7.2.2.6. A more formal definition of To Be Considered materials has been added to Section 1 of Appendix E.
		a. Sites on the ORR underlain by carbonate rocks fail a key technical requirement for siting facilities for land disposal of radioactive waste in Tennessee [TN Rule 0400-20-11-.17 (1) (b)]. Consequently, sites on the ORR underlain by carbonate rocks should not be candidate sites for CERCLA land disposal of radioactive wastes.	The commenter's reference to carbonate is apparently meant to imply that delineation of flow paths in karst terrain is usually not possible. The EMDF site is not underlain by the pure carbonate rocks in which karst is best formed. There is no evidence of karst at the site or at similarly positioned sites in Bear Creek Valley, e.g., EMWMF. The EMDF site is expected to be fully capable of being characterized, modeled, analyzed, and monitored. **Text stating that the site can meet the TDEC criteria has been added to Section 7.2.2.6.**

No.	Reference	Comment	Response Approach/Comment
		b. Risk modeling is ultimately based on the inventory of contaminant mass or Curies disposed. Using a volume weighted sum of fractions rather than a limit on total mass or curie content (or a mass/Curie weighted SOF) adds an extra and unnecessary step between the calculation of risk and waste acceptance. A less complex and more transparent WAC attainment process than that currently used at the EMWMF would be a goal for any new ORR CERCLA disposal facility, although impacts to the conclusions of this RI/FS might not be significant.	The SOF method used in meeting final WAC is beyond the scope of this RI/FS. The final methodology for WAC attainment will be developed and submitted for regulator and LFRG approval at a later date. WAC approval by LFRG is a required element for obtaining a Disposal Authorization Statement.
		c. The list of waste types proposed for the EMDF (section 2.1.2 of the RI/FS) includes a range of demolition material, but it is not apparent that this has been reflected in the choice of solid-liquid partition coefficients used in modeling.	Please see Appendix F, Section 5.1, 3rd paragraph for more detail on the reasons that K_d for soil-like materials are considered appropriate. This paragraph has been revised to improve clarity.
		d. The cell design, waste forms, hydrologic setting, and operations proposed for the EMDF is not sufficient to assure that a 1 centimeter per year infiltration rate through the cell represents a plausible worst case.	This comment lacks specificity, but can be addressed by stating that the design contained within the RI/FS is conceptual. Infiltration rates of 1 cm/yr [i.e., 0.38 in/yr (Partially Functional Stage) and 0.42 in/yr (Long-Term performance Stage)] were calculated by the Hydrologic Evaluation of Landfill Performance (HELP) model using input parameters based on the conceptual landfill design (please see Table F-2 in Appendix F). This approach is conservative because it assumes partial and then total failure of synthetic liners and drainage diversion layers, relying instead on the long-term stability of the compacted clay layers to limit infiltration. No revisions have been made to the RI/FS with regard to this comment.
		e. There is little rationale provided for the scenarios used to establish long-term performance of the proposed facility. Other than a proposed three foot thick layer of 4 inch to 12 inch diameter rip-rap in the final cap design, there is nothing to address the performance objective limiting the risk to inadvertent intruders in TN Rule 0400-20-11-.16 (3), or satisfy the similar requirement in Chapter IV, paragraph (P) (2) (h) of DOE M 435.1. The RI should evaluate long term facility performance in accordance with TN Rule 0400-20-11-.16 and DOE Orders, or should provide sufficient justification to demonstrate an equivalent	The biointrusion layer and the cap thickness work to discourage inadvertent intrusion, such as construction of a house basement or drilling a water well. Further, the steep side slopes will discourage construction. Penetration of the cap's layers, especially the biointrusion layer, would require heavy equipment and would therefore be intentional intrusion. Analyses of acute- and chronic-exposure inadvertent human intruder scenarios will be contained in the Performance Assessment (PA) required by O 435.1. The intruder analyses are expected to conform to Manual 435.1, Chapter IV requirements. Additional protective measures could be incorporated into the final design should the PA indicate the need for additional measure to protect from inadvertent intrusion**.** Revisions have been made to RI/FS Section

No.	Reference	Comment	Response Approach/Comment
		standard of performance under the requirements for formal waiver of ARARS, given in 40 CFR 300.430 (f)(1)(ii)(c)(4).	7.2.2.3 to clarify the expectations regarding inadvertent intrusion.
		f. It also appears that the placement of the well (pages F-5 to F-9 of the RI/FS) to establish risks through groundwater pathways does not achieve the stated goal of determining a point of compliance at the point of highest projected dose or concentration beyond a 100 meter buffer zone surrounding the disposed waste, per DOE M 435.1 (P) (2) (b). In order to be consistent with both DOE requirements the withdrawal well should not be far outside the 100 meter buffer. A sensitivity analysis should be performed to show that the dilution factor achieved by the hypothetical location and construction of a withdrawal well is at least typical of worst case scenarios.	The location of the hypothetical receptor well for modeling purposes was analogous to the approach approved for EMWMF by the regulators. This location was used to calculate the preliminary WAC, based on the assumption that this is the nearest reasonable location for a resident farmer with a well, watering livestock and crops from Bear Creek. It is not intended to comply with O 435.1 Performance Assessment requirements, which will be addressed in a Performance Assessment and Composite Analysis to be prepared at a later date. No revisions have been made.
2)	General	A more thorough consideration of all state and federal laws and regulations than that given in Appendix E will be required before establishing a list of ARARs. Some specific examples relative to siting, design, and operations requirements for the proposed facility considered by TDEC to be most significant are discussed below:	Development of ARARs is an iterative process; and includes incorporation of some regulator comments. The ARARs list will continue to evolve as the remedial design is completed. Additional responses to this multi-part comment are provided below.
		a. The discussion in Chapter 3 of Appendix E (pages E-3 and E-4) of this document is not adequate to provide a basis for the waiver of ARARs, specifically TSCA requirement 40 CFR 761.75(b) (3) or TDEC Rule 1200-2-11-.17(1)(h) (now TN 400-20 11-.17(1)(h)). The intent of both of these rules is the long term hydrologic isolation of the disposal facility liner from the water table.	40 CFR 761.75(b)(3) requirements will be met, except for the 50 ft buffer requirement between the liner and the historic high water table. A waiver is requested for this requirement on the basis that the landfill liner design provides equivalent protection. Citations to 40 CFR 300.430 (f)(ii)(B)(1) and (C)(4) have been added to Sections 1 and 3 of Appendix E, and additional rationale for the waiver has been added to Section 3. TDEC Rule 0400-2-11-.17(1)(h) would also require a waiver. This waiver would be requested based on the use of an underdrain and packed soil base under the landfill liner to lower the water table sufficient to prevent any springs or seeps to the landfill floor after cell construction is complete. The underdrain system would eliminate the discharge of groundwater to the ground surface. This waiver is requested on the grounds of equivalent protection, per 40 CFR 300.430 (f)(ii)(B)(1) and (C)(4). Additional discussion is presented in Section 3 of Appendix E.

No.	Reference	Comment	Response Approach/Comment
		b. Perimeter drains and stormwater diversion channels are required to hydrologically isolate the proposed facility from surface water discharge and ground water recharge along Pine Ridge. There is no evaluation of the potential for these constructed features to fail after the closure of the facility. A record of surface water discharge and hydraulic head and water table fluctuations at the proposed site should be done to demonstrate long term performance and compliance with ARARs listed on pages E-38 and E-39 of the RI/FS (now TN Rule 0400-02-11-.17, subparagraphs (e), (f), (g), and (i), as well as the monitoring requirements of TN Rule TN Rule 0400-02-11-.17, paragraph (4).	1) The text in Section 6.2.2.4 of the RI/FS has been modified to indicate a design requirement will be to evaluate the possibility that the upgradient shallow French drain, storm water diversion ditches, and/or underdrain fail after closure of the disposal facility and demonstrate the landfill remains protective of the environment in the event one or more of these engineered features are no longer functional. 2) An extensive site characterization study is currently in the planning process and is expected to begin in FY2014. Characterization is expected to involve continuous ground water level monitoring in multiple wells for one year, continuous surface water flow monitoring in NT-2 and NT-3 for one year, quarterly water quality monitoring and geological and geotechnical testing of soils and bedrock. The results of this study will be used in performance assessment and as a basis for landfill designs. A surface water and groundwater monitoring program will be instituted during operation and after closure of the landfill to demonstrate long-term performance and compliance with ARARs, in accordance with TDEC Rule 0400-20-11-.17(4)(a).
		c. TN Rule 0400-02-11-.17, subparagraph (2)(d). These requirements should be met through proper cap design and void space reduction measures.	Text was added to Section 6.2.2.4 of the RI/FS stating the landfill cap would be designed to meet the requirements of TN Rule 0400-20-11-.17, subparagraph (2)(d): "Covers must be designed to minimize to the extent practicable water infiltration, to direct percolating or surface water away from the disposed waste and to resist degradation by surface geologic processes and biotic activity" (Note this TDEC Rule is listed in the ARARs table in Appendix E.) The following wording was added to Section 6.2.5: "A goal of the waste placement and compaction operations will be to minimize the void space within the waste, which will lessen the potential for long-term settlement/subsidence of the waste and enhance the long-term stability of the final cover system."
		d. TN Rule 0400-02-11-.17, subparagraph (2)(f). The requirements would not allow for the current proposal of a low permeability protective layer (modeled in the RI/FS as 1 foot of native soils – hydraulic conductivity of approximately 10^{-6} cm/s on page F-18) above the cell drainage layer and leachate collection system.	TN Rule 0400-02-11-.17, subparagraph (2)(f) states: "The disposal site must be designed to minimize to the extent practicable the contact of water with waste during storage, the contact of standing water with waste during disposal and the contact of percolating or standing water with wastes after disposal." The use of the protective soil layer, as described in this RI/FS, does not violate the requirements of TN Rule 0400-02-11-.17 stated above. Similar to the process being performed at EMWMF, contact water

No.	Reference	Comment	Response Approach/Comment
			would be collected in the lower portion of the landfill cell away from the waste. Temporary berms would be constructed to contain the contact water and separate it from the waste. Contact water would be removed promptly from the landfill cell after collection to prevent it from standing within the waste during and after disposal. Thus, to the extent practicable the contact of water with waste during storage, the contact of standing water with waste during disposal, and the contact of percolating or standing water with wastes after disposal would be minimized.
		e. Wastewater treatment is described in section 6.2.2.7 of the RI/FS. ARARs specific to treatment and discharge of leachate and contaminated storm water cited in this document are listed on pages E-40 and E-60 of the document. Subpart A of 40 CFR 445 for point source discharges of wastewater from landfills subject to the provisions of 40 CFR part 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, Subpart N–(Landfills) is applicable to wastewater discharges from the proposed facility. TN Rule 1200-04-05-.04 (1) (b), which prohibits the discharge of radioactive waste into waters, should be considered relevant and appropriate.	Leachate treatment has been removed from the RI/FS. Contact water and leachate will be handled in the same manner as for EMWMF.
3)	General	DOE concluded in 2004 (BJC/OR-1908) that the expenditure of 7 to 10 million dollars on volume reduction technologies would save 60,000 to 90,000 cubic yards of landfill capacity under the assumption that void space reduction of wastes generated from scrapyards and large buildings would translate directly into 1:1 clean fill savings requirements. Experience has shown that clean fill savings are likely to be much more significant, since ratios of over 2 to 1 clean fill: waste are required to get proper compaction for a variety of waste materials. The following comments concern the use of volume reduction techniques.	See responses below:

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		a. Appendix B seems to demonstrate the cost effectiveness of volume reduction methods. There are, however, inconsistencies in discussion of unit cost. In comparing disposal costs for on-site and off-site options, cost per unit volume of on-site disposal was made with a basis that includes clean fill in the total disposed volume. The feasibility of processing equipment, structural steel, piping, and other items requiring a high clean fill to void ratio for off-site disposal while disposing of materials not as suitable for volume reduction such as soil or concrete on-site should be evaluated.	Table B-9 provides a comparison of unit costs for on-site and off-site disposal both with and without volume reduction. The cost for on-site disposal has to be based on the amount of air space occupied by the waste material along with the required quantity of clean feel required for the particular material. The cost of the landfill air space was divided by the as-generated volume of the material to obtain $/As-G vol, which is the same basis as the cost for off-site disposal. As shown in Table B-9, the cost of off-site disposal for equipment and structural steel, even with VR, is far greater than the cost of on-site disposal, therefore using a combination of off-site disposal for equipment and on-site disposal for soil will always be more expensive than disposing of all the materials on-site.
		b. The conceptual design, and presumably, operational costs, of wastewater treatment are based on the assumption that the characteristics of leachate and contaminated stormwater will be similar to the characteristics of wastewater currently generated at the EMWMF. The projected waste stream for EMDF disposal is, however, to be generated from somewhat different sources than waste disposed at EMWMF, and may contain contaminants that will be more expensive to treat to water quality standards. Water handling and wastewater treatment options for the proposed facility should be described in greater detail, including costs associated with possible wastewater treatment at the ORNL process waste treatment plant.	The treatment facility has been removed from the estimate, however the ORNL PWTC uses a very robust system that can accommodate a wide variety of contaminants. All costs for handling leachate and contact water are included in the estimated annual operating cost, which is taken directly from the actual EMWMF operating costs (includes their management of leachate and contact water).
1)	Executive Summary, Page ES-2, Paragraph 3	**"RI/FS Approach"** Risk assessments on individual remedial sites may not be in the scope of this document, but a risk assessment of this new proposed disposal facility on the EMWMF receptor is required. Our preliminary evaluation indicates that the dose from the new facility close to the EMWMF receptor would be cumulative and could approximately double the dose with the same waste acceptance criteria. This situation requires a composite analysis of the two disposal facilities on the EMWMF receptor. Furthermore, a composite analysis should also incrementally include other sources in Bear Creek Valley, such as S3 ponds, Bear Creek Burial Ground, Bone Yard Burn Yard and so forth, even to consider the Spallation Neutron Source groundwater	A risk assessment was conducted using coupled ground water – surface water models to determine if a receptor located near the confluence of NT-3 with Bear Creek. Modeling results were then used to calculate waste acceptance criteria for specific constituents expected to be present in the waste placed in the EMDF only. A Composite Analysis (CA) will be prepared to meet the requirements of DOE Order 435.1, which includes consideration of the cumulative impacts of all low-level radioactive and chemical waste disposal areas in EBCV. The CA, reviewed and approved by LFRG (see response to comment 1, above), is an element of the Disposal Authorization Statement required by DOE prior to placing waste.

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		pathway into spring SS5. It could be that this proposed facility only reduces totaled risk if other sources in Bear Creek Valley are removed, remediated, or consolidated.	
2)	Executive Summary, Page ES-5, Top of Page	Waste Control Specialists (WCS) should be included in this discussion or explained why they are not available. Especially since DOE has anticipated capability at the site that may be beneficial. WCS also has rail access. In general, the discussion should include more sorting alternatives for the purpose of disposing non-rad waste in RCRA permitted facilities. "Cradle to cradle" reuse/recycling of metal and other valuable material should also be discussed up front. Please state current and anticipated contract rates for each commercial facility. The discussion, as is, seems to have unsubstantiated cost estimates.	WCS is addressed in some detail as a process modification in Section 6.3.3.8.1, but is not included in the Executive Summary since it is not a primary component of the Off-Site Alternative. DOE recently entered into a contract with WCS. The RIFS addresses only the waste materials that are LLW or LLW/mixed and the WGF basis assumes all non-rad materials have been segregated and properly dispositioned elsewhere. There is no basis for estimating the volume of additional materials for segregation or recycle. Anticipated contract rates for ES disposal are given in the detailed discussion of the Off-Site alternative in Section 6.
		Subsequent pages through about 2-9, including figure 2-2 should include diversion of more debris into non- rad disposal. Some demolition buildings (Table A–2) will not produce all rad waste unless they are mixed with radioactive wastes (dilution). It was not our intent to allow clean waste to be mixed with concentrated rad waste to get higher volume lower activity rad waste (dilution).	Waste that is disposed in the EMDF will only be that generated by CERCLA actions. Clean soils and soil-like materials may be used as void fill necessary to maintain structural stability and prevent cap subsidence. This is not dilution. It is worth noting, however that addition of clean fill in and around radioactive wastes acts as shielding and therefore helps to reduce exposure and risk.
3)	Executive Summary, Page ES-4	*"The estimated total project cost for implementing the Off-site Disposal Alternative is $1.992 billion (B [2012 dollars]) or $1.408B (present worth)."* Is the EMDF cost estimate a fixed price "turn-key" bid where DOE closes the facility upon depletion of the proposed funding cost? The Off-site Disposal Alternative of $1.992 billion should be based on hard bids from off-site disposal facilities.	The contracting approach (i.e., turn-key, fixed price, design-build, incremental, etc.) has not been decided and is not germane to this document. It is assumed that DOE will fund landfill construction, operation, closure, and post-closure to the extent required to achieve remedial goals and ROD requirements. The cost estimates presented in this RI/FS are based on commonly available commercial rate tables (e.g., R.S. Means), material quotes (if available), available disposal rate tables, experience, and labor rate tables for the ORR. Hard bids are not appropriate at this stage because the design is conceptual, not for construction.
4)	Page 5-2, Table 5-1	Table 5-1 does not evaluate waste classification. Disposal of clean wastes into non-rad RCRA permitted facilities is not mentioned. This infers dilution will be practiced.	Table 5-1 is intended to evaluate effectiveness, implementability, and relative cost only; waste characteristics and classification are discussed in Section 2 of the RI/FS. Table 5-1 has been extensively revised in response to EPA General Comment 10 and TDEC Specific Comment 5. Please also see response to the second part of Specific Comment 2, above.

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5)	Page 5-3, Table 5-1	Waste Control Specialists (WCS) is a viable alternative that is not listed. Include WCS.	WCS has been added to Table 5-1. Additionally, note that WCS is addressed in Section 6 as a process modification. Please also see response to Specific Comment 2, above.
6)	Section 6.2.2.4, Page 6-15	**"Disposal Facility"** *"The geologic buffer could be comprised of compacted native soil or in-situ fine-grained native soil, saprolite, bedrock, or combinations of these geologic materials, depending on measured in situ hydraulic conductivity and layer thickness."* There is some concern with the geologic material used in the buffer. The use of saprolite or bedrock may not be accurately measured in determining hydraulic conductivity. Saprolite and bedrock contains rock pieces that make it difficult to compact and meet the hydraulic conductivity criteria uniformly. The native soils should be sieved before use.	In-situ fine-grained native soil, saprolite, and bedrock refers to these materials in their natural undisturbed (i.e., unexcavated) positions. The hydraulic conductivity of these undisturbed materials would be measured using standard field and/or laboratory testing methods, as appropriate for these various materials during the site investigation program. Excavated bedrock and rocky saprolite materials would not be used to construct the geologic buffer layer. DOE concurs large pieces of rock would not be allowed in compacted soil used to construct the geologic buffer layer. The text in Section 6.2.2.4 was revised to clarify native soil used to construct the geologic buffer layer (i.e., compacted native soil) would be sieved in the borrow area, as required, to remove large pieces of rock that could make it difficult to compact and meet hydraulic conductivity criteria, prior to placement and compaction beneath the landfill.
		"A lesson learned from the EMWMF construction is that a landfill can be successfully constructed over a tributary in BCV. An underdrain is necessary within the tributary channel to provide a flow path for groundwater immediately below the landfill and prevent upwelling, since tributaries are natural discharge areas for groundwater." A concern using an underdrain is for physical and chemical weathering of the No. 57 stone (limestone). Eventually the underdrain will fail.	As shown on Figure 6-9, the underdrain would be constructed of siliceous rock and not limestone to avoid weathering issues. Wording was added to the text in section 6.2.2.4 stating the underdrain will be constructed of siliceous rock to avoid weathering issues.
7)	Section 6.2.2.7, Page 6-28	**"Leachate/Contact Water Treatment Facility"** *"The portion of precipitation that falls within an open, active cell potentially coming in contact with the waste materials and collecting on the floor of the cell (referred to as "contact water") would be pumped out of the active cells and stored temporarily in lined basins located near the landfill. While in the basin, the contact water would be sampled and tested to determine whether it is contaminated. If the results of the analytical tests indicate the contact water is free of contamination, it would be released to the storm water detention basin. If contaminated, the contact water could not be released as storm water and would be transferred to the treatment facility via a dedicated piping*	The term "contact water" as used in this RI/FS is the same term as used in EMWMF regulatory documents. Based on EMWMF experience, the volume of contact water generated in a given year of landfill operation is approximately three times the volume of leachate removed from the leachate collection and removal system. Since testing of the contact water at EMWMF has demonstrated this fluid is typically not contaminated above environmental release criteria and typically can be released to surface water without treatment, this RI/FS describes managing this fluid separately from leachate to reduce the volume of leachate potentially requiring treatment and disposal. Section 6.2.2.9 of the RI/FS has been revised to include the process option of making "windows" in the protective soil layer and collecting contact water as leachate. The pros and cons of collecting contact water as leachate are discussed in Section 6.2.2.9.

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		system." The term *"Contact Water"* as used here is a term invented as a matter of convenience for the EMWMF. It has no basis in TN Rules and Regulations. The state's position is that the protective soil layer should be engineered with permeability such that water entering the active cells will be collected as leachate as much as possible.	
8)	Page 6-52	**"Process Modifications"** Volume reduction prior to rail shipment should be a given and not a Process Modification?	The value of VR for off-site shipments depends on the quantities processed and the manner in which VR is executed. As stated in Appendix B, VR would be cost effective if implemented programmatically and/or for large volumes of material. If implemented at a project level for small quantities, the cost effectiveness is not clear.
9)	Appendix C, Page C-4, First Paragraph, Lines 2-3	From available maps it appears that the proposed EMDF lies in the Anderson County and not the Roane County Census Tract 9801. Please explain this discrepancy.	The text erroneously identified the county as Roane; the error has been corrected to show that EMDF site is in Anderson County.
10)	Appendix C, Page C-20, Figure C-10	Faults that are referred to in the text in section 3.2.3 should be labeled in Figure C-10.	According to Lemiszki (2000, *Geologic Map of the Bethel Valley Quadrangle*. USGS Draft Open-File Map GM 130-NE.) the White Oak Mountain Thrust fault is more than 2,000 ft below land surface at Bear Creek Valley, more than 1,000 ft below the base of the cross-section. No change was made.
11)	Appendix C, Section 3.2.2.2.2, Page C-21	**"Rutledge Limestone"** This formation appears to be labeled ***"Friendship Formation"*** in Figures C-9 and C-10 (maps) on pages C-19 and C-20, respectively. As the nomenclature ***"Friendship Formation"*** seems limited to only the Oak Ridge Reservation it is suggested that the designations on the two maps be changed to reflect the commonly accepted formation name Rutledge Limestone.	Figures C-9 and C-10 have been revised.
12)	Appendix C, Section 3.2.2.2.4, Page C-21	**"Maryville Limestone"** This formation appears to be labeled ***"Dismal Gap Formation"*** in Figures C-9 and C-10 (maps) on pages C-19 and C-20, respectively. As the nomenclature ***"Dismal Gap Formation"*** seems limited to only the Oak Ridge Reservation it is suggested that the designations on the two maps be changed to reflect the commonly accepted formation name Maryville Limestone.	Figures C-9 and C-10 have been revised.

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13)	Appendix C, Page C-22	*"…weathers to for a strongly weathered saprolite…"* What is a strongly weathered saprolite? Is it not still a saprolite?	Sentence has been revised to omit the words "strongly weathered".
14)	Appendix C, Page C-24	Section 3.2.3 1st sentence, reference to the Whiteoak Mountain thrust fault- the fault needs to be labeled on the figure (C-10)	Figure has been revised.
15)	Appendix C, Section 3.2.3, Page C-25	**"Geologic Structure"** Moore (1988) noted the presence of 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."* So, what is being said is that faults as conduits are uncommon or rare, unless drilling or other data support that?	That is correct. Coring is expected to be included in the site characterization study to help evaluate the presence of fractures and evidence of faulting.
16)	Appendix C, Page C-25	*"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."* The wording in this document should not be so dismissive about possible seismic hazards nearer to the facility. The USGS estimate that an earthquake as large as magnitude 7.5 (Richter) are possible in the ETSZ (East Tennessee Seismic Zone) and events of magnitude 5 – 6 are possible every 200-300 years. The largest event measured (magnitude 4.6) occurred near Knoxville in 1973.	Agreed. This paragraph has been moved to a new subsection 3.2.4 entitled Seismicity, which discusses earthquake history and probability of future earthquakes in more detail.
17)	Appendix C, Page C-25 & C-26	The extensive discussion about fractures in this section, although useful and fascinating, should be taken within the context that it is dissolution along bedding planes that is more important. Although tributary flow must occur along fractures, convergent regional flow occurs along conduits or macrofissures to discharge locations that maybe springs far downgradient or conduits inadvertently intercepted by wells (probably domestic or industrial) at depth.	This is the premise of the site conceptual flow model. Please also note that bedding planes are considered to be a type of fracture. The sentence "It is possible that flow converges in one or more master fractures, including bedding planes, which discharge to springs outside the EMDF area." has been added to the discussion of flow presented in subsection 3.3.3.2.1, 3rd paragraph. Additional supporting text has been added to Sections 3.2.3, 3.3.1.2, and 3.5.
18)	Appendix C, Page C-26, Third Paragraph, Last Sentence	*"Further, they corroborate the notion that the most conductive zone is near the water table."* The nature of flow in carbonates and probably in fractured rocks like shales associated with carbonates is one of vertical tiers of conduits that initially form deep below the water table. Tiers are formed during initial development of	It is a misconception to view the ground water flow system on the flank of Pine Ridge in terms of a classical karst. A review of available borehole data suggests that few if any conduits are to be found in Conasauga Group units, except for the Maynardville Limestone, where they are relatively abundant. Tiers, in the classical karst sense, are unlikely to form in the shaley rocks under the EMDF site, although there is evidence that there may be a deeper tier in the Maynardville

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		a setting/aquifer (Worthington, 1991). There is evidence that there is continuous discharge via conduits from settings/aquifers through many millions of years (Worthington, 2004) despite base level lowering. Lower tiers discharge base flow where higher tiers discharge near the water table. Geologically recent changes to the landscape would not affect flow in deeper tiers, when sea level was 130 m lower than at present during the last glacial maximum this further deepened flow systems.	Limestone. Worthington (1991) notes that even in classical karst terrains, many cave/conduit systems do not have tiers. Where tiers exist, they develop in response to decreases in water table elevation as a result of lowered base level or uplift. It is unlikely that Pleistocene glacial sea level change greatly affected areas as far inland as eastern Tennessee. See added text in Sections 3.3.1.3, 3.3.3, and 3.3.3.2.1.
19)	Appendix C, Section 3.3, Page C-27, Second Paragraph	**"Groundwater"** The quote and reference that follows summarizes the use of the term aquitard in Oak Ridge. *"Contaminant migration through aquitards is often erroneously believed to depend only on bulk hydraulic properties of aquitards, without regard to preferential flowpaths in the aquitard or different contaminant types. Actual rates of contaminant transport through aquitards can be very different from those based on estimates of bulk flow rates. Using a two-dimensional, discrete-fracture model, Harrison, Sudicky, and Cherry (1992) showed even though the volumetric flow rates (i.e., Darcy flux) from an aquitard to an aquifer can be very low, contaminant transport through aquitards may be relatively rapid because of fractures, even very small fractures, if they fully penetrate the aquitard. Basic hydrogeologic techniques designed for aquifers, such as pumping and slug tests, commonly need modification to be appropriate for assessment of low permeability geologic media (Novakowski and Bickerton 1997, Shapiro and Greene 1995, van der Kamp 2001)."*	No change has been made to the text of Section 3.3. Aquitard is a comparative term used primarily to convey a difference in relative permeability, and by extension, transmissivity and yield, between two or more hydrologic units. It does not, and is not intended to, indicate that groundwater does not occur in rock units identified as aquitards, nor does it indicate that these units will not also transmit contaminants. In the Oak Ridge Reservation, aquifers are those high-flow units, such as the Maynardville Limestone and Copper Ridge Dolomite, and aquitard refers to those units that are less productive, like the Nolichucky Shale. The USGS defines an aquitard as "A saturated, but poorly permeable, geologic unit that impedes ground-water movement and does not yield water freely to wells, but which may transmit appreciable water to and from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage unit. Aquitards are characterized by values of leakage that may range from relatively low to relatively high. Areally extensive aquitards of relatively low leakage may function regionally as confining units within aquifer systems." (USGS Water Supply Paper 2025).
		There are also other recent references that show it is not appropriate to describe settings as aquitards simply based upon lithology, where rather than lithological changes, what is observed are sharp changes in hydraulic head profiles in boreholes, not related to lithological changes in stratigraphy (Meyer at al, 2010, 2012). The use of the term aquitard for lithologies in Oak Ridge should be abandoned, they are shelf sequences and in variably contain both shale and carbonate, by their nature, shales in such sequences are also most commonly	The term *aquitard* does not refer to lithology, but to aquifer properties, particularly the inability to transmit water at high rates. In East TN, poorly transmissive water bearing units are typically shales, clayey limestones, silts, and tightly cemented sandstones and are therefore correlated to lithology. The reviewer is correct that the rock units under Bear Creek Valley were deposited on continental shelf environments and that individual layers can be discontinuous or exhibit lithologic and facies changes across an area. However, such discontinuities are not significant at the at the scale of the EBCV. The Warsaw and Ft. Payne Limestones of south-central

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		discontinuous laterally. In one case an Oak Ridge aquitard has a significant spring that discharges from it, in another an Oak Ridge aquitard is, in an adjacent state a karst preserve, and overall, many domestic wells produce from what are allegedly the aquitards. Use of this term is very misleading and should be discontinued.	Kentucky (Mammoth Cave area) provide an example of a similar lithologic assemblage that produces water at low volumes and does not contain highly evolved conduit systems (Brown, 1966). **No revision has been made.**
20)	Appendix C, Section 3.3.1, Page C-27	**"Aquifer Characteristics"** The use of the term cavities implies that these features are closed. This is theoretically almost impossible to conceive of unless within the framework of the initial deposition of the sediments. Cavities as they are often referred to are simply fragments of sinuous conduits that are intersected by borings. It is known in carbonates in many locations that most of the flux (> 99%, for Oak Ridge; Davies, 2008,) is in conduits with most of the storage in the rock matrix. 94% flux is in conduits regardless of the age of the carbonate rock or the location.	A cavity is a void in the rock, and there is no genetic implication as to its size, shape, or connectivity with other openings. The word cavity is a good general term for use on borehole logs because of the very small area accessed by the boring. It must be recognized that, while the Maryville and Rutledge formations are nominally limestones, in the vicinity of the proposed EMDF these units are dominated by shales and siltstones that are far less susceptible to dissolution than are more purely calcium carbonate limestones. As a result, conduits are unlikely to carry as great a proportion of the ground water flux as purer limestones. Evidence for the lack of strongly developed conduit flow is found in the lack of karst landforms. Revisions have been made to first and second paragraphs of Section 3.3.1.3.
21)	Appendix C, Section 3.3.1.2, Page C-29	**"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."* It should be noted that low gradients also can indicate that a preferred pathway has developed.	Comment accepted and text in Section 3.3.1.2 has been revised.
22)	Appendix C, Section 3.3.2, Page C-30	**"Hydraulic Conductivity and Results of Tracer Tests"** *"Tracer tests offer one means of direct groundwater flow rate measurement, although they require either a large number of sampling points, or knowledge of or good predictions of flow patterns."* Actually the way tracing is done using injected tracers, is that a hydrogeological conceptual model of flow is made and then tested by using injected tracers.	Agreed. It is anticipated that tracer tests will be conducted as part of the site characterization effort to test the conceptual model. No revision required.
23)	Appendix C, Page C-32,	It has been established that in all measured carbonate aquifers in geological old or relatively young rocks, > 94%	This statement may be true of more or less pure carbonate limestones, but is not applicable to shaley limestones and shales such as those

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	Last Paragraph	of the discharge is in conduits, with only a small fraction in the fractures and an insignificant amount in the rock matrix (Davies, 2008; Worthington et al, 2000a, 2000b). This paragraph sets the case for an equivalent porous medium or a continuum approach. However, in the second to last sentence, beginning *"Worthington, (2003, p. 30)......"* reference is made to using MODFLOW to simulate flow in carbonates. This is not the complete discussion from the reference, and is misleading. The complete discussion in (Worthington, 1999, incorrectly cited as 2003) does not endorse using MODFLOW as is implied.	occurring on the flank of Pine Ridge. Please see White and White (2001)[1] who note that extensive conduit/cave systems form mainly in relatively pure limestones, while shaley limestones tend to act as aquicludes. Changes have been made in Sections 3.3.1.3 and 3.3.2.1 to clarify this relationship. A review of available well data suggests that conduits are rare or non-existent in the stratigraphic units underlying the proposed EMDF site (see App. C, Sect. 3.3.1.3. The correct reference is Worthington, S.R.H., 2003[2]. Worthington notes that three approaches are commonly used to model flow in fractured aquifers, and while he does not make a value judgment, he does favor a more complex, more representative approach that uses multiple inputs. However, there are, in this case, insufficient data available to employ the method Worthington suggests.
24)	Appendix C, Page C-34, Table C-9	Evans, et al. 1996 applied a particle tracking model and inverse modeling to get an aniotropic ratio of 10:1 for BCV.	The 10:1 ratio was in fact used in the model presented in Appendix F. This reference has been added to Table C-9. Note that one of the authors of this article actually performed the modeling discussed in Appendix F. Text was also added to Section 3.3.2.1, paragraph 5 to further discuss anisotropy.
25)	Appendix C, Section 3.3.2.2, Page C-35	***"Results of Tracer Tests"*** *"Tracer tests are commonly used in fractured and karstic aquifers because they are strongly anisotropic and flow paths are difficult to determine."* Since > 94% of the discharge/flow is in conduits and conduits are known to connect sinking streams and springs, with lengths sometimes of several tens of kilometers, one would know the possible extent of the flow path if the spring was the base flow spring.	No revision is required. Please see answer to Specific Comment 24 above. The aquifer at the proposed EMDF site is primarily fractured, not karstic, and conduits are unlikely to be present under the site.
26)	Appendix C, Page C-36	*"Both of these types of behavior indicate a high degree of longitudinal dispersion, which is typical of systems in which matrix diffusion is dominant."* The reasons for a high value for longitudinal dispersivity in contaminant or tracer transport is also hydraulic complexity and the nature of the release of the substance.	Agreed. One purpose of the test was to determine if gas tracers would be effective in hydraulically complex fractured rock, i.e., the matrix. Text in paragraph 6 of Appendix C Section 3.3.2.2 has been slightly revised.

[1] 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.
[2] Worthington, S.R.H., 2003[2]. "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

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		"Matrix diffusion retarded tracer movement by uptake in small blind fractures and pores, and maintained high tracer concentrations by diffusing back into the flowing groundwater in fractures over time." Velocities in conduits are known to be rapid (geometric mean = 0.022 m/s, n = 3,077) and therefore mostly turbulent (Worthington et al, 2000a, 2000b). How would matrix diffusion work if flow is turbulent?	This questions presupposes the existence of highly evolved and integrated conduit systems under the proposed EMDF footprint; there is little evidence of such conduit systems in Conasauga units outside of the Maynardville Limestone. The conceptual model for the rock units underlying the EMDF area is that groundwater flows in highly and complexly fractured rock, not conduits, and hence, matrix diffusion is not only possible, but likely.
		"It is not the arrival time, but the peak concentration, that is of interest, since this represents the greatest risk." The determination of an accurate peak concentration is dependent upon sampling frequency to avoid aliasing. Most current sampling done under State, Federal, or any other protocols do not sample often enough, so the values obtained are the minimum that could be passing a monitoring point. If the monitoring location is a well there could be other complications to interpreting the results.	The quoted statement refers to modeling results, not actual sampling. However, the point is taken, and will be considered in designing the site characterization study.
27)	Appendix C, Page C-37	The discussion of the storm-flow zone in the second paragraph implies that this is how recharge works in karst terrane in any climate or landscape. The reference used is for ***"semi-arid karst shrublands...."*** which would not be automatically appropriate for a temperate region like Oak Ridge. There are data from the ORR that refute the general thesis of the storm flow zone that must be cited.	That is not the intended implication; it is rather that storm flow occurs in many environments. Storm-flow is well documented for steep forested slopes in humid climates, and has been documented in many other areas as well. The author of Appendix C is not aware of data that refute the storm-flow thesis for the Oak Ridge Reservation. The text of the 2nd paragraph of Appendix C Section 3.3.3.1.1 has been slightly revised.
28)	Appendix C, Page C-38, Figure C-13	***"Conceptual Model of Groundwater Zones in BCV"*** This figure lists water flux in the storm flow and vadose zone as 90%, estimates of storm flow were obtained from very steeply sloping sites. It is extremely unlikely that 90% of water flux is retained in storm flow or vadose on the moderately sloping portions of the ORR.	Much of the site is steep, and the moderately sloped areas also appear to be unaffected by overland flow. Surface flow occurs rapidly in response to heavy or prolonged precipitation in zero and first order basins. The clayey soils beneath the root zone are of too low permeability to absorb more than a small fraction of storm precipitation. Water balance calculations indicate that most precipitation is lost to stream flow and evapotranspiration. The portion that rapidly enters streams must be due to shallow transport. No revisions have been made.
		Further this figure shows what is referred to as an aquiclude at >500 ft. BGS. Based on the definition of the aquiclude on page C-43. Contaminants are reported from these depths on the ORR (OREIS). Domestic wells emplaced within the Conasauga Group Formations offsite in the area offsite of Melton Valley were reported to be completed at depths that would be within the "aquiclude". The presence of contaminants and the use of this interval for domestic water	Solomon, et al. (1992) note that the saline aquiclude in Melton Valley began with brackish water at about 120 m (~395 ft) and became saline below 180 m (~590 ft). In Bear Creek Valley, brackish water is encountered at about 150 m to 300 m (492 ft – 985 ft) range, but saline water was not encountered. This indicates that the aquiclude is deeper in Bear Creek Valley than in Melton Valley. Note that brackish and saline water is not potable.

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		production suggest that the term aquiclude is inappropriate.	
29)	Appendix C, Section 3.3.3.2.2 Pages C-42 & C-43	**"Intermediate and Deep Aquifer Zones"** This discussion and table C-10 suggests that elevated pH in the deeper briny groundwaters of Oak Ridge are normal. Most deep wells (not affected by contamination) encountering brines in the Valley and Ridge are somewhat acidic not caustic as presented in ESD publication 2863. Elevated pH is unlikely to be a normal condition of groundwater beneath the ORR.	Schreiber (1995)[3] reported that only two of 55 samples of formation waters from 3 shallow wells in the Nolichucky Shale of East Bear Creek Valley exhibited a pH of < 6.0 S.U.; the remaining 53 ranged from a low of 7.8 S.U. to 8.3 S.U. Similarly, Drier, et al. reported a pH range of 7.0 to 9.6 for samples from multiple depths in 3 deep wells in the Conasauga Group near the S-3 Ponds.
30)	Appendix C, Section 3.3.4, Page C-44	***"Groundwater Contaminants"*** According to the Final Report End Use Working Group 1998, chemicals of concern at the integrator plane are uranium, nitrate, boron and fluoride. Nitrate and gross alpha in groundwater exceed legal requirements. Boron and fluoride are not included.	Site Specific Advisory Board Recommendations are advisory, not requirements. Boron and fluoride limits are not remedial action objectives or primary contaminants as identified in the ROD, and are therefore not monitored at the Integration Point (Bear Creek kilometer 9.2). For comparison only, the Safe Drinking Water Act maximum contaminant limit (MCL) for fluoride in drinking water is 4.0 mg/L; the Bear Creek Valley Remedial Investigation reported that fluoride did not exceed 2.0 mg/L in either NT-1 or at the BCK 12.71 sampling point. There is no MCL for boron.
31)	Appendix C, Section 3.4.2.4, Page C-50	***"Tributary Contaminants"*** *"Water in NT-3 currently meets ambient water quality criteria (AWQC)."* Is the referred AWQC, ambient water quality criteria, the State of Tennessee General Water Quality Criteria, listed within the TDEC Water Pollution Control document, General Water Quality Criteria, chapter 1200-04-03?	This does refer to the TDEC ambient water quality criteria. However, the statement was in error. The NT-3 monitoring station had one exceedance for a PCB in 2011. Annualized uranium flux continues to exceed the NT-3 goal of 4.3 kg/yr. The second paragraph of Section 3.4.2.4 has been revised accordingly.
32)	Appendix C, Section 3.6.2, page C-56	***"Aquatic Resources"*** There is considerably more information relating to species in Bear Creek than is presented for NT-2 and NT-3. The ORNL Biological Monitoring and Abatement Program collect annual samples of macroinvertebrates in NT-3; why is this information not presented?	Text in Appendix C, Section 3.6.2, Aquatic Resources has been substantially revised to include biologic monitoring data and interpretations from recent DOE and TDEC reports. A new Section 3.6.3 has been added to discuss recent conditions on NT-3. Additionally, minor updates were made in Sections 3.3.4 Groundwater Contaminants, 3.4.2.4, Tributary Contaminants, and 3.4.3.4, Bear Creek Contaminants to reflect the 2012 Remediation Effectiveness Report that available after the D1 RI/FS was issued.
33)	Appendix F, Section 4.1.1, Page F-16	***"Conceptual Design of Disposal Facility"*** *"The waste layer is assumed to consist of contaminated soil, cement stabilized soil-like materials, cement-solidified waste, and debris (rubble)."*	We agree that geochemical conditions within the cell and along the flow/transport pathway have various impacts on leaching rates and migration of contaminants. However, the impacts are contaminant-specific and geochemical conditions within the waste may either reduce

[3] Schreiber, M. E., 1995. Spatial Variation in Groundwater Chemistry in Fractured Rock: Nolichucky Shale, Oak Ridge, TN. Master's Thesis: University. of Wisconsin-Madison.

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		Cement rubble and related material has the potential to induce a hyper-alkaline plume in groundwater (See http://www.grimsel.com/gts-phase-v/hpf/hpf-introduction). Hyper-alkaline conditions in and of themselves may pose a risk to end receptors, hyper-alkaline conditions may mobilize inorganics within wastes and country rock so as to cause groundwater to exceed drinking water limits. Hyper-alkaline conditions may alter the absorptive capacity of matrix materials so as to enhance contaminant transport. This model does not seem to address the potential for cement waste material emplaced in the waste cell to alter pH of liquids leaching through the waste cell and to alter basic groundwater geochemistry.	or enhance contaminant mobility. Numerous studies have been conducted to derive the relationship of Kd to geochemical conditions (EPA, 1999a, 1999b). Data from EMWMF leachate indicate that its pH is near neutral, at about 7.3 S.U. The waste release model used to support WAC development is based on a partition (Kd) mass release model and an assumed uniform waste source. Wastes consist of contaminated soil, cement stabilized soil-like materials, cement-solidified waste, and concrete and other debris (rubble). Void spaces are typically filled with soils, and the waste mass itself is encased in soils compacted to the required density. Thus, even though the leachate solution from the concrete debris may be alkaline, it will be buffered by the pH of surrounding soil before it starts its migration to the undisturbed vadose zone. It is also expected that the waste zone will not be fully saturated after final cover is placed. Since the waste zone is assumed to be a constant leaching source with fixed leaching characteristics for each contaminant through the duration of the model (>100,000 yr), using a Kd for a neutral pH condition is the most representative approach. Experience with EMWMF operational leachate indicates a consistently near-neutral pH, which supports the approach used in the model. **See changes to text on pp. F-11, F-16, and F-48.**
		The modeling assumptions are not explicitly spelled out, explain what they are.	The model suites used in pWAC development are discussed in Section 3 of Appendix F and a visualization of their interrelationship is presented in Figure F-4. As discussed in the appendix, the HELP model provides water mass input into the waste and out of the cell liner. **No revisions have been made**.
		What assumptions from the various model types overlap and have compound effects?	MODFLOW/MODPATH models predict the groundwater flow field, direction, and velocity. The MT3D model, even though it is a complete fate-transport model, is only used to derive the dilution factor between the well water and leachate into the water table directly beneath the cell caused by advection process (water mixing only in the flow field and applied to all contaminants). All of the other fate-transport processes, such as contaminant specific dispersion, retardation due to absorption, and degradation (radioactive decay), are considered during PATHRAE model application. Therefore, there are no overlap or compound effects from any of the fate-transport processes. As discussed in EMWMF WAC development (Page E-52 of DOE, 1998) and confirmed by this analysis, majority of the water travel time occurs in the vadose zone, and the travel time to surface water through bedrock pathways is very fast. Thus the disposal design cell design is the primary element in attaining

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			long-term environmental isolation of the waste. The natural geochemical properties of the site aquifer play a relatively minor role in reducing potential impacts from contaminant release. **No revisions have been made.**
		What are the assumptions about the waste cell with regards to rapid groundwater flow and transport that should be expected for the terrane beneath the site?	All the fate-transport processes downgradient from the cells in the groundwater zone, such as advection, contaminant specific dispersion, retardation due to absorption, and degradation (radioactive decay), are considered either in the MT3D model or PATHRAE model. As stated in the appendix, different parameters are used as these of vadose zone that leachate properties are used. **No revisions have been made.**
		What is the assumption for leachate far down gradient of the cell?	A steady state flow condition in a constant physiochemical system is assumed for the duration of the modeling period. Geochemical reaction and transport parameters remain constant. This is a generally accepted approach because of the many uncertainties associated with these processes. In this particular application for the EMDF, the impact will be likely minimal as the WAC was developed using the assumption that the worst case leaching scenario started as soon as disposal cell closed. In reality, it will take up to thousands of years before the worst case developed after the cell closure with system function of the cell design.
34)	Appendix F, Section 2.1, Page F-3, Fourth Paragraph	*"Small-scale geologic features, such as fractures and solution features are a major factor in groundwater movement through the formations underlying the BCV."* These features rarely have a major role in groundwater movement because they will only be tributary pathways to major large-scale features. Unfortunately these maybe be missed by drilling, even though the small-scale features may be encountered by drilling.	Studies conducted on Oak Ridge Reservation weathered bedrock zones suggest that small-scale geologic features, such as fractures, joints, bedding planes, and solution features, are in the primary pathways for groundwater movement through the in the weathered and competent bedrock. These features are the only void spaces available that are widely distributed, sufficiently open, and interconnected to accommodate ground water flow. A sentence has been added to Section 2.1, paragraph 4, to make this distinction more clearly. We do agree that large scale features, such as a major fracture, karst zone, or a fault zone, will impact or control groundwater flow if they are present in the area. Karst-like conditions, while not present under the proposed EMDF site, do exist in the Maynardville Limestone on the floor of Bear Creek Valley and together with Bear Creek, provide the exit path for waters in the basin. However fractures, bedding planes, and to a lesser extent, conduits carry the majority of ground water flow in and near the proposed EMDF footprint. **No revisions have been made.**
35)	Appendix F, Page F-5, First Paragraph	The majority of flow in only the upper 100 ft of bedrock is not supported by data. The problem is that if enough deeper wells were not drilled then it is flawed logic that leads to this conclusion, especially when conduits are difficult to intercept when drilling. For example, there are	Numerous studies conducted on the ORR have indicated that the majority of groundwater flow occurs in relatively shallow saturated zone of bedrock. These studies have included water balance analysis, aquifer tests, core-hole geophysical observations, core description of fracture and porosity distribution with depth, ground water geochemistry, and

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		many deep wells in every valley on the ORR that exhibit meteoric water signatures and often contaminants. Would this not be evidence that probably a considerable amount of groundwater circulates much deeper than 100 ft below the land surface? The true nature of groundwater circulation at depth should be revisited, because it has been inadequately addressed in this document and others. The potential depth of circulation in the carbonates could well in excess of 400m or even deeper (Brahana and Bradley, 1985). For a basin length of 12 kilometers, (approximately from S3 ponds to the Clinch River) the calculated depth of circulation is 170 m below the present water table, circulation along the whole length of the projected basin (~80 km). This is far deeper than the river, which has been claimed to be a barrier to groundwater flow. The 170 m depth is not extreme, in fact, it was predicted in early and recent models constructed in Bear Creek Valley and such a circulation depth has been openly discussed in other documents. The fact that deep circulation has been predicted and documented on the ORR (Nativ et al., 1997) should mean that caution should be exercised when dealing with eventualities involving accidental waste releases. This would be of particular concern in Bear Creek Valley because it is known that there are sections of Bear Creek that sink into the ground downstream and down gradient of the proposed new waste cell. As of yet there has not been a quantitative assessment made of how much groundwater, tracers, or contaminants flow in shallow, intermediate or deep groundwater zones (deeper than 120 m, 400 ft) as determined by Bailey and Lee (1991) from both potentiometric and geochemical data. It should be noted that the hydraulic conductivity value used in the digital model constructed by Bailey and Lee (1991) of 3E-10 m/s is extremely low when it is known that contamination and evidence of meteoric water circulation is documented at greater depths (Nativ et al., 1997). Evidence of deep flow in the Cambrian and Ordovician carbonates, that extend across the mid-continent and that underlie the ORR is well known and well documented (Graven et al., 1993; Brahana and Bradley, 1985; Brahana et al., 1986).	observed behavior of contaminant plumes. Some of these conclusions are summarized below: As Brahana and Bradley (1985, p. 2) point out, “The Knox Group in the Valley and Ridge of East Tennessee is . . . complexly folded and faulted and hydrologically distinct from the Knox in the remainder of the State.” The structure of the valley and Ridge thus limits development of a regional aquifer with regional flow. Regional flow that resulted in MVT-type ore deposits Evidence that the majority of ground water flow occurs in the shallow zone is discussed in Appendix C and summarized below: • Surface water budget analysis included the USGS study for the Bear Creek Valley (Robinson, J.A. and Johnson, G.C. 1995) and site specific studies (DOE, 1997; Shevnell, 1994; Dreier, et al. 1993; Solomon, 1992; Moore and Toran, 1992; Bailey and Lee, 1991; Haase, 1991; Haase, et al., 1987) that concluded that most of the surface water and ground water interactions occur within the shallow intervals. Appendix C discusses this in greater detail. • Bear Creek is a shallow stream exhibiting seasonally variable flow, reflecting the interaction between surface water and ground water flow. The existence of short gaining and losing segments suggests active interaction between surface water and shallow groundwater. Shevnell, 1994 showed that the Maynardville Limestone underlying Bear Creek responds rapidly to precipitation events. This is further discussed in Appendix C. • The majority of the contaminant plumes in east Bear Creek Valley are within relatively shallow (<500 ft) intervals (S3 and BG/BY plumes) and have migrated in ground water a relatively short distance from the sources. SAIC (1997) identified nitrate contaminants from the S-3 Ponds to depths of approximately 500 ft below grade in EBCV. The S-3 plume surfaces to the lower reaches of NT-3 and Bear Creek, and does not appear to extend the length of Bear Creek Valley. • Several studies conducted on the ORR found that fracture density, aperture, and porosity decrease with depth, with concomitant reductions in bulk permeability and flow. (Solomon, et al., 1992; Moore and Young, 1992). Numerous aquifer tests demonstrate that hydraulic conductivity is highest in the shallow zone and decreases with depth (Moore and Young, 1992); see Appendix C. Any number of studies from many different aquifers and petroleum

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		In several locations near the proposed site there are losing reaches of Bear Creek. Most models constructed in the past for Bear Creek Valley assumed that groundwater could circulate at various depths below the current water table. These depths were assumed from early investigations. This is a reasonable assumption and follows the documented nature of flow in carbonates worldwide (Worthington, 1991; 2004). The losing reaches of Bear Creek recharge groundwater and thus recharge regional flow paths. Davies et al. (2012) show that regional groundwater flow in the Valley and Ridge province is related to brine migration and Mississippi Valley type ore emplacement between 380 and 100 Ma, across the US Midcontinent as originally conceived and measured by Graven et al., (1993) and Leech at al., (2001). The issue of regional migration of groundwater and contaminants from the ORR along regional pathways has not been addressed.	reservoirs lend support to these conclusions. • The shallow zone (<100 ft. below the water table) is characterized by Ca, Mg-HCO3 geochemistry, indicating strong meteoritic influence. Water chemistry data from the deeper zone (~800 ft) is dominantly saline (NaCl), an indication of long residence time, A poorly defined zone of NaCl – $NaHCO_3$ ground water has been documented in EBCV (Bailey and Lee, 1991; Haase, 1991); this may be the result of diffusive mixing. Please see Appendix C for further discussion. The shallow ground water flow regime within the east Bear Creek watershed is confined by the surrounding ridges, and is not apparently part of a reservation-wide regional flow system. A potential contaminant plume exiting the EMDF is not expected to extend any great distance before it discharges into Maynardville Limestone conduits and Bear Creek. The conclusion is supported by the geometries of contaminant plumes from those from Bear Creek Burial Grounds, the S3 Ponds, and the BY/BG. Further, the Bear Creek passes through a water gap in Pine Ridge, separating the lower basin from the upper basin. The basin length in the upper Bear Creek catchment is about 8.3 km, and based on Worthington (1991), the maximum flow depth would be estimated at about 150 m, which is consonant with the depth of contamination in the S-3 nitrate plume in the Maynardville limestone. However, using Worthington's (1991, Eq. 7.4) approach to calculating mean flow depth, $D_m – 0.061(L_x \sin \Theta + 0{,}034 L_x \sin \Phi)^{0.87}$, where $\Theta = 45°$ (dip), $\Phi = 60°$ (angle of flow vector parallel to NT-3 relative to strike), and Lx = 0.91 km (flow length from top of Pine Ridge to confluence of NT-3 and Bear Creek), the mean flow depth is about 43 m (~140 ft) for the EMDF area. Regarding MVT ores, please see the response to Comment 41B, below.
36)	Appendix F, Page F-48, Table F-5	The table contains values that require some discussion.	See responses below.
		Groundwater zone: horizontal velocity, the value of 14 ft/ y (0.012 m/y) is far too slow for the terrane underlying the proposed facility. The geometric mean groundwater velocity in conduits in carbonates is 1,700 m/day (Worthington et al., 2000a; 2000b). In general between wells, most of which do not often intersect conduits traced velocities are in the range of 100 - 500 m/day. The	Reasoning from the general to the specific does not provide accuracy; at the EMDF site, the carbonates are shaley and do not contain extensive conduit systems. . The values provided in the table are the average flow velocity for an assumed aquifer system in which all connected void spaces, including matrix pores, fractures, and conduits, contribute to steady-state flow. It does not represent fracture flow only, where high ground water velocities may exist during a storm event but which

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		reviewer understands the modeling limitations with regards to MODFLOW not being compatible with settings with high velocities and aspects of turbulent flow that should be expected even in small-sized openings. Knowledge of the limits of such models should eliminate their choice early on in the design process.	contributes a relatively small amount of contaminant mass movement on an annual basis. High velocity flow during storm event is generally short in duration and extremely diluted in terms of contaminant concentration. To calculate a risk, all pathways and the total available contaminant mass have to be considered. The final footprint of a contaminant plume is determined by groundwater interacting with all aquifer rocks and conditions that host ground water storage and flow. Use of an average flow velocity for the whole aquifer matrix in the model actually provides the most conservative risk estimation in term of peak contaminant concentrations. The travel time within the aquifer zone is much shorter than the travel time in the unsaturated zone from the bottom of the waste to the water table. Also, since the risk is based on peak concentrations, rather than travel time within the ground water zone, small changes in travel time will have minimal impact on overall risk.
		Migration of deep brines and groundwater related to the formation of MVT (Mississippi Valley Type) ore deposits in early Paleozoic sediments (mostly carbonates) over great distances across the mid continent is a concept that has been discussed for decades and is well accepted (Graven et al., 1993). Modeling and dating show that the deep flow system was in place before the extensive folding and faulting in the Valley and Ridge province. This would mean that any recharge or water associated with the waste cell that was lost to the ground could enter this regionally large flow system.	MVT ore bodies that formed as the result of large deep regional ground water flows that occurred after the tectonic deformations that formed the Appalachian Mountains. According to Garven (1993), these flow were driven by gravity from distant highlands, such that velocities declined to essentially zero as topographic relief in the source areas was reduced. These flow systems were hypothesized as occurring at depths of several kilometers, well below the aquifers of the ORR. Further, the structural faulting and folding of the Valley and Ridge Province interrupts possible regional flow paths that might once have been present. This migration route is not credible. Further, it is doubtful that sufficient contaminant mass could reach and be transported by any very deep regional aquifer without dilution to undetectable levels. No revisions have been made.
37)	Appendix G, Section 4.1, Page G-8	***"On-Site Disposal Alternative Cost-Estimate Assumptions"*** *"The long-term monitoring and maintenance for the EMDF would continue after closure of the facility. A perpetual care fee of $1M per year for each year of operation of the EMDF would be paid into an escrow account to be used for long-term monitoring and maintenance."* The state has not agreed to the use of a perpetual care fund for long term maintenance post closure of the EMDF.	Consistent with the agreement reached with the State of Tennessee regarding perpetual care and surveillance and maintenance of the EMWMF, DOE anticipates some residual annual costs associated with long-term monitoring and maintenance similar to those agreed upon for EMWMF. A perpetual care fee of $1M per year of operation is accounted for in the EMDF cost estimate to cover the expected costs of long-term monitoring and maintenance. However, no assumptions have been made to address the performer of those actions, since that is beyond the scope of this document.