Oak Ridge Reservation

Annual Site Environmental Report

2022

DOE-SC-OSO/RM-2023-01

Oak Ridge Reservation

Annual Site Environmental Report 2022

Cover Image

Sarah E. Darling,
Oak Ridge National Laboratory

Design

Professional Project Services, Inc.

DOE-SC-OSO/RM-2023-01
September 2023

Oak Ridge Reservation Annual Site Environmental Report 2022

US Department of Energy project manager and Oak Ridge Reservation coordinator: Katatra Vasquez

Technical coordinators:

Y-12 National Security Complex: Paula Roddy, Chloe Hutchison

Oak Ridge National Laboratory: Joan Hughes, Walt Doty

East Tennessee Technology Park: Mike Coffey, Roger Petrie

Project director: James J. Rochelle
Project coordinator: Kimberly L. Davis, PhD
Integrating editor: Teresa J. Thompson
Technical support: Ellen J. Wald

Prepared by the following for the US Department of Energy:

UT-Battelle, LLC
under Contract DE-AC05-00OR22725

Consolidated Nuclear Security, LLC
under Contract DE-NA0001942

United Cleanup Oak Ridge LLC (UCOR)
under Contract DE-SC-0004645

Professional Project Services, Inc.
under Contract GS-00F-112CA/89243118FSC400042

This report is available online at https://doeic.science.energy.gov/aser/aser2022/index.html.

DOE contact: *If you have questions or comments about the ASER documents, or wish to provide review comments or suggestions for improvement, please complete the survey at the bottom of the web page at the link above, or contact Katatra Vasquez, DOE/SC, at katatra.vasquez@science.doe.gov.*

Disclaimer

Contents

Figures xii
Tables xix
Appendices xxiii
Acronyms and Abbreviations xxiv
Units of Measure and Conversion Factors xxx
Acknowledgments xxxii
Executive Summary xxxiii

1 Introduction to the Oak Ridge Reservation 1-1

1.1. Background 1-2
1.2. History of the Area around the Oak Ridge Reservation 1-2
1.3. Location and Description 1-3
1.3.1. Population 1-3
1.3.2. Climate 1-5
1.3.3. Regional Air Quality 1-5
1.3.4. Surface Water 1-5
1.3.5. Geological Setting 1-6
1.3.6. Natural, Cultural, and Historic Resources 1-7
1.3.6.1. Wetlands 1-7
1.3.6.2. Wildlife and Endangered Species 1-7
1.3.6.3. Threatened and Endangered Plants 1-14
1.3.6.4. Historical and Cultural Resouces 1-15
1.4. Oak Ridge Sites 1-16
1.4.1. Oak Ridge National Laboratory 1-17
1.4.2. Y-12 National Security Complex 1-18
1.4.3. East Tennessee Technology Park 1-20
1.4.4. Environmental Management Waste Management Facility 1-22
1.4.5. Oak Ridge Environmental Research Park 1-23
1.4.6. Oak Ridge Institute for Science and Education 1-24
1.4.7. National Nuclear Security Administration Office of Secure Transportation, Agent Operations Eastern Command 1-25
1.4.8. Transuranic Waste Processing Center 1-25
1.5. References 1-26

2 Compliance Summary and Community Involvement 2-1
2.1. Laws and Regulations 2-1
2.2. External Oversight and Assessments 2-1
2.3. Reporting of Oak Ridge Reservation Spills and Releases 2-2
2.4. Notices of Violations and Penalties 2-2
2.5. Community Involvement and Resources 2-2
2.5.1. Environmental Justice 2-3
2.5.2. Public Comments Solicited 2-3
2.5.3. Oak Ridge Site Specific Advisory Board 2-3
2.5.4. DOE Information Center 2-3
2.5.5. Other Resources 2-4
2.6. References 2-11
3 East Tennessee Technology Park 3-1
3.1. Description of Site and Operations 3-2
3.2. Environmental Management System 3-4
3.2.1. Sustainable Environmental Stewardship 3-5
3.2.1.1. Greenhouse Gas Emissions Reduction 3-5
3.2.1.2. Climate-ready Operations and Infrastructure 3-7
3.2.1.3. Education and Partnerships 3-8
3.2.2. Environmental Compliance 3-9
3.2.3. Environmental Aspects/Impacts 3-9
3.2.4. Environmental Performance Objectives and Targets 3-9
3.2.5. Implementation and Operation 3-10
3.2.6. Pollution Prevention/Waste Minimization/Release of Property 3-10
3.2.7. Competence, Training, and Awareness 3-12
3.2.8. Communication 3-12
3.2.9. Benefits and Successes of Environmental Management System Implementation 3-12
3.2.10. Management Review 3-12
3.3. Compliance Programs and Status 3-12
3.3.1. Environmental Permits Compliance Status 3-13
3.3.2. National Environmental Policy Act 3-13
3.3.3. National Historic Preservation Act 3-13
3.3.3.1. NHPA Compliance at ETTP 3-15
3.3.3.2. NHPA Compliance Throughout the ORR 3-15

3.3.4. Clean Air Act Compliance Status ... 3-16

3.3.5. Clean Water Act Compliance Status ... 3-16

3.3.6. National Pollutant Discharge Elimination System Permit Noncompliances ... 3-16

3.3.7. Safe Drinking Water Act Compliance Status ... 3-16

3.3.8. Resource Conservation and Recovery Act Compliance Status ... 3-16

3.3.9. Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status ... 3-17

3.3.10. East Tennessee Technology Park RCRA-CERCLA Coordination ... 3-17

3.3.11. Toxic Substances Control Act (TSCA) Compliance Status—Polychlorinated Biphenyls ... 3-17

3.3.12. Emergency Planning and Community Right-to-Know Act Compliance Status ... 3-18

3.3.12.1. Chemical Inventories (EPCRA Section 312) ... 3-18

3.3.12.2. Toxic Chemical Release Reporting (EPCRA Section 313) ... 3-18

3.3.12.3. Environmental Justice ... 3-18

3.4. Quality Assurance Program ... 3-19

3.5. Air Quality Program ... 3-20

3.5.1. Construction and Operating Permits ... 3-20

3.5.1.1. Generally Applicable Permit Requirements ... 3-20

3.5.1.2. Fugitive Particulate Emissions ... 3-21

3.5.1.3. Radionuclide National Emission Standards for Hazardous Air Pollutants ... 3-21

3.5.1.4. Quality Assurance ... 3-22

3.5.1.5. Greenhouse Gas Emissions ... 3-22

3.5.1.6. Source-Specific Criteria Pollutants ... 3-24

3.5.1.7. Hazardous Air Pollutants (Nonradionuclide) ... 3-26

3.5.2. Ambient Air ... 3-26

3.6. Water Quality Program ... 3-29

3.6.1. National Pollutant Discharge Elimination System Permit Monitoring ... 3-29

3.6.2. Storm Water Pollution Prevention Program ... 3-29

3.6.2.1. Radiologic Monitoring of Storm Water ... 3-29

3.6.2.2. Demolition and Remedial Action Monitoring of Storm Water ... 3-30

3.6.2.3. K-25 Building ^{99}Tc Contaminated Soil Remedial Action Monitoring ... 3-30

3.6.2.4. K-1203 Sewage Treatment Plant Post-Demolition and Remedial Action Monitoring ... 3-30

3.6.2.5. EU-21 Remedial Action Monitoring ... 3-30

3.6.2.6. Monitoring of Outfalls Designated in the CERCLA Phased Construction Completion Reports ... 3-31

3.6.2.7. Legacy Mercury Contamination Monitoring of Storm Water 3-31
3.6.2.8. Investigative Monitoring of Storm Water 3-34
3.6.2.9. Chromium Water Treatment System and Plume Monitoring 3-34
3.6.3. Surface Water Monitoring 3-36
3.6.4. Groundwater Monitoring at ETTP 3-39
3.7. Biological Monitoring 3-48
3.7.1. Task 1: Bioaccumulation Monitoring 3-48
3.7.1.1. Mitchell Branch 3-51
3.7.1.2. 1007-P1 Pond 3-54
3.7.1.3. K-901-A Pond 3-61
3.7.1.4. K-720 Slough 3-62
3.7.2. Task 2: Instream Benthic Macroinvertebrate Communities 3-64
3.7.2.1. Benthic Macroinvertebrates 3-64
3.7.2.2. Mitchell Branch–ORNL and TDEC Protocols 3-65
3.7.2.3. Comparison between Mitchell Branch and Other Reference Sites on ORR 3-71
3.7.3. Task 3: Fish Community 3-74
3.8. Environmental Management and Waste Management Activities 3-78
3.8.1. Waste Management Activities 3-78
3.8.2. Environmental Remediation Activities 3-81
3.8.2.1. Soil Remediation 3-81
3.8.2.2. Groundwater Protection 3-81
3.8.3. Reindustrialization 3-82
3.9. References 3-82

4 The Y-12 National Security Complex 4-1

4.1. Description of Site and Operations 4-1
4.1.1. Mission 4-1
4.1.2. Modernization 4-2
4.1.3. Production Operations 4-3
4.1.4. Support Facilities 4-4
4.1.5. Excess Facility Disposition 4-5
4.2. Environmental Management System 4-5
4.2.1. Integrating with Integrated Safety Management System 4-6
4.2.2. Policy 4-6
4.2.3. Planning 4-6

4.2.3.1. Y-12 Environmental Aspects 4-6
4.2.3.2. Legal and Other Requirements 4-8
4.2.3.3. Objectives, Targets, and Environmental Action Plans 4-8
4.2.3.4. Programs 4-8
4.2.4. Implementing and Operating 4-9
4.2.4.1. Roles, Responsibility, and Authority 4-9
4.2.4.2. Community and Community Involvement 4-10
4.2.4.3. Environmental Justice 4-10
4.2.4.4. Emergency Preparedness and Response 4-11
4.2.5. Checking 4-11
4.2.5.1. Monitoring and Measuring 4-11
4.2.5.2. Environmental Management System Assessments 4-11
4.2.6. Performance 4-11
4.2.6.1. Environmental Management System Objectives and Targets 4-12
4.2.6.2. Sustainability and Stewardship 4-12
4.2.6.3. Energy Management 4-15
4.2.6.4. Sustainable Goals and Performance 4-16
4.2.6.5. Water Management 4-19
4.2.6.6. Fleet Management 4-20
4.2.6.7. Electronic Stewardship 4-21
4.2.6.8. Greenhouse Gases 4-21
4.2.6.9. Storm Water Management and the Energy Independence and Security Act of 2007 4-21
4.3. Compliance Status 4-22
4.3.1. Environmental Permits 4-22
4.3.2. National Environmental Policy Act 4-26
4.3.3. National Historic Preservation Act 4-27
4.3.4. Clean Air Compliance Status 4-28
4.3.5. Clean Water Act Compliance Status 4-28
4.3.6. Safe Drinking Water Act Compliance Status 4-28
4.3.7. Resource Conservation and Recovery Act Compliance Status 4-29
4.3.7.1. Resource Conservation and Recovery Act Underground Storage Tanks 4-30
4.3.7.2. Resource Conservation and Recovery Act Subtitle D Solid Waste 4-30
4.3.8. Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination 4-30

4.3.9. Toxic Substances Control Act Compliance Status 4-30
4.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status 4-30
4.3.11. Spill Prevention, Control, and Countermeasures 4-31
4.3.12. Unplanned Releases 4-32
4.3.13. Audits and Oversight 4-32
4.3.14. Radiological Release of Property 4-33
4.3.14.1. Property Potentially Contaminated on the Surface 4-34
4.3.14.2. Property Potentially Contaminated in Volume (Volumetric Contamination) 4-34
4.3.14.3. Process Knowledge 4-36
4.4. Air Quality Program 4-38
4.4.1. Construction and Operating Permits 4-38
4.4.1.1. Generally Applicable Permit Requirements 4-39
4.4.1.2. National Emission Standards for Hazardous Air Pollutants for Radionuclides 4-40
4.4.1.3. Quality Assurance 4-41
4.4.1.4. Source-Specific Criteria Pollutants 4-42
4.4.1.5. Mandatory Reporting of Greenhouse Gas Emissions Under 40 CFR 98 4-42
4.4.1.6. Hazardous Air Pollutants (Nonradiological) 4-43
4.4.2. Ambient Air 4-45
4.4.2.1. Mercury 4-45
4.4.2.2. Quality Control 4-47
4.4.2.3. Ambient Air Monitoring Complementary to Y-12 Ambient Air Monitoring 4-49
4.5. Water Quality Program 4-50
4.5.1. National Pollutant Discharge Elimination System Permit and Compliance Monitoring 4-50
4.5.2. Radiological Monitoring Plan and Results 4-56
4.5.3. Storm Water Pollution Prevention 4-59
4.5.4. Ambient Surface Water Quality 4-60
4.5.5. Industrial Wastewater Discharge Permit 4-61
4.5.6. Quality Assurance and Quality Control 4-63
4.5.7. Biomonitoring Program 4-63
4.5.8. Biological Monitoring and Abatement Program 4-65
4.5.8.1. Bioaccumulation Studies 4-67
4.5.8.2. Benthic Invertebrate Surveys 4-69

4.5.8.3. Fish Community Monitoring 4-72
4.6. Groundwater at the Y-12 National Security Complex 4-73
4.6.1. Hydrogeologic Setting 4-74
4.6.2. Groundwater Monitoring 4-76
4.6.3. Groundwater Quality 4-78
4.6.3.1. Upper East Fork Poplar Creek Hydrogeologic Regime 4-79
4.6.3.2. Bear Creek Hydrogeologic Regime 4-85
4.6.3.3. Chestnut Ridge Hydrogeologic Regime 4-90
4.6.4. Emerging Contaminants 4-91
4.7. Quality Assurance Program 4-92
4.8. Environmental Management and Waste Management Activities 4-94
4.8.1. Environmental Management Activities 4-95
4.8.2. Waste Management Activities 4-97
4.8.2.1. Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal 4-97
4.8.2.2. Solid Waste Disposal 4-97
4.8.2.3. Wastewater Treatment 4-97
4.9. References 4-98

5 Oak Ridge National Laboratory 5-1

5.1. Description of Site, Missions, and Operations 5-2
5.2. Environmental Management Systems 5-5
5.2.1. UT-Battelle Environmental Management System 5-5
5.2.1.1. Integration with the Integrated Safety Management System 5-6
5.2.1.2. UT-Battelle Environmental Policy for ORNL 5-6
5.2.1.3. Environmental Management System Planning 5-6
5.2.1.4. Site Sustainability 5-7
5.2.1.5. Storm Water Management and the Energy Independence and Security Act of 2007 5-19
5.2.1.6. Emergency Preparedness and Response 5-19
5.2.1.7. Environmental Management System Performance Evaluation 5-20
5.2.2. Environmental Management System for the Transuranic Waste Processing Center 5-20
5.2.3. Environmental Management System for Isotek 5-21
5.3. Compliance Programs and Status 5-22
5.3.1. Environmental Permits 5-22

5.3.2. National Environmental Policy Act/National Historic Preservation Act 5-25
5.3.3. Clean Air Act Compliance Status 5-26
5.3.4. Clean Water Act Compliance Status 5-26
5.3.5. Safe Drinking Water Act Compliance Status 5-28
5.3.6. Resource Conservation and Recovery Act Compliance Status 5-28
5.3.7. ORNL RCRA-CERCLA Coordination 5-30
5.3.7.1. RCRA Underground Storage Tanks 5-30
5.3.8. CERCLA Compliance Status 5-30
5.3.9. Toxic Substances Control Act Compliance Status 5-31
5.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status 5-31
5.3.10.1. Safety Data Sheet/Chemical Inventory (Section 312) 5-32
5.3.10.2. Toxic Chemical Release Reporting (EPCRA Section 313) 5-32
5.3.11. US Department of Agriculture/Tennessee Department of Agriculture 5-32
5.3.12. Wetlands 5-32
5.3.13. Radiological Clearance of Property at ORNL 5-33
5.3.13.1. Graded Approach to Evaluate Material and Equipment for Release 5-33
5.3.13.2. Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples 5-34
5.4. Air Quality Program 5-35
5.4.1. Construction and Operating Permits 5-35
5.4.2. National Emission Standards for Hazardous Air Pollutants—Asbestos 5-35
5.4.3. Radiological Airborne Effluent Monitoring 5-36
5.4.3.1. Sample Collection and Analytical Procedure 5-36
5.4.3.2. Results 5-39
5.4.4. Stratospheric Ozone Protection and Hydrofluorocarbon Phasedown 5-39
5.4.5. Ambient Air 5-40
5.5. ORNL Water Quality Program 5-41
5.5.1. Treatment Facility Discharges 5-42
5.5.2. Residual Bromine and Chlorine Monitoring 5-42
5.5.2.1. Monitoring Results and Corrective Actions 5-43
5.5.2.2. Cooling Tower Discharge Outfalls 5-45
5.5.3. Radiological Monitoring 5-45
5.5.4. Mercury in the White Oak Creek Watershed 5-51
5.5.4.1. Mercury in Ambient Water 5-53
5.5.4.2. Water Quality Protection Plan Mercury Investigation 5-55

5.5.4.3. Legacy Outfall Source Investigation ... 5-58
5.5.4.4. Baseline Preconstruction Investigation of 207 and 304 Storm Catch Basins ... 5-61
5.5.5. Storm Water Surveillances and Construction Activities ... 5-61
5.5.6. Biological Monitoring ... 5-61
5.5.6.1. Bioaccumulation Studies ... 5-62
5.5.6.2. Benthic Macroinvertebrate Communities ... 5-64
5.5.6.3. Fish Communities ... 5-72
5.5.7. Polychlorinated Biphenyls in the White Oak Creek Watershed ... 5-73
5.5.8. Oil Pollution Prevention ... 5-75
5.5.9. Surface Water Surveillance Monitoring ... 5-75
5.5.10. Carbon Fiber Technology Facility Wastewater Monitoring ... 5-76
5.6. ORNL Groundwater Monitoring Program ... 5-79
5.6.1. Summary of US Department of Energy Office of Environmental Management Groundwater Monitoring ... 5-79
5.6.1.1. Bethel Valley ... 5-79
5.6.1.2. Melton Valley ... 5-81
5.6.2. DOE Office of Science Groundwater Surveillance Monitoring ... 5-81
5.6.2.1. Exit Pathway Monitoring ... 5-82
5.6.2.2. Active Sites Monitoring—High Flux Isotope Reactor ... 5-86
5.6.2.3. Active-Sites Monitoring—Spallation Neutron Source ... 5-87
5.6.2.4. Emerging Contaminant Assessment—Potential for Per- and Polyfluoroalkyl Substances in ORNL Area Groundwater ... 5-91
5.7. Quality Assurance Program ... 5-91
5.7.1. Work/Project Planning and Control ... 5-92
5.7.2. Personnel Training and Qualifications ... 5-92
5.7.3. Equipment and Instrumentation ... 5-93
5.7.3.1. Calibration ... 5-93
5.7.3.2. Standardization ... 5-93
5.7.3.3. Visual Inspection, Housekeeping, and Grounds Maintenance ... 5-93
5.7.4. Assessment ... 5-93
5.7.5. Analytical Quality Assurance ... 5-94
5.7.6. Data Management and Reporting ... 5-95
5.7.7. Records Management ... 5-95
5.8. Environmental Management and Waste Management Activities at ORNL ... 5-96
5.8.1. Wastewater Treatment ... 5-96

5.8.2. Newly Generated Waste Management 5-96

5.8.3. Transuranic Waste Processing Center 5-96

5.9. References 5-96

6 Oak Ridge Reservation Environmental Monitoring Program 6-1

6.1. Meteorological Monitoring 6-1

6.1.1. Data Collection and Analysis 6-1

6.1.2. Results 6-4

6.2. Ambient Air Monitoring 6-4

6.2.1. Data Collection and Analysis 6-5

6.2.2. Results 6-6

6.3. External Gamma Radiation Monitoring 6-7

6.3.1. Data Collection and Analysis 6-7

6.3.2. Results 6-7

6.4. Surface Water Monitoring 6-9

6.4.1. Data Collection and Analysis 6-9

6.4.2. Results 6-9

6.5. Groundwater Monitoring 6-11

6.5.1. Off-Site Groundwater Assessment 6-11

6.5.2. Regional and Site-Scale Flow Model 6-11

6.6. Food 6-12

6.6.1. Hay 6-12

6.6.1.1. Data Collection and Analysis 6-12

6.6.1.2. Results 6-12

6.6.2. Vegetables 6-12

6.6.2.1. Data Collection and Analysis 6-13

6.6.2.2. Results 6-13

6.6.3. Milk 6-13

6.6.4. Fish 6-13

6.6.4.1. Data Collection and Analysis 6-13

6.6.4.2. Results 6-15

6.6.5. White-Tailed Deer 6-15

6.6.6. Waterfowl 6-15

6.6.6.1. Data Collection and Analysis 6-15

6.6.6.2. Results 6-16

6.6.7. Wild Turkey 6-16

6.7. Habitat Quality Improvement 6-16
6.7.1. Invasive Plant Management. 6-16
6.7.2. Wetlands 6-19
6.7.3. Special Projects 6-19
6.8. Fire Protection Management and Planning 6-20
6.9. Quality Assurance 6-23
6.10. References 6-23

7 Dose 7-1

7.1. Radiation Dose 7-2
7.1.1. Terminology 7-2
7.1.2. Methods of Evaluation 7-2
7.1.2.1. Airborne Radionuclides 7-2
7.1.2.2. Waterborne Radionuclides 7-8
7.1.2.3. Radionuclides in Food 7-13
7.1.2.4. Direct Radiation 7-16
7.1.3. Current-Year Summary 7-16
7.1.4. Five-Year Trends 7-16
7.1.5. Doses to Aquatic and Terrestrial Biota 7-17
7.1.5.1. Aquatic Biota 7-17
7.1.5.2. Terrestrial Biota 7-19
7.2. Chemical Dose 7-20
7.2.1. Drinking Water Consumption 7-20
7.2.1.1. Surface Water 7-20
7.2.1.2. Groundwater 7-21
7.2.2. Fish Consumption 7-22
7.3. References 7-23

Figures

Figure *Page*

1 Introduction to the Oak Ridge Reservation

1.1. Location of the Oak Ridge Reservation in Tennessee 1-4

1.2. Map of the Oak Ridge Reservation........ 1-4

1.3. Location of Oak Ridge Reservation wetlands........ 1-8

1.4. American woodcock fledgling on ORR........ 1-12

1.5. Bald eagle photographed on ORR........ 1-13

1.6. Purple gallinule caught on a trail surveillance camera at ETTP in 2017 1-13

1.7. Aerial view of the Oak Ridge National Laboratory........ 1-18

1.8. Aerial view of the Y-12 National Security Complex 1-20

1.9. Aerial view of East Tennessee Technology Park 1-22

1.10. Aerial view of the Environmental Management Waste Management Facility........ 1-23

1.11. Location of the Oak Ridge National Environmental Research Park 1-24

1.12. Transuranic Waste Processing Center 1-26

3 East Tennessee Technology Park

3.1. The K-25 Site in 1946 3-3

3.2. East Tennessee Technology Park since the start of decontamination and decommissioning activities in 1991 3-3

3.3. East Tennessee Technology Park in 2022, showing progress in reindustrialization........ 3-4

3.4. Oak Ridge Powerhouse Six Solar Farm........ 3-5

3.5. Pollution prevention recycling activities related to solid waste reduction at ETTP in FY 2022........ 3-7

3.6. ETTP NPDES permit noncompliances since 2012........ 3-13

3.7. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history 3-21

3.8. East Tennessee Technology Park stationary source greenhouse gas emissions tracking history........ 3-23

3.9. East Tennessee Technology Park greenhouse gas annual emissions (Scopes 1 and 2, including industrial landfills at Y-12)........ 3-25

3.10. Fiscal year 2022 East Tennessee Technology Park greenhouse gas emissions by scope........ 3-25

3.11. East Tennessee Technology Park ambient air monitoring station 3-27

3.12. East Tennessee Technology Park ambient air monitoring station locations 3-28

3.13. Storm water outfall monitoring 3-29

3.14. Mercury concentrations at Outfalls 180 and 190, and the K-1700 Weir 3-33

3.15. Mercury concentrations at Outfall 05A/05A-2 3-33

3.16. The Chromium Water Treatment System 3-35

3.17. Total chromium sample results for the chromium collection system 3-35

3.18. Hexavalent chromium sample results for the chromium collection system 3-36

3.19. Surface water surveillance monitoring 3-36

3.20. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations 3-37

3.21. Annual average percentage of derived concentration standards at surface water monitoring locations, 2022 3-38

3.22. Trichloroethene concentrations in Mitchell Branch 3-40

3.23. Total chromium concentrations in Mitchell Branch 3-40

3.24. East Tennessee Technology Park volatile organic compound and ^{99}Tc plumes 3-43

3.25. Water bodies at the East Tennessee Technology Park 3-49

3.26. Major storm water outfalls and biological monitoring locations on Mitchell Branch 3-50

3.27. Mean total PCB (Top: µg/g, wet wt; 1993–2022) and mercury (Bottom: µg/g wet wt; 2009–2022) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch 3-52

3.28. Total (top panel) and methylmercury (bottom panel) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2022) 3-53

3.29. Mean PCB (top panel) and mercury (bottom panel) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2), 1989–2022 3-55

3.30. Mean aqueous total PCB concentrations, total suspended solids, and vegetation cover in the K-1007-P1 Pond, 2007–2022 3-56

3.31. Mean total PCB concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2022 3-57

3.32. Mean PCB concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2022 3-58

3.33. Mean (+1 standard error) total PCB concentrations (µg/g, wet wt) in whole body fish from K1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2022 3-59

3.34. Mean total PCB concentrations in largemouth bass from the K-901-A Pond and the K-720 Slough ... 3-61

3.35. Mean total PCB (µg/g, wet wt; 1993–2022) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4-week period ... 3-62

3.36. Mean total PCB (µg/g, wet wt; 2009–2022) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough ... 3-63

3.37. Collecting an invertebrate sample using Oak Ridge National Laboratory Biological Monitoring and Abatement Program protocols ... 3-64

3.38. Sampling for benthic macroinvertebrates with TDEC protocols ... 3-64

3.39. Mean (± 95 percent confidence interval) total taxonomic richness (top) and richness of the pollution-intolerant taxa per sample (bottom) for Mitchell Branch sites, April 1987–2022 ... 3-66

3.40. Mean percent density of pollution-intolerant taxa and of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) at Mitchell Branch sites, April 1987–2022 ... 3-68

3.41. Temporal trends in the TDEC Macroinvertebrate Index (top) and Stream Habitat Index (bottom) scores for four Mitchell Branch sites, August 2008–2022 ... 3-69

3.42. Mean total taxonomic richness (top) and pollution-intolerant taxa per sample (bottom) for the benthic macroinvertebrate community at Mitchell Branch and the 95% confidence interval for ORR reference sites, April 2005–2022 ... 3-72

3.43. Mean percent density of pollution-intolerant taxa (top) and pollution-tolerant Chironomidae (bottom) in Mitchell Branch the 95% confidence interval for ORR reference sites, April 2005–2022 ... 3-73

3.44. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998 ... 3-74

3.45. More recent habitat conditions at Mitchell Branch in 2022 ... 3-74

3.46. Species richness for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2022 ... 3-75

3.47. Density for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2022 ... 3-76

3.48. Biomass for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2022 ... 3-76

3.49. Sensitive fish species observed in lower Mitchell Branch ... 3-77

3.50. Changes in the K-1007-P1 Pond fish community from 2007–2022 ... 3-79

4 The Y-12 National Security Complex

4.1. Age of facilities at Y-12, 2022 ... 4-3

4.2. The Environmental Management System "plan-do-check-act" cycle of continual improvement ... 4-6

4.3. Y-12's environment, safety, and health policy 4-7

4.4. Cost efficiencies from Y-12 pollution prevention activities, 2005–2022........ 4-13

4.5. Y-12 pollution prevention initiatives, 2005–2022 4-13

4.6. Y-12 recycling results, 2005–2022........ 4-15

4.7. Y-12 energy intensity versus baseline goal........ 4-16

4.8. Water intensity graph from baseline 2007 through FY 2022........ 4-20

4.9. Path to eliminate Y-12's legacy mixed waste inventory by fiscal year (2016–2022)........ 4-29

4.10. Y-12 hazardous waste generation, 2018–2022 4-30

4.11. Total curies of uranium discharged from Y-12 to the atmosphere, 2017–2022........ 4-40

4.12. Locations of ambient air monitoring stations at Y-12........ 4-46

4.13. Temporal trends in mercury vapor concentration for the boundary monitoring stations at Y-12, July 1986 to December 2022 [(a) and (b)] and January 1994 to December 2022 for ambient air station 8 [(c)]........ 4-48

4.14. Major Y-12 National Pollutant Discharge Elimination System outfalls and monitoring locations........ 4-51

4.15. Surface water and sanitary sewer radiological sampling locations at Y-12 4-58

4.16. Six-year trend of Y-12 uranium releases to East Fork Poplar Creek........ 4-59

4.17. Y-12 storm water monitoring locations, East Fork Poplar Creek 4-61

4.18. Biological monitoring sites in East Fork Poplar Creek relative to Y-12........ 4-66

4.19. Biological monitoring reference site locations relative to Y-12 4-66

4.20. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek, 1988–2022 4-68

4.21. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets, 1986–2022........ 4-69

4.22. Benthic macroinvertebrate communities in three sites along East Fork Poplar Creek and the 95 percent confidence interval for two nearby reference streams 4-71

4.23. Comparison of mean sensitive species richness collected each year from four sites in East Fork Poplar Creek and a reference site, 1985–2022........ 4-72

4.24. Fish density for two sites in Upper East Fork Poplar Creek and a reference site, 1996–2022........ 4-73

4.25. Known or potential contaminant source areas where groundwater is monitored at Y-12 4-74

4.26. Hydrogeologic regimes, flow directions, perimeter/exit pathway locations, and position of Maynardville Limestone at Y-12........ 4-75

4.27. Groundwater elevation contours and flow directions at Y-12 4-76

4.28. Groundwater monitoring well sampling at Y-12 4-78

4.29. Nitrate in groundwater at Y-12, 2022 4-80

4.30. Nitrate concentration trends in surveillance monitoring wells GW-274/GW-275 and 55-2A/55-2B/55-2C in the East Fork regime 4-80

4.31. Summed volatile organic compounds in groundwater at Y-12, 2022 4-81

4.32. Gross-alpha activity in groundwater at Y-12, 2022 4-82

4.33. Gross-beta activity in groundwater at Y-12, 2022 4-83

4.34. Nitrate trend in surveillance monitoring well GW-537, Bear Creek Regime, 1998–2022 4-86

4.35. Indeterminate and increasing VOC trends in surveillance monitoring wells GW-626 and GW-627, Bear Creek Regime 4-87

4.36. Concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime, 2022 4-89

5 Oak Ridge National Laboratory

5.1. Location of ORNL within ORR and its relationship to other local DOE facilities 5-3

5.2. Power electronics capabilities at the Grid Research Integration and Deployment Center on the ORNL Hardin Valley Campus 5-5

5.3. Sustainable ORNL focus areas (roadmaps) 5-8

5.4. Tennessee observed and projected temperature change (Runkle et al. 2022) 5-11

5.5. Summary of ORNL's greenhouse gas inventory in FY 2022 5-16

5.6. Controlled pyrolysis: creating a robust, scalable composite recycling technology source 5-17

5.7. Locations of major radiological emission points at ORNL, 2022 5-37

5.8. Total curies of ^{3}H discharged from ORNL to the atmosphere, 2018–2022 5-40

5.9. Total curies of ^{131}I discharged from ORNL to the atmosphere, 2018–2022 5-40

5.10. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from ORNL to the atmosphere, 2018–2022 5-40

5.11. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at ORNL 5-49

5.12. Outfalls and instream locations, including storm water outfalls at ORNL with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2022 5-50

5.13. Cesium-137 discharges at White Oak Dam, 2018−2022 5-50

5.14. Gross alpha discharges at White Oak Dam, 2018−2022 5-50

5.15. Gross beta discharges at White Oak Dam, 2018−2022 5-51

5.16. Total radioactive strontium discharges at White Oak Dam, 2018−2022 5-51

5.17. Tritium discharges at White Oak Dam, 2018−2022 5-51

5.18. Annual flow volume at White Oak Dam 2018–2022 5-51

5.19. Outfalls 211 and 207 and associated storm drain connections that are potential mercury sources 5-52

5.20. Instream mercury monitoring and data locations, 2022 5-54

5.21. Aqueous mercury concentrations of grab samples at sites in White Oak Creek downstream from ORNL, 1998–2022 5-55

5.22. Total mercury concentration in discharges to outfall X01 from the Sewage Treatment Plant, 2010–2022 5-56

5.23. Total mercury concentrations and fluxes in Process Waste Treatment Complex discharges to outfall X12, 2009–2022 5-56

5.24. Locations and data for instream sampling sites coordinated with treatment plant sampling, 2022 5-57

5.25. Mercury concentrations and fluxes at Sewage Treatment Plant and Process Waste Treatment Complex and dry-weather instream values in White Oak Lake at WCK 4.4 (no flux available), 3.4, and X15 (White Oak Dam), 2020–2022 5-58

5.26. Outfall 211 dry-weather flow, concentration, and flux, 2017–2022 5-59

5.27. Outfall 211 storm flow, total mercury concentration and flux, 2017–2022 5-60

5.28. Outfall 207 storm flow, total mercury concentration, and total mercury flux, 2015–2022 5-60

5.29. Mean mercury concentrations in muscle tissue of sunfish and bass sampled from the White Oak Creek watershed, 1998–2022 5-63

5.30. Mean total PCB concentrations in fish sampled from the White Oak Creek watershed, 1998–2022 5-64

5.31. Benthic macroinvertebrate communities in Fifth Creek, 1987−2022 5-66

5.32. Benthic macroinvertebrate communities in Walker Branch, Melton Branch, and White Oak Creek, 1987−2022 5-67

5.33. Benthic macroinvertebrate communities in First Creek, 1987−2022 5-68

5.34. Temporal trends in Tennessee Department of Environment and Conservation Tennessee Macroinvertebrate Index scores for White Oak Creek watershed streams, August sampling, 2009–2022 5-70

5.35. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams, Brushy Fork and Mill Branch, 1985–2022 5-73

5.36. Locations of monitoring points for First Creek source investigation 5-74

5.37. Total polychlorinated biphenyl content in semipermeable membrane devices in the White Oak Creek watershed and in First Creek forage fish composite samples (n = 3), 2022 5-75

5.38. ORNL surface water sampling locations, 2022 5-77

5.39. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2022 5-83

5.40. Groundwater and precipitation monitoring locations at the Spallation Neutron Source, 2022 5-88

6 Oak Ridge Reservation Environmental Monitoring Program

6.1. The ORR meteorological monitoring network, including light and sonic detection and ranging (LIDAR and SODAR) devices 6-3

6.2. ORR ambient air station 6-5

6.3. Locations of ORR perimeter air monitoring stations 6-6

6.4. External gamma radiation monitoring locations on ORR 6-8

6.5. ORR surface water surveillance sampling locations 6-10

6.6. Fish-sampling locations for the ORR Surveillance Program 6-14

6.7. Map of invasive plant treatment areas on ORR for 2022 6-19

6.8. Experimental kudzu control using goats grazing. 6-20

6.9. Wildland management units on ORR 6-22

7 Dose

7.1. Location of the maximally exposed individual for ORR, 2022 7-5

7.2. Nuclides contributing to effective dose at the Y-12, 2022 7-6

7.3. Nuclides contributing to effective dose at ORNL, 2022 7-7

7.4. Nuclides contributing to effective dose at ETTP, 2022 7-7

Tables

Table *Page*

1 Introduction to the Oak Ridge Reservation

1.1. Animal species of special concern reported on ORR 1-8

1.2. Vascular plant species of special concern sighted or reported on or near ORR 1-14

2 Compliance Summary and Community Involvement

2.1. Applicable environmental laws and regulations and 2022 status 2-5

2.2. Summary of external regulatory environmental audits, inspections, and assessments at ORR, 2022 2-10

3 East Tennessee Technology Park

3.1. Surface contamination values and DOE Order 458.1 authorized limits for surface activity 3-11

3.2. East Tennessee Technology Park environmental permits, 2022 3-14

3.3. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2022 3-15

3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2022 through December 2022 3-22

3.5. Radionuclides released to off-site waters from the East Tennessee Technology Park storm water system in 2022 3-30

3.6. CERCLA PCCR monitoring results for 2022 3-32

3.7. Mercury results for Outfalls 180, 190, and 05A/05A-2 in 2022 3-32

3.8. Average concentrations of total PCBs in fillets and whole-body composites of fish collected in 2022 near the East Tennessee Technology Park 3-60

3.9. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation 3-65

3.10. Tennessee Macroinvertebrate Index metric values and scores and index scores for Mitchell Branch, August 16, 2022 3-70

4 The Y-12 National Security Complex

4.1. Fiscal year 2022 sustainability goals and performance 4-17

4.2. Summary of external regulatory audits and reviews, 2022 4-22

4.3. Y-12 environmental permits, CY 2022 4-23

4.4. National Nuclear Security Administration-approved Categorical Exclusions for 2022 4-27

4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for Y-12, 2021–2022 4-31

4.6. Summary of materials released in 2022 4-34

4.7. DOE Order 458.1 preapproved authorized limits for surface contamination 4-35

4.8. DOE Order 458.1 preapproved authorized limits for volumetric contamination 4-37

4.9. Actual versus allowable air emissions from the Y-12 Steam Plant, 2022 4-39

4.10. Greenhouse gas emissions from Y-12 stationary fuel combustion sources 4-43

4.11. Summary of data for the Y-12 Ambient Air Monitoring Program for mercury, CY 2022 4-47

4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, January–September 2022 4-52

4.13. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, October–December 2022 4-54

4.14. Radiological parameters monitored at Y-12, 2020 4-57

4.15. Summary of Y-12's radiological monitoring plan sample requirements and 2022 results 4-58

4.16. Uranium release from Y-12 to the off-site environment as liquid effluent, 2014–2022 4-59

4.17. Mercury concentrations at Outfall 014 4-60

4.18. Y-12 discharge point SS6 4-62

4.19. Serial dilutions for whole effluent toxicity testing, as a percent of effluent, before October 2022 and after October 1, 2022, with the new permit 4-64

4.20. Y-12 biomonitoring program summary information for Outfalls 200 and 135, 2022 4-64

4.21. Summary of groundwater monitoring at the Y-12 National Security Complex, 2022 4-77

4.22. Nitrate and uranium concentrations in Bear Creek 4-86

4.23. Treatment, storage, and disposal facilities used to disposition radiological and hazardous waste, 2022 4-94

5 Oak Ridge National Laboratory

5.1. 2022 ORNL Sustainability goals and performance status 5-12

5.2. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORNL, 2022 5-22

5.3. Environmental permits in effect at ORNL in 2022 5-23

5.4. National Environmental Policy Act activities, 2022 5-25

5.5. National Pollutant Discharge Elimination System compliance at ORNL, January through December 2022 5-27

5.6. ORNL Resource Conservation and Recovery Act operating permits, 2022 5-29

5.7. Main elements of the Emergency Planning and Community Right-to-Know Act..... 5-32

5.8. Excess items requested for release or recycling, 2022..... 5-34

5.9. Radionuclide concentrations measured at ORNL air monitoring Station 7, 2022..... 5-41

5.10. Overview of 2022 chlorine control strategy 5-43

5.11. Total residual oxidant mitigation summary: emergency repairs, 2022 5-44

5.12(a). Radiological monitoring conducted under the ORNL Water Quality Protection Plan, January–June 2022..... 5-47

5.12(b). Radiological monitoring conducted under the ORNL Water Quality Protection Plan, July–December 2022 5-48

5.13. Tennessee Macroinvertebrate Index metric values, metric scores, and index scores for White Oak Creek, First Creek, Fifth Creek, and Melton Branch streams, August 22, 2022 5-71

5.14. ORNL surface water sampling locations, frequencies, and parameters, 2022..... 5-78

5.15. Industrial and commercial user wastewater discharge permit compliance at the ORNL Carbon Fiber Technology Facility, 2022..... 5-78

5.16. Exit pathway groundwater monitoring conducted in 2022..... 5-84

5.17. Radiological parameters detected in 2022 exit pathway groundwater monitoring..... 5-85

5.18. Spallation Neutron Source monitoring program schedule, 2022 5-89

5.19. Radiological concentrations detected in samples collected at the Spallation Neutron Source, 2022..... 5-90

5.20. Summary of precipitation ^{3}H monitoring results, 2016–2022 5-90

6 Oak Ridge Reservation Environmental Monitoring Program

6.1. ORR meteorological towers..... 6-2

6.2. Radionuclide concentrations at ORR perimeter air monitoring stations sampled annually, 2022..... 6-7

6.3. External gamma exposure rate averages for ORR, 2022..... 6-9

6.4. ORR surface water sampling locations, frequencies, and parameters, 2022..... 6-11

6.5. Concentrations of radionuclides detected in hay, August 2022 (pCi/kg) 6-12

6.6. Concentrations of radionuclides detected in tomatoes, 2022 (pCi/kg)..... 6-14

6.7. Tissue concentrations in catfish and sunfish for detected PCBs and radionuclides, 2022..... 6-15

6.8. Twelve most problematic invasive plants on ORR..... 6-17

6.9. Invasive plant control on ORR, 2003–2022 6-18

7 Dose

7.1. Emission point parameters and receptor locations used in the dose calculations, 2022 7-3

7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2022 7-5

7.3. Calculated radiation doses to maximally exposed individuals from airborne releases from ORR, 2022 7-6

7.4. Calculated collective effective doses from airborne releases, 2022 7-6

7.5. Hypothetical effective doses from living near ORR and ETTP ambient air monitoring stations, 2022 7-8

7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2022 7-13

7.7. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2022 7-17

7.8. Trends in effective dose from ORR activities, 2018–2022 (mrem) 7-18

7.9. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 23 and 16, 2022 7-21

7.10. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on ORR, 2022 7-22

Appendices

A. Glossary A-1

B. Climate Overview of the Oak Ridge Area B-1

C. Reference Standards and Data for Water C-1

D. National Pollutant Discharge Elimination System Noncompliance Summaries for 2022 .... D-1

E. Radiation E-1

F. Chemicals F-1

G. Radiological Airborne Emissions at Oak Ridge National Laboratory G-1

Acronyms and Abbreviations

A	ACM	asbestos-containing material
	AFFF	aqueous film-forming foams
	ANSI	American National Standards Institute
	AOEC	Agent Operations Eastern Command
	AROD	amended record of decision
	ASER	*Oak Ridge Reservation Annual Site Environmental Report*
	AWQC	ambient water quality criterion
B	BCG	biota concentration guide
	BCK	Bear Creek kilometer
	BFK	Brushy Fork kilometer
	BMAP	Biological Monitoring and Abatement Program
C	CAA	Clean Air Act
	CAP-88 PC	Clean Air Act Assessment Package-1988 (software)
	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
	CFR	*Code of Federal Regulations*
	CFTF	Carbon Fiber Technology Facility
	CNS	Consolidated Nuclear Security, LLC
	COLEX	column exchange
	COVID-19	Coronavirus Disease 2019
	CRK	Clinch River kilometer
	CROET	Community Reuse Organization of East Tennessee
	CWA	Clean Water Act
	CWTS	ETTP Chromium Water Treatment System
	CX	categorical exclusion
	CY	calendar year
D	D&D	decontamination and decommissioning
	DCE	dichloroethene/dichloroethylene
	DCS	derived concentration standard
	DMRQA	Discharge Monitoring Report Quality Assurance Study
	DOD-ELAP	US Department of Defense Environmental Laboratory Accreditation Program
	DOE	US Department of Energy
	DOECAP	DOE Consolidated Audit Program
	DU	depleted uranium
E	EA	environmental assessment
	EC&P	environmental compliance and protection

	ECD	Y-12 Environmental Compliance Department
	ED	effective dose
	EESP	Energy Efficiency and Sustainability Program
	EFK	East Fork Poplar Creek kilometer
	EFPC	East Fork Poplar Creek
	EISA	Energy Independence and Security Act of 2007
	EJ	environmental justice
	EM	DOE Office of Environmental Management
	EMDF	Environmental Disposal Facility
	EMP	Environmental Monitoring Program
	EMS	environmental management system
	EMWMF	Environmental Management Waste Management Facility
	EO	executive order
	EPA	US Environmental Protection Agency
	EPCRA	Emergency Planning and Community Right-to-Know Act
	EPEAT	Electronic Product Environmental Assessment Tool
	EPSD	UT-Battelle Environmental Protection Services Division
	EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
	e-RICE	emergency reciprocating internal combustion engine
	ES&H	environment, safety, and health
	ESPC	Energy Savings and Performance Contract
	ESS	ORNL Environmental Surveillance System
	ETTP	East Tennessee Technology Park
	EU	exposure unit
F	FCK	First Creek kilometer
	FFK	Fifth Creek kilometer
	FFS	focused feasibility study
	FLC	Federal Laboratory Consortium
	FMD	ORNL Facilities Management Division
	FONSI	Finding of No Significant Impact
	FWS	US Fish and Wildlife Service
	FY	fiscal year
G	GHG	greenhouse gas
	GP	guiding principle
	GSA	General Services Administration
H	HBCU	Historically Black Colleges and Universities
	HFIR	High Flux Isotope Reactor
	HPSB	high-performance sustainable building
	HQ	hazard quotient
	HVC	ORNL Hardin Valley Campus

I	IC_{25}	25-percent inhibition concentration
	ISMS	integrated safety management system
	ISO	International Organization for Standardization
	Isotek	Isotek Systems, LLC
L	LEED	Leadership in Energy and Environmental Design
	LLW	low-level radioactive waste
	LPF	Lithium Processing Facility
M	M&E	material and equipment
	MAPEP	Mixed Analyte Performance Evaluation Program
	MARSAME	*Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual*
	MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
	MBK	Mill Branch kilometer
	MCK	McCoy Branch kilometer
	MCL	maximum contaminant level
	MEI	maximally exposed individual
	MEK	Melton Branch kilometer
	MAPEP	Mixed Analyte Performance Evaluation Program
	MIK	Mitchell Branch kilometer
	MLLW	mixed low-level waste
	MOA	memorandum of agreement
	MSRE	Molten Salt Reactor Experiment
	MT	meteorological tower
N	NAAQS	National Ambient Air Quality Standards
	NELAP	National Environmental Laboratory Accreditation Program
	NEPA	National Environmental Policy Act
	NESHAPs	National Emission Standards for Hazardous Air Pollutants
	NHPA	National Historic Preservation Act
	NNSA	National Nuclear Security Administration
	NPDES	National Pollutant Discharge Elimination System
	NPO	NNSA Production Office
	NRC	US Nuclear Regulatory Commission
	NRHP	National Register of Historic Places
	NTRC	National Transportation Research Center
	NWSol	North Wind Solutions, LLC
O	ODS	ozone-depleting substance
	OREM	DOE Oak Ridge Office of Environmental Management
	ORETTC	Oak Ridge Enhanced Technology and Training Center
	ORGDP	Oak Ridge Gaseous Diffusion Plant
	ORISE	Oak Ridge Institute for Science and Education

	ORNL	Oak Ridge National Laboratory
	ORO	DOE Oak Ridge Office
	ORR	Oak Ridge Reservation
	ORRL	Oak Ridge Reservation Landfills
	ORSSAB	Oak Ridge Site Specific Advisory Board
	OST	Office of Secure Transportation
P	P2	pollution prevention
	PCB	polychlorinated biphenyl
	PCBADL	Polychlorinated Biphenyl Annual Document Log
	PCCR	phased construction completion report
	PCE	tetrachloroethene
	PFAS	per- and polyfluoroalkyl substances
	PFOA	perfluorooctanoic acid
	PFOS	perfluorooctane sulfonate
	PM_{10}	particulate matter with an aerodynamic diameter $\leq$ 10 μm
	$PM_{2.5}$	fine particulate matter with an aerodynamic diameter $\leq$ 2.5 μm
	PWTC	Process Waste Treatment Complex
Q	QA	quality assurance
	QC	quality control
	QMS	quality management system
R	R&D	research and development
	RA	remedial action
	Rad-NESHAPs	National Emission Standards for Hazardous Air Pollutants for Radionuclides
	RCRA	Resource Conservation and Recovery Act
	RMAL	Radiochemical Materials Analytical Laboratory
	ROD	record of decision
	RSI	Restoration Services, Inc.
	RTR	real-time radiography
S	SA	supplement analysis
	SARA	Superfund Amendments and Reauthorization Act
	SBMS	UT-Battelle Standards-Based Management System
	SC	DOE Office of Science
	SD	storm water outfall/storm drain
	SNS	Spallation Neutron Source
	SODAR	sonic detection and ranging
	SOF	sum of fractions
	SOP	state operating permit
	SPCC	spill prevention, control, and countermeasures
	SPMD	semipermeable membrane devices

	SSP	site sustainability plan
	STP	sewage treatment plant
	SWEIS	sitewide environmental impact statement
	SWPP	storm water pollution prevention
	SWPPP	storm water pollution prevention plan
	SWSA	solid waste storage area
T	TCE	trichloroethene/trichloroethylene
	TDEC	Tennessee Department of Environment and Conservation
	TEMA	Tennessee Emergency Management Agency
	TMDL	total maximum daily load
	TMI	Tennessee Macroinvertebrate Index
	TRI	toxic chemical release inventory
	TRN	Technical Resilience Navigator
	TRO	total residue oxidant
	TRU	transuranic
	TSCA	Toxic Substances Control Act
	TSS	total suspended solids
	TVA	Tennessee Valley Authority
	TWPC	Transuranic Waste Processing Center
	TWRA	Tennessee Wildlife Resources Agency
U	UCOR	United Cleanup Oak Ridge LLC
	UPF	Uranium Processing Facility
	USDA	US Department of Agriculture
	UST	underground storage tank
	UT	University of Tennessee
	UT-Battelle	UT-Battelle, LLC
V	VARP	Vulnerability Assessment and Resilience Planning
	VC	vinyl chloride
	VOC	volatile organic compound
W	WBK	Walker Branch kilometer
	WCK	White Oak Creek kilometer
	WEPAR	West End Protected Area Reduction
	WFMP	*Oak Ridge Reservation Wildland Fire Management Plan*
	WM/WRM	weapon material/weapon-related material
	WOC	White Oak Creek
	WOD	White Oak Dam
	WQC	water quality criterion
	WQPP	water quality protection plan
	WRRP	Water Resources Restoration Program

Y	Y-12 or Y-12 Complex	Y-12 National Security Complex

Units of Measure and Conversion Factors*

Units of measure and their abbreviations

acre	acre	micrometer	µm
becquerel	Bq	millicurie	mCi
British thermal unit	Btu	milligram	mg
centimeter	cm	milliliter	mL
curie	Ci	millimeter	mm
day	d	million	M
degrees Celsius	°C	million gallons per day	MGD
degrees Fahrenheit	°F	millirad	mrad
disintegrations per minute	dpm	millirem	mrem
foot	ft	milliroentgen	mR
gallon	gal	millisievert	mSv
gallons per minute	gpm	minute	min
gram	g	nanogram	ng
gray	Gy	nephelometric turbidity unit	NTU
gross square feet	gsf	parts per billion	ppb
hectare	ha	parts per million	ppm
hour	h	parts per trillion	ppt
inch	in.	picocurie	pCi
joule	J	pound	lb
kilocurie	kCi	pound mass	lbm
kilogram	kg	pounds per square inch	psi
kilometer	km	pounds per square inch gauge	psig
kilowatt	kW	quart	qt
linear feet	LF	rad	rad
liter	L	roentgen	R
megajoule	MJ	roentgen equivalent man	rem
megawatt	MW	second	S
megawatt-hour	MWh	sievert	Sv
meter	m	standard unit (pH)	SU
metric tons	MT	ton, short (2,000 lb)	ton
metric tons of carbon	MTCO2e	yard	yd
microcurie	µCi	year	yr
microgram	µg		

Quantitative prefixes

exa	$\times 10^{18}$	atto	$\times 10^{-18}$
peta	$\times 10^{15}$	femto	$\times 10^{-15}$
tera	$\times 10^{12}$	pico	$\times 10^{-12}$
giga	$\times 10^{9}$	nano	$\times 10^{-9}$
mega	$\times 10^{6}$	micro	$\times 10^{-6}$
kilo	$\times 10^{3}$	milli	$\times 10^{-3}$
hecto	$\times 10^{2}$	center	$\times 10^{-2}$
deka	$\times 10^{1}$	decic	$\times 10^{-1}$

**Due to differing permit reporting requirements and instrument capabilities, various units of measurement are used in this report. This list of units of measure and conversion factors is intended to help readers make approximate conversions to other units as needed for specific calculations and comparisons.*

Unit conversions

Unit	Conversion	Equivalent	Unit	Conversion	Equivalent
Length					
in.	× 2.54	cm	cm	× 0.394	in.
ft	× 0.305	m	m	× 3.28	ft
mile	× 1.61	km	km	× 0.621	mile
Area					
acre	× 0.405	ha	ha	× 2.47	acre
ft^2	× 0.093	m^2	m^2	× 10.764	ft^2
$mile^2$	× 2.59	km^2	km^2	× 0.386	$mile^2$
Volume					
ft^3	× 0.028	m^3	m^3	× 35.31	ft^3
qt	× 0.946	L	L	× 1.057	qt
gal	× 3.7854118	L	L	× 0.264172051	gal
Concentration					
ppb	× 1	µg/kg	µg/kg	× 1	ppb
ppm	× 1	mg/kg	mg/kg	× 1	ppm
ppb	× 1	µg/L	µg/L	× 1	ppb
ppm	× 1	mg/L	mg/L	× 1	ppm
Weight					
lb	× 0.4536	kg	kg	× 2.205	lb
lbm	× 0.45356	kg	kg	× 2.2046226	lbm
ton, short	× 907.1847	kg	kg	× 0.00110231131	ton, short
Temperature					
°C	°F = (9/5)°C + 32	°F	°F	°C = (5/9) (F–32)	°C
Activity					
Bq	× 2.7×10^{-11}	Ci	Ci	× 3.7×10^{10}	Bq
Bq	× 27	pCi	pCi	× 0.037	Bq
mSv	× 100	mrem	mrem	× 0.01	mSv
Sv	× 100	rem	rem	× 0.01	Sv
nCi	× 1,000	pCi	pCi	× 0.001	nCi
mCi/km^2	× 1	nCi/m^2	nCi/m^2	× 1	mCi/km^2
dpm/L	× 0.45×10^9	$\mu Ci/cm^3$	$\mu Ci/cm^3$	× 2.22×10^9	dpm/L
pCi/L	× 10^{-9}	µCi/mL	µCi/mL	× 10^9	pCi/L
pCi/m^3	× 10^{12}	$\mu Ci/cm^3$	$\mu Ci/cm^3$	× 10^{12}	pCi/m^3

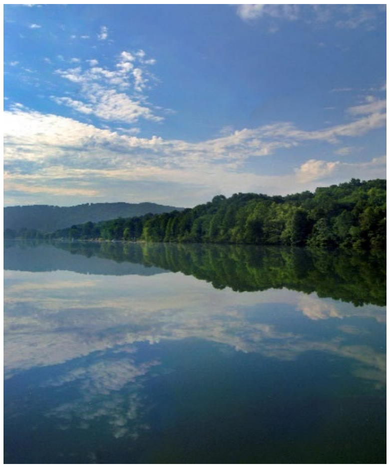
Acknowledgments

The US Department of Energy (DOE) is responsible for producing this document. DOE acknowledges with deep appreciation the efforts of the following individuals who provided valuable resources, information, and technical data and management, administrative, field, or other support.

ENVIRONMENTAL MANAGEMENT
Betsy Brucken
David Buhl
Kim Cole
Kevin Crow
Steve Foster
Justin Frazer
Sidney Garland
Sherry Gibson
Matthew Hagenow
Crystal Hann
Amber Harshman
Kevin Ironside
Charles Justice
Richard Ketelle
Jeff Maddox
Terry Mathews
Tammy Phillips
Tony Poole
Annette Primrose
Rebecca Rogers
Gill Sallade
Cheryl Sayler
Alison Terebush
Natasha Thomsen
Wesley White

ORNL
Karen Atchely
Caroline Barber
Gio Barton
Brenda Becker-Khaleel
Mary Brown
Greg Byrd
Jason Case
Gary Chadwick
Sara Cornwell
Sara Darling
Kathy Davidson
Sharon Deane
Jamie Evans
Allison Fortner
Rich Franco
Taylor Frye
Wes Goddard
Mark Goines
Scott Gregory
Natalie Griffiths
Julie Hancock
Amber Harshman
Jamie Herold
Hurtis Hodges
Joan Hughes
Trent Jett
Kathy Jones
Nikki Jones
Richard Ketelle
Walter Koncinski, Jr.
Jessica Langstaff
Jeff Maddox
Michael Masters
Teresa Mathews
Paul Matson
William McCarter
Kitty McCracken
Susan Michaud
Amy Miller
Jesse Morris
Lori Muhs
Todd North
Jenn Parikh
Karen Sabo
Denise Saunders
David Skipper
George Stephens
Searia Stephenson
Louise Stevenson
Patrick Garcia Strickland
Billey Thomas
Terri Torres
Erin Trent
Steve Trotter
Charlie Valentine

Y-12 COMPLEX
Brandy Belicek
Scott Brooks
Steven Brooks
Vicki Brumback
Wayne Carlton
Sara Cornwell
Laura Cunningham
Christa Davis
Alexandra Detweiler
Stan Duke
Matthew Frost
Kim Hanzelka
Abigail Harmon
Amber Harshman
Caitlin Hoch-Nussbaum
William C. Hurst
Chloe Hutchison
Steven Jones
Kris Kinder
Michelle Kunz
Daniel Lawson
Jennifer Linton
Stacey Loveless
Kenneth Lowe
Teresa Mathews
Mary Murray
Jane Nations
Scott Nelson
Caitlin Newman
Elizabeth Owens
Aprell Patterson
Annette Primrose
Jeremy Price
Paula Roddy
Stephen Shults
Eugene Sievers
Bradley Skaggs
Johnny Skinner
Terri Slack
Adam Smith
Rae Spencer
James Stinnett
Larissa Welch
Christian Wenzel
Eve Whittenburg
Jeannette Widman



Located on the banks of the Clinch River, the Oak Ridge Reservation comprises three major facilities involved in every mission in the DOE portfolio. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment.

Executive Summary

Overview

The Oak Ridge Reservation (ORR), located in Roane and Anderson Counties in East Tennessee about 40 km (25 mi) west of Knoxville, is managed by the US Department of Energy (DOE). Today ORR is one of DOE's most complex sites. Established in the early 1940s as part of the Manhattan Project to enrich uranium and pioneer methods for producing and separating plutonium, ORR continued those activities until the mid-1980s. Today ORR comprises three major facilities with thousands of employees performing every mission in the DOE portfolio: energy research, environmental restoration, national security, nuclear fuel supply, reindustrialization, science education, basic and applied research in areas important to US security, and technology transfer. Scientists at the Oak Ridge National Laboratory (ORNL), DOE's largest science and energy laboratory, conduct leading-edge research in advanced materials, neutron scattering, nuclear programs (including isotope production), and high-performance computing. The Y-12 National Security Complex (Y-12 or Y-12 Complex) is vital to maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile and reducing the global threat posed by nuclear proliferation and terrorism. The East Tennessee Technology Park (ETTP), a former uranium enrichment complex, is being transitioned to a clean, revitalized industrial park.

ORR is managed by three DOE Program Secretarial Offices and their management and operating contractors and other prime contractors. This calendar year 2022 Oak Ridge Reservation Annual Site Environmental Report (ASER) contains information furnished to the DOE ORR integrating contractor by other contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; United Cleanup Oak Ridge LLC (UCOR); North Wind Solutions, LLC (NWSol); Oak Ridge Associated Universities; and Isotek Systems, LLC (Isotek). DOE and its contractors at ORR are committed to environmental protection, compliance, and sustainability, which includes the site's utmost efforts to ensure the validity and accuracy of monitoring data.

Chapter 3 of this report was prepared by UCOR, the lead environmental management contractor for ETTP. Chapter 4 was developed by Consolidated Nuclear Security, LLC, which manages and operates the Y-12 Complex. Chapters 5, 6, and 7 were written by UT-Battelle, LLC, the ORNL management and operating contractor. These contractors are responsible for independently carrying out the various DOE missions at the three major ORR sites. They manage and implement environmental protection programs through environmental management systems that adhere to International Organization for Standardization Standard 14001, Environmental Management Systems. Chapters 3, 4, and 5 include detailed information on each contractor's environmental management systems, which interface with DOE's signature integrated safety management system (ISMS) to provide unified strategies for managing resources. ISMS incorporates safety in all aspects of work and helps ensure safety at all DOE facilities. Safety, as defined in ISMS, encompasses protection of the public, the worker, and the environment, and includes all safety, health, and environmental disciplines: radiation protection, fire protection, nuclear safety, environmental protection, waste management, and environmental management.

DOE operations on ORR have the potential to release various constituents to the environment via atmospheric, surface water, and groundwater pathways. Some of these constituents, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to specialized research and production activities like those conducted on ORR. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment. To encourage the public to participate in matters related to ORR's environmental impact on the community, DOE solicits citizens' input on matters of significant public interest through multiple channels. DOE also offers access to information on its Oak Ridge environmental, safety, and health activities.

The ASER is prepared for DOE according to the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*. The ASER includes data on the environmental performance of each of the major DOE ORR contractors and describes significant accomplishments in pollution prevention and sustainability programs that reduce many types of waste and pollutant releases to the environment. DOE has published an annual environmental report with consolidated data on overall ORR performance and status since the mid-1970s. The ASER is a key component of DOE's effort to keep the public informed about environmental conditions across DOE and National Nuclear Security Administration sites.

Impacts

DOE ORR operations resulted in minimal impact to the public and the environment in 2022. Permitted discharges to air and water continued to be well below regulatory standards, and potential radiation doses to the public from activities on the reservation were much less than the 100 mrem standard established for DOE sites in DOE Order 458.1, *Radiation Protection of the Public and the Environment*.

The maximum radiation dose a hypothetical off-site individual could have received from DOE activities on ORR in 2022 was estimated to be 0.2 mrem from air pathways, 0.9 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 2 mrem from consumption of wildlife harvested on ORR. This is about 3 percent of the DOE 100 mrem standard for all pathways and is significantly less than the 300 mrem annual average dose to people in the United States from background radiation.

Environmental Monitoring

Each year extensive environmental monitoring is conducted across ORR. Site-specific environmental protection programs are implemented at ORNL, the Y-12 Complex, and

ETTP. ORR-wide environmental surveillance programs, which include locations and media both on and off the reservation, enhance and supplement data from site-specific efforts. In 2022 many thousands of samples and measurements of air, water, direct radiation, vegetation, fish, and wildlife were collected from across the reservation and analyzed for radioactive and nonradioactive contaminants. Sample media, locations, frequencies, and parameters were selected based on environmental regulations and standards, public and environmental exposure pathways, environmental permits, and measurement capabilities. Chapters 2 through 7 of this report summarize the environmental protection and surveillance programs on ORR. These extensive sampling and monitoring efforts demonstrate DOE's commitment to ensuring safety; protecting human health; complying with regulations, standards, DOE orders, and "as low as reasonably achievable" principles; reducing the risks associated with past, present, and future operations; and improving cost-effectiveness.

Compliance with Environmental Regulations

Federal, state, and local government agencies including the US Environmental Protection Agency and the Tennessee Department of Environment and Conservation monitor ORR for compliance with applicable environmental regulations. These agencies issue permits, review compliance reports, participate in monitoring programs, and inspect facilities and operations. Compliance with environmental regulations and DOE orders ensures ORR activities do not result in adverse impacts to the public or the environment.

Compliance with applicable regulations in 2022 for the three major ORR sites is summarized as follows:

- ETTP had no notices of environmental violations or penalties.
- Y-12 had 100 percent compliance with water quality permit discharge limits for 2022 and no Clean Air Act violations or exceedances. Personnel from the Tennessee Department of Environment and Conservation Division of Solid Waste Management conducted a Resource Conservation and Recovery Act hazardous waste compliance inspection of Y-12 on February 23, 2022. The inspections covered waste storage areas and reviews of records. Eight issues were identified, including roof leak repairs that were not documented, one container that exceeded 90 days in a storage area, inadequate aisle space in one area, one facility that did not conduct daily inspections when hazardous waste activities occurred for a period of time, and two instances each of containers being inadequately labeled for hazards and improperly closed. Immediate corrective actions were taken where possible. The issues and their causes were reviewed at the time of the incident and all issues were resolved.
- ORNL facilities include those on the Oak Ridge campus as well as off-campus entities such as the National Transportation Research Center and the Carbon Fiber Technology Facility. In 2022 there were no Clean Air Act violations by UT-Battelle, LLC, the ORNL managing contractor, and no Clean Air Act violations or exceedances by the other contractors who conducted activities at ORNL in 2022 (Isotek, NWSol, and UCOR). ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 100 percent in 2022. In October 2022, water from a potable water line break in the 7000 Area was released into White Oak Creek and caused aquatic species mortality (a total of 141 fish, 11 salamanders, and 13 aquatic worms). This incident was reported as a noncompliance with narrative criteria in the National Pollutant Discharge Elimination System permit, which was reissued in December 2022.

Chapter 2 provides a more detailed summary of ORR environmental compliance during 2022. Chapters 3, 4, and 5 further discuss each site's compliance status for the year.

Environmental Management, Pollution Prevention, and Site Sustainability

Numerous environmental management, pollution prevention, and sustainability programs across ORR embody efforts to achieve enduring sustainability in facilities, operations, and organizational culture. The objectives of these programs are to conserve water and energy, minimize waste, and promote energy-efficient buildings, sustainable landscaping, green transportation, and sustainable acquisition. Consequently, these initiatives decrease the life cycle costs of programs and projects while also reducing risks to the environment. As described in Chapters 3, 4, and 5, ORR contractors achieved a high level of excellence in environmental management, pollution prevention, and sustainability programs in 2022.

Environmental Management

Since 1943 ORR has played key roles in America's defense and energy research. However, past waste disposal practices, operational and industrial practices, changing standards, and unintentional releases left some land and facilities contaminated with radioactive elements, mercury, asbestos, polychlorinated biphenyls, and industrial wastes. The DOE Environmental Management program is responsible for cleaning up these sites, and numerous cleanup projects are underway at the reservation's three main facilities.

ETTP completed several soil remedial actions in 2022 that help protect groundwater. Exposure Unit (EU)-25 remedial action centered on the slab, foundation, and underlying soil of the former K-1413 Building, which was constructed in the 1950s and operated until the early 1980s for a range of chemical waste processing activities. This project was completed in 2022 with over 18,000 yd^3 of concrete and soil being removed from the site. EU-13 has several excavation areas for ongoing soil remediation at the sites of the former buildings designated as K-413, K-1131, and K-631. This is an area near Poplar Creek that once housed many of the gaseous diffusion and uranium hexafluoride enrichment support facilities. Remediation was also underway within EU-21, an area that is located in the middle of the K-25 footprint, which is part of the Manhattan Project National Historical Park. Based on results of model calculations, workers are set to excavate 16,000 yd^3 of soil to eliminate risks to groundwater.

Y-12 achievements in 2022 included progress in constructing the Outfall 200 Mercury Treatment Facility, developing DOE Environmental Management research in new remediation technologies to address mercury releases into the environment from past operations, and contracting for the first mercury remediation technology demonstration. Shoring and major excavations were completed at the headworks site. Crews continued placing concrete pads and walls of the treatment plant. Crews also began erecting structural steel and continued installing underground utilities. The new facility is slated to be operational in 2025. As part of the technology demonstration initiative, an existing ORR facility is being evaluated for the necessary modifications to carry out the proposed demonstration of mercury treatment technologies.

In 2022, UCOR workers finished removing the remaining slabs at the now demolished Biology Complex, readying the land for transfer back to Y-12 for construction of the new Lithium Processing Facility. Crews completed backfilling and seeding the portion of the site where the last two buildings (Buildings 9207 and 9210) once stood. Labs remaining from previous demolition of buildings at the location were removed and their footprints were backfilled and graveled. Between removal of those slabs and the slabs at Buildings 9207 and 9210, more than 6,141 yd^3 of waste and debris were removed.

ORNL achievements in 2022 included continuing demolition and deactivation. These activities included the demolition of the Tritium Target Preparation Facility and former Radiological Development Lab's West Cell Bank. Deactivation activities took place at multiple facilities, including the Low Intensity Test Reactor, the Oak Ridge

Research Reactor, and a group of buildings called "Isotope Row" that were constructed in the 1950s and early 1960s to process radioisotopes. Also in 2022, the Oak Ridge Office of Environmental Management (OREM) and its contractor Isotek successfully completed processing and disposing the low-dose inventory of ^{233}-U stored at ORNL, ending a 2-year effort that has eliminated a portion of the site's legacy nuclear material.

The Environmental Management Waste Management Facility received 7,172 waste shipments from ORR cleanup projects in 2022. Environmental Management Waste Management Facility operations also collected, analyzed, and disposed of approximately 3.3 million gallons of leachate treated by the Liquid and Gaseous Waste Operations Facility.

In FY 2022, the Transuranic Waste Processing Center completed contact-handled transuranic waste shipments of 59.3 m^3 to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, 58.5 m^3 mixed low-level waste to treatment and disposal, and 2.7 m^3 of hazardous waste to treatment and disposal, eliminating 475 containers of the stored inventory. Construction of the Sludge Processing Mock Test Facility was completed in June 2022; OREM will now test six critical technology elements to gather the data necessary to complete the final design and construction of the Sludge Processing Facility later this decade to address the site's 400,000-gallon inventory of transuranic sludge waste.

Pollution Prevention and Sustainability

The three main ORR sites made significant strides in sustainability and pollution prevention in 2022, and highlights are summarized below.

Within the next 10 years, 58 excess facilities at Y-12 and another 60 National Nuclear Security Administration facilities are projected to be taken down. To date, more than 2.8 million gross square feet of excess facilities have been demolished at Y-12. This progress aligns with meeting the DOE site sustainability plan reduction goal of 25 percent by FY 2025.

In 2022, Y-12 experienced a slight uptick in energy intensity (1.1 percent above 2021). The upward trend in the site energy intensity figures is largely attributed to the height of the pandemic occurring during FY 2020 and then having a larger portion of the plant population returning to the site, thus increasing infrastructure use.

Y-12 diverted 55.8 percent of municipal and 7.5 percent of construction and demolition waste from landfill disposal through reuse and recycle in 2022, and 95 percent of eligible electronic acquisitions were registered through EPEAT, the Electronic Product Environmental Assessment Tool. Greenhouse gas emissions were reduced by 1.3 percent from 2021.

ORNL implemented 26 ongoing and new pollution prevention projects during 2022, which eliminated more than 3.6 million kg of waste. As of the end of 2022, 82 percent of all ORNL vehicles are alternative fuel vehicles, with 90 percent of all replacements over the past two fiscal years being alternative fuel or electric vehicles. Also in 2022, 100 percent of the light-duty vehicles operated on alternative fuels, exceeding DOE fleet management goals. Water use intensity increased by 1.7 percent between 2021 and 2022, despite an overall reduction in water consumption. This is because of increased demands for cooling tower makeup water to support growth of high-performance computing systems. Calculated energy use intensity for FY 2022 was 234,194 Btu per gross square foot, a cumulative reduction of 35.6 percent since FY 2003 and a slight increase of 2.8 percent from 2021.

During 2022 at ETTP, more than 226 metric tons of greenhouse gas emissions, 273,490 metric tons of waste, and 282,000 gallons of wastewater generation were avoided as a result of implementation of pollution prevention measures by site projects. In addition to lessening the impact on the environment, these measures also saved more than $1,600,000.

OREM continued planning for capital asset projects that will further advance ORR cleanup objectives. These include the Outfall 200 Mercury Treatment Facility at Y-12, the new disposal facility that will accept debris from future cleanup at Y-12 and ORNL, and the sludge treatment facility at the Transuranic Waste Processing Center.

Signs such as this were common in the city of Oak Ridge during the Manhattan Project era and for years afterward.

1

Introduction to the Oak Ridge Reservation

It was not shown on any maps. No visitors were allowed without special approval. US Army guards were posted at the entrances to the city, and all residents were required to wear badges at all times outside their homes. Thus Oak Ridge existed for seven years, from 1942 to 1949, as a truly secret city. It was here and also in supporting locations where humankind made the leap from candlepower to nuclear power in a single generation. The engineering marvel that materialized in the Secret City changed the world, helped end World War II, and launched life-saving diagnostic tools such as magnetic resonance imaging and nuclear medicine. Today the former Secret City exists in two parts: the City of Oak Ridge and the Oak Ridge Reservation (ORR). ORR's mission continues to evolve as it adapts to meet the changing basic and applied research and national security needs of the United States.

ORR covers a little over 50 square miles of land in Anderson and Roane counties and is home to two major US Department of Energy (DOE) operating facilities: the Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12). Other ORR facilities include the East Tennessee Technology Park (ETTP), the site of a former gaseous diffusion plant that has undergone significant environmental cleanup and transitioned to a private sector business and industrial park; the Oak Ridge Institute for Science and Education (ORISE) South Campus, which includes training, laboratory, and support facilities; the government-owned, government-operated Agent Operations Eastern Command (AOEC) of the National Nuclear Security Administration (NNSA) Office of Secure Transportation (OST); the Transuranic Waste Processing Center (TWPC); and small government-owned, contractor-operated environmental cleanup facilities.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxx and xxxi are included to help readers convert numeric values as needed for specific calculations and comparisons.

1.1. Background

The ORR Annual Site Environmental Report (ASER) is a summary of environmental data that characterizes environmental performance, lists environmental occurrences reported during the year, confirms compliance with environmental standards and requirements, and highlights significant environmental program activities. The ASER meets the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*, and its Attachment 2 (DOE 2012) regarding the preparation of an integrated annual site environmental report.

Summary results in this report are based on data collected before and continuing through 2022. Not all results of the environmental monitoring associated with ORR are reported here, and this is not intended to be a comprehensive monitoring report. Data collected for other site and regulatory purposes, such as environmental restoration and remedial investigation reports, waste management characterization sampling data, and environmental permit compliance data, are presented in other documents that have been prepared in accordance with applicable laws, regulations, policies, and guidance. These data are referenced herein as appropriate.

Environmental monitoring of ORR activities consists primarily of effluent monitoring and environmental surveillance. Effluent monitoring involves the collection and analysis of samples or measurements of liquid and gaseous effluents at the points of their release to the environment. These measurements allow quantification and official reporting of contaminant levels, assessment of public exposures to radiation (see Appendix E) and chemicals (see Appendix F), and demonstration of compliance with applicable standards and permit requirements. Environmental surveillance consists of direct measurement, collection, and analysis of samples taken from the site and its environs, exclusive of effluents. These surveillance activities provide information on contaminant concentrations in air, water, groundwater, soil, foods, biota, and other media. Other environmental surveillance data support environmental compliance and, when combined with data from effluent monitoring, also support chemical and radiation dose and exposure assessments of any potential effects of ORR operations on the local environment.

1.2. History of the Area around the Oak Ridge Reservation

Native Americans first inhabited the ORR area during the Woodland Period (c. 900 BC to AD 1000). Descendants of these early dwellers, whose ancestors were Neolithic and Stone Age people, still lived in the East Tennessee region when European settlers arrived in the late 1700s. The Cherokee Nation controlled the region at this time, but the 1791 Treaty of the Holston and the 1798 Treaty of Tellico allowed for European settlement, which forever altered the landscape. As settlements continued to grow in numbers, new counties were formed including Roane County and Anderson County in 1801. Early European settlers of the area lived on farms or in four small communities named Elza, Robertsville, Wheat, and Scarborough. These villages served primarily as gathering centers and usually contained one or two churches and a general store. About one thousand families inhabited the area in the early 1940s (Souza 2001, Hogan 2021).

In 1939 President Franklin D. Roosevelt received the famous Einstein-Szilard letter informing him that German scientists were working on a nuclear weapon. In utmost secrecy, he formed the Advisory Committee on Uranium, a team of scientists and military officials tasked with researching uranium's potential role as a weapon, which later evolved into the Office of Scientific Research and Development. After the United States was thrust into World War II following the Japanese attack on Pearl Harbor, the Manhattan Project emerged in 1942 as a full-scale program to build an atomic bomb. The super-secret code name gave no indication of the classified activities it carried out, and was so named because of the location of its original headquarters at 270 Broadway in New York City's Manhattan district. In the summer of 1943, the project moved to East

Tennessee where construction of America's first full-scale gaseous diffusion plant was underway, to fulfill the mission of isolating ^{235}U for the first atomic bomb.

The selection of the area now known as ORR for the nuclear development site was largely due to the vision of General Leslie Groves. The presence of abundant water from the Clinch River, a good source of labor in nearby Knoxville, railroad accessibility, and a supply of ample amounts of electricity from the Tennessee Valley Authority were viewed as key assets. Moreover, the parallel northeast-to-southwest valleys separated by 200-300 foot ridges were seen as useful to segregate the production areas and to provide protection in case of a catastrophe within any one of them. The federal government's acquisition of property for the uranium enrichment plants and a pilot scale nuclear reactor took place through eminent domain and immediately affected more than 3,000 individuals, many whose families had occupied homes and farms for generations. Although the families were compensated by the federal government, the urgency of the eviction was difficult for the landowners, who were forced to abandon their houses and crops. Many property owners also felt they were underpaid for the value of their homes and land, although many later successfully appealed the initial land valuations offered to them.

The site's wartime name was Clinton Engineer Works, and the area now known as Oak Ridge was the workers' city on the reservation's northern edge. Although Oak Ridge did not appear on any map until 1949, it quickly grew to a population of 75,000, becoming the fifth largest city in Tennessee. To the south of the residential area at the Y-12 Complex, an electromagnetic method separated ^{235}U from natural uranium. The K-25 gaseous diffusion plant was built on the reservation's western edge. Near the reservation's southwest corner, about 16 km (10 mi) from the Y-12 Complex, a third facility—known as X-10 or Clinton Laboratories—housed the experimental graphite reactor. X-10 served as a pilot scale facility for the larger plutonium production facilities built at Hanford, Washington (Olwell 1999, Broad 2007, Reed 2014, Johnson 2018).

The missions of the three major ORR installations have continued to evolve and operations have adapted to meet America's changing defense, energy, and research needs. Section 1.4 describes the current missions of these and several smaller ORR facilities and activities.

1.3. Location and Description

Situated in the Great Valley of East Tennessee between the Cumberland and Great Smoky Mountains, ORR borders the Clinch River (see Figures 1.1 and 1.2). The Cumberland Mountains are 16 km (10 mi) to the northwest and the Great Smoky Mountains are 51 km (31.6 mi) to the southeast. Except for the city of Oak Ridge, the land within 8 km (5 mi) of ORR is semirural and is used primarily for residences, small farms, and cattle pasture. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities. ORR encompasses a little over 13,000 hectares (32,258.54 acres) of mostly contiguous, federally owned land in Anderson and Roane Counties, and is under the management of DOE.

1.3.1. Population

As reported in *US Department of Energy FY 2020 Economic Impact in Tennessee* (East Tennessee Economic Council), ORR supported nearly 43,000 members of the region's labor force. The Vintage 2022 US Census Population Estimate for the Knoxville Metropolitan Statistical Area, including Oak Ridge, was 907,968.[1] The combined US Census Vintage 2022 Population Estimate for the 10 counties surrounding ORR (Anderson, Blount, Campbell, Cumberland, Knox, Loudon, McMinn, Monroe, Morgan, and Roane) was 1,053,497. Knoxville, the nearest major city, is about 40 km (25 mi) to the east and had a population of

[1] Vintage 2022 is the base population of the 2020 census plus estimates from the time series starting April 1, 2020 through July 1, 2022.

195,889, according to the US Census Vintage 2022 Population Estimate. Other municipalities within about 30 km (18.6 mi) of ORR include Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman.

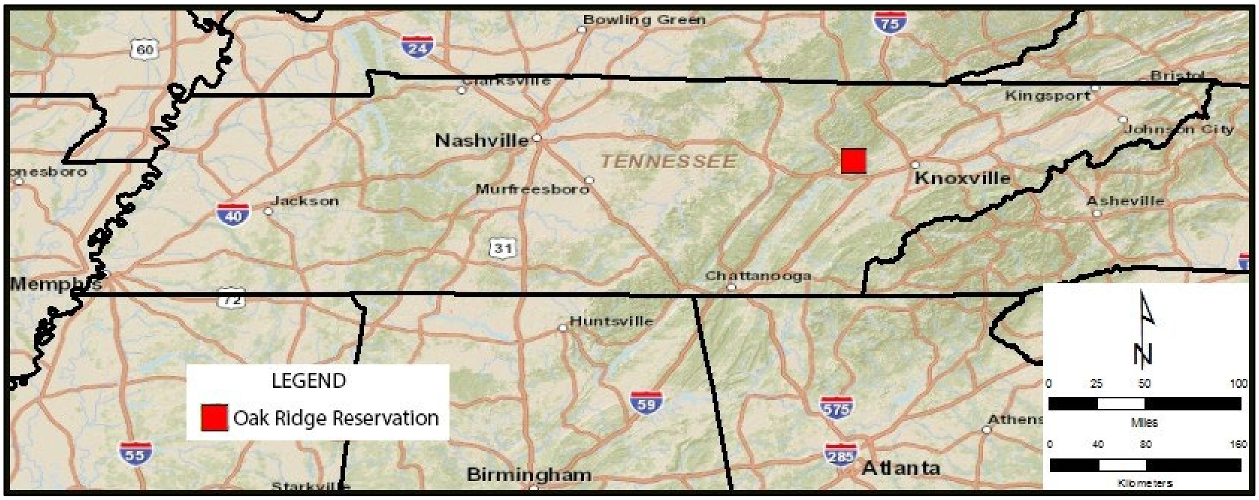


Figure 1.1. Location of the Oak Ridge Reservation in Tennessee

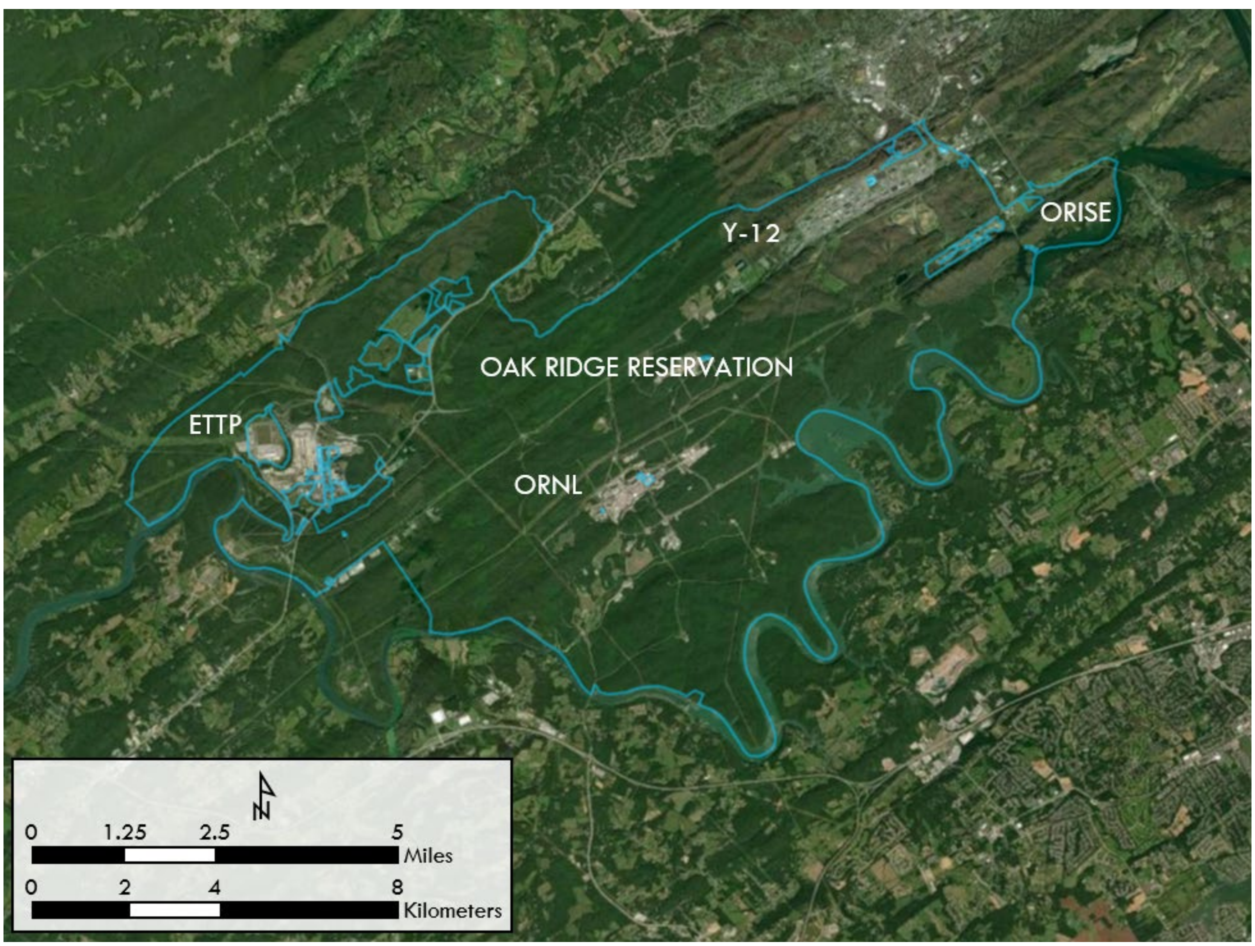


Figure 1.2. Map of the Oak Ridge Reservation

1.3.2. Climate

Although it features significant temperature changes between summer and winter, the climate of the Oak Ridge region qualifies as humid subtropical. The 30-year average temperature for 1991–2020 was 14.9°C (58.8°F). The average temperature for the Oak Ridge area in 2022 was 14.0°C (57.2°F). January temperatures were coldest in 2022, averaging -2.8°C (27.0°F). July was the warmest month, with an average temperature of 31.5°C (88.7°F). Monthly summaries of temperature averages, extremes, and 2022 values are provided in Appendix B, Table B.1.

Average annual precipitation in the Oak Ridge area for the 30-year period from 1991 to 2020 was 1,417.8 mm (55.82 in.), including about 14.5 cm (5.7 in.) of snowfall. Total precipitation during 2022 as measured at meteorological tower (MT)2 was 1482.0 mm (58.35 in.), which is 5 percent above the 30-year average. Monthly summaries of precipitation averages, extremes, and 2022 values can also be found in Appendix B, Table B.1.

The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2022 were greater than 89.2 percent for wind sensors at the ORNL sites (towers MT2, MT3, MT4, and MT12). All other (MT6, MT9, MT11, and MT13) instrument recoveries were above 81.7 percent for annual values.

The local ridge-and-valley terrain reduces average wind speeds at valley bottoms, resulting in frequent periods of calm or near-calm conditions, particularly during clear early morning hours in weak synoptic weather environments. Wind direction frequencies with respect to precipitation hours for the ORR towers may be reviewed **here** under the heading 2022 Annual Precipitation Wind Roses–Oak Ridge Reservation.

Detailed information on the climate of the Oak Ridge area is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006) and in Appendix B of this report. An in-depth analysis of wind patterns for ORR conducted from 2009 to 2011 and documented in “Wind Regimes in Complex Terrain in the Great Valley of Eastern Tennessee” (Birdwell 2011) is available online **here**.

1.3.3. Regional Air Quality

The US Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards set national ambient air quality standards (NAAQS) for key principal pollutants, also known as criteria pollutants. These key pollutants are sulfur dioxide, carbon monoxide, nitrogen dioxide, lead, ozone, particulate matter with an aerodynamic diameter less than or equal to 10 µm (PM_{10}), and fine particulate matter with an aerodynamic diameter less than or equal to 2.5 µm ($PM_{2.5}$). EPA evaluates NAAQS based on ambient, or outdoor, levels of the criteria pollutants. Areas that satisfy NAAQS are classified as attainment areas, and areas that exceed NAAQS for a particular pollutant are considered non-attainment areas for that pollutant.

As of August 30, 2017, EPA designated Anderson, Knox, Blount, and Roane Counties as attainment areas for the $PM_{2.5}$ air quality standard. (ORR is located in Anderson and Roane Counties.) The greater Knoxville and Oak Ridge area is a NAAQS attainment area for all other criteria pollutants for which EPA has made attainment designations (EPA 2022).

1.3.4. Surface Water

The ORR area comprises a series of drainage basins or troughs containing numerous small streams that feed the Clinch River. Surface water on ORR drains into a series of tributaries, streams, or creeks in different watersheds. Each of these watersheds drains into the Clinch River, which in turn flows into the Tennessee River. The Tennessee Valley Authority reported 55 inches of precipitation in 2022 for the Tennessee River Valley region (TVA 2023). Although this amount of rainfall was about 28 percent less than the record-breaking 70.36 inches of rainfall in 2020, it was the sixth straight year of exceeding the average annual rainfall of 51 inches in this region.

The largest of the ORR drainage basins is Poplar Creek, which receives drainage from a 352 km^2 (136 mi^2) area including the northwestern sector of ORR. Flow is from northeast to southwest, roughly through the center of ETTP, and the creek discharges directly into the Clinch River.

East Fork Poplar Creek, which discharges into Poplar Creek east of ETTP, originates within the Y-12 Complex and flows northeast along the south side of the complex. Bear Creek also originates within the Y-12 Complex and flows southwest. Bear Creek is affected by storm water runoff, groundwater infiltration, and tributaries that drain former waste disposal sites in the Bear Creek Valley Burial Grounds Waste Management Area and the current Environmental Management Waste Management Facility (EMWMF).

Both the Bethel Valley and Melton Valley portions of ORNL are in the White Oak Creek (WOC) drainage basin, which covers 16.5 km^2 (6.4 mi^2). The headwaters of WOC originate on Chestnut Ridge, north of ORNL and near the Spallation Neutron Source site. The creek flows west along the southern boundary of the developed area of the ORNL site, then flows southwest through a gap in Haw Ridge to the western portion of Melton Valley, forming a confluence with Melton Branch. The headwaters of Melton Branch originate in Melton Valley east of the High Flux Isotope Reactor complex, and the area of the drainage basin is about 3.8 km^2 (1.47 mi^2). The waters of WOC enter White Oak Lake, an impoundment formed by White Oak Dam. Water flowing over White Oak Dam enters the Clinch River after passing through the WOC embayment area.

1.3.5. Geological Setting

ORR is in the Tennessee portion of the Valley and Ridge Physiographic Province, which is part of the southern Appalachian fold-and-thrust belt. Thrust faulting, associated fracturing of the rock, and differential erosion rates created a series of parallel valleys and ridges that trend southwest to northeast.

Two geologic units on ORR, the Knox Group and the Maynardville Limestone of the Upper Conasauga Group, consist of dolostone and limestone, respectively, and make up the most significant water-bearing hydrostratigraphic units in the Valley and Ridge Province (Zurawski 1978) and on ORR. Composed of moderately soluble minerals, these bedrock formations are prone to dissolution as slightly acidic rainwater and percolating recharge water come in contact with the mineral surfaces. This dissolution increases fracture apertures and can, under some circumstances, form caverns and extensive solution conduit networks. This hydrostratigraphic unit is locally known as the Knox Aquifer. A combination of fractures and solution conduits in the aquifer control flow over substantial areas and large quantities of water may move long distances. Active groundwater flow can occur at substantial depths (91.5 to 122 m, or 300 to 400 ft) in the Knox Aquifer. The Knox Aquifer is the primary source of groundwater (base flow) for many streams, and most large springs on ORR receive discharge from the Knox Aquifer. Yields of some wells penetrating larger solution conduits exceed 3,785.4 liters per minute (1,000 gallons per minute). The high productivity of the Knox Aquifer results from the combination of its abundant and sometimes large solution conduit systems and frequently thick overburden soils that promote recharge and storage of groundwater.

The remaining geologic units on ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) are composed predominantly of shale, siltstones, and sandstones with a subordinate and locally variable amount of carbonate bedrock. These formations are primarily composed of insoluble minerals such as clays and quartz that were derived from ancient continental erosion. Groundwater occurs in and moves through fractures in these bedrock units. Groundwater availability in such settings depends on the abundance and interconnectedness of fractures and the connection of fractures to sources of recharge, such as alluvial soils along streams, which can provide some sustained infiltration. The shale and sandstone formations are the poorest aquifers in the Valley and Ridge Province

(Zurawski 1978). Well yields are generally low in the Rome, Conasauga, and Chickamauga bedrock formations except in localized areas where carbonate beds may provide greater groundwater storage than adjacent clastic bedrock. Detailed information on ORR groundwater hydrology and flow is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006).

1.3.6. Natural, Cultural, and Historic Resources

ORR has an exceptional variety of natural, cultural, and historic resources. Ongoing efforts continue to focus on preserving the rich diversity of these resources.

1.3.6.1. Wetlands

Wetlands occur across ORR at low elevations, primarily in riparian zones of headwater streams and receiving streams and in the Clinch River embayments, as shown in Figure 1.3. Surveys of wetland resources presented in *Identification and Characterization of Wetlands in the Bear Creek Watershed* (Rosensteel and Trettin 1993), *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Rosensteel 1996), and *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee* (Rosensteel 1997) serve as references to support wetland assessments for upcoming projects and activities.

About 243 hectares (600 acres) of potential wetlands (jurisdictional and non-jurisdictional wetland areas) have been identified on ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands. Wetlands identified to date range from several square meters at small seeps and springs to about 10 hectares (25 acres) at White Oak Lake. The Tennessee Department of Environment and Conservation's wetland mitigation aquatic resource alteration permits, required by Section 401 of the Clean Water Act (CWA 1972), entail monitoring restored or created wetland mitigation sites for five years. Activities and conditions in and around ORR wetlands are verified by site inspections when appropriate.

1.3.6.2. Wildlife and Endangered Species

Animals listed as species of concern by state, federal, or international organizations and known to have occurred on the reservation (excluding the Clinch River bordering the reservation) are listed, along with their status, in Table 1.1. Some of these, such as hellbender, have been seen only once or a few times; others, including wood thrush, are comparatively common and widespread on ORR. As of April 2023, Tennessee had 58 species listed under the federal Endangered Species Act (ESA 1973), including 25 endangered and 33 threatened species. The complete Tennessee Threatened and Endangered List–New Rules is available **here** (TDEC 2023a).

Birds, fish, reptiles and amphibians, and aquatic invertebrates are the most thoroughly surveyed animal groups on ORR. Nevertheless, the only federally listed animal species observed on ORR in recent years are mammals. The only federally listed animal species known to occur on the ORR in recent years are bat species. Endangered gray bats have been detected in acoustic surveys and mist net captures for more than 30 years. Endangered Indiana bats and northern long-eared bats have been detected in acoustic surveys and mist net captures since 2013 (McCracken et al. 2015). Surveys conducted in 2022 indicate use of several caves on the ORR by gray bats and other bat species. Suitable roosting and foraging habitat for the three federally listed bat species is abundant across the ORR. Additional bat species found on the ORR include tricolored bat (state-listed as threatened and proposed for federal listing), little brown bat (state-listed as threatened and under consideration for federal listing), Rafinesque's big-eared bat (state-listed as in need of management), and eastern small-footed bat (state-listed as in need of management) (TDEC 2023a, TDEC 2023b).

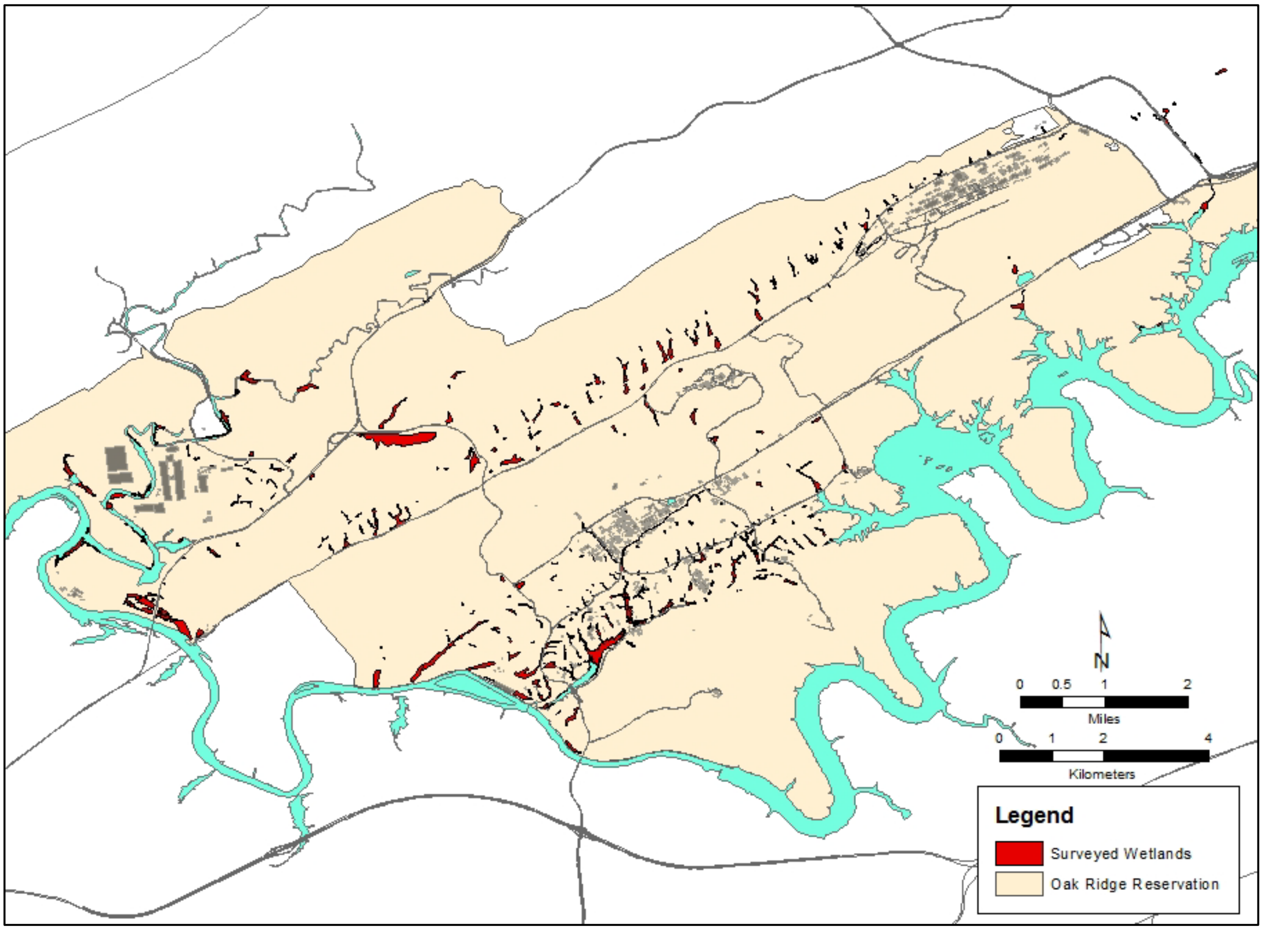


Figure 1.3. Location of Oak Ridge Reservation wetlands

Table 1.1. Animal species of special concern reported on ORR[a]

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
FISH					
Phoxinus tennesseensis	Tennessee dace		NM	S3	
AMPHIBIANS AND REPTILES					
Cryptobranchus alleganiensis	Hellbender		E	S3	
Hemidactylium scutatum	Four-toed salamander		NM	S3	
Ophisaurus attenuatus longicaudus	Eastern slender glass lizard		NM	S3	
Pituophis melanoleucus	Northern pinesnake		T	S3	
BIRDS					
Swans, Geese, and Ducks					
Branta canadensis	Canada goose	BMC, OA		S5	
Aix sponsa	Wood duck	BMC		S5	
Mareca strepera	Gadwall	BMC		S4	

Table 1.1. Animal species of special concern reported on ORR[a] (continued)

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
Mareca americana	American wigeon	BMC		S4	
Anas rubripes	American black duck	BMC		S3	IM
Anas platyrhynchos	Mallard	BMC		S5	
Spatula discors	Blue-winged teal	BMC		S2	
Anas crecca	Green-winged teal	BMC		S4	
Spatula clypeata	Northern shoveler	BMC		S4	
Anas acuta	Northern pintail	BMC		S4	
Aythya valisineria	Canvasback	BMC		S3	
Aythya americana	Redhead	BMC		S4	
Aythya collaris	Ring-necked duck	BMC		S5	
Aythya affinis	Lesser scaup	BMC		S4	
Grebes					
Podilymbus podiceps	Pied-billed grebe	BMC		S4	
Podiceps auritus	Horned grebe	BMC		S4	
Frigatebirds, Boobies, Cormorants					
Nannopterum auritum	Double-crested cormorant	BMC, OA		S2	
Bitterns and Herons					
Ixobrychus exilis	Least bittern	BMC	NM	S2	
Egretta caerulea	Little blue heron	BMC	NM	S2	
Nycticorax nycticorax	Black-crowned night heron	BMC	NM	S2	
Butorides virescens	Green heron			S4	MA
Mycteria americana	Wood stork	T		S3	
Kites, Hawks, Eagles, and Allies					
Haliaeetus leucocephalus	Bald eagle	BMC[e]		S3	
Rails, Gallinules, and Coots					
Rallus limicola	Virginia rail	BMC		S1	
Porzana carolina	Sora	BMC		S1	
Fulica americana	American coot	BMC		S2	
Tringa solitaria	Solitary sandpiper	BMC, BCC		S5	
Tringa flavipes	Lesser yellowlegs	BMC, BCC		S5	
Scolopax minor	American woodcock	BMC		S4	MA
Grouse, Turkey, and Quail					
Colinus virginianus	Northern bobwhite	BMC, BCC, E		S2	CR
Pigeons and Doves					
Zenaida macroura	Mourning dove	BMC		S5	
Cuckoos and Roadrunners					
Coccyzus americaus	Yellow-billed cuckoo	BMC, BCC, T		S4	IM

Table 1.1. Animal species of special concern reported on ORR[a] (continued)

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
Goatsuckers					
Antrostomus carolinensis	Chuck-will's widow	BMC, BCC		S3	IM
Antrostomus vociferus	Eastern whip-poor-will	BMC, BCC		S3	IM
Chordeiles minor	Common nighthawk	BCC		S4	IM
Swifts					
Chaetura pelagica	Chimney swift	BCC		S5	IM
Kingfishers					
Megaceryle alcyon	Belted kingfisher	BCC		S5	MA
Woodpeckers					
Melanerpes erythrocephalus	Red-headed woodpecker	BMC, BCC		S4	PR
Colaptes auratus	Northern flicker	BMC		S5	MA
Tyrant Flycatchers					
Contopus virens	Eastern wood-pewee			S5	MA
Empidonax virescens	Acadian flycatcher			S5	MA
Contopus cooperi	Olive-sided flycatcher	BMC, BCC		S1	PR
Empidonax trailii	Willow flycatcher	BMC, BCC, E		S2	
Swallows					
Progne subis	Purple martin			S5	MA
Hirundo rustica	Barn swallow			S5	MA
Kinglets, Gnatcatchers, and Thrushes					
Hylocichla mustelina	Wood thrush	BMC, BCC	NM	S4	MA
Shrikes					
Lanius ludovicianus	Loggerhead shrike	BMC, BCC, E	NM	S1	
Wood Warblers					
Vermivora chrysoptera	Golden-winged warbler	BMC, BCC	T	S3	IM
Setophaga cerulea	Cerulean warbler	BMC, BCC	NM	S3	IM
Setophaga discolor	Prairie warbler	BMC, BCC		S3	MA
Mniotilta varia	Black-and-white warbler			S4	MA
Protonotaria citrea	Prothonotary warbler	BMC, BCC		S4	MA
Geothlypis formosa	Kentucky warbler	BMC, BCC		S4	MA
Cardellina canadensis	Canada warbler	BMC, BCC		S3	MA
Icteria virens	Yellow-breasted chat	BCC		S4	MA
Tanagers					
Piranga rubra	Summer tanager	BMC		S4	MA
Towhees, Sparrows, and Allies					
Pipilo erythrophthalmus	Eastern towhee			S5	MA
Spizella pusilla	Field sparrow	BMC, BCC		S4	MA
Ammodramus savannarum	Grasshopper sparrow	BMC, BCC		S4	IM
Ammodramus henslowii	Henslow's sparrow	BMC, BCC	T	S1	IM

Table 1.1. Animal species of special concern reported on ORR[a] (continued)

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
MAMMALS					
Myotis grisescens	Gray bat	E	E	S2	
Myotis lucifugus	Little brown bat[f]		T	S3	
Myotis sodalis	Indiana bat[g]	E	E	S1	
Myotis septentrionalis	Northern long-eared bat	E	E	S1	
Myotis leibii	Eastern small-footed bat		NM	S2	
Perimyotis subflavus	Tri-colored bat[f]		T	S2	
Corynorhinus rafinesquii	Rafinesque's big-eared bat		NM	S3	
Sorex dispar	Long-tailed shrew		NM	S2	

[a] *Land and surface waters of the Oak Ridge Reservation (ORR) exclusive of the Clinch River, which borders ORR.*
[b] *Status codes:*
E = endangered (TDEC 2023a, TDEC 2023b, FWS 2021)
T = threatened (TDEC 2023a, TDEC 2023b, FWS 2021)
S1 = critically imperiled (NatureServe 2023, TDEC 2023b)
S2 = imperiled (NatureServe 2023, TDEC 2023b)
S3 = vulnerable (NatureServe 2023, TDEC 2023b)
S4 = apparently secure (NatureServe 2023, TDEC 2023b)
S5 = secure (NatureServe 2023, TDEC 2023b)
BMC = Birds of management concern (FWS 2011)
BCC = Birds of conservation concern (FWS 2021)
NM = in need of management (TDEC 2023a, TDEC 2023b)
OA = overly abundant (FWS 2011)
CR = critical recovery for Bird Conservation Region (BCR) 28 (Appalachian Mountains Bird Conservation Region) (PIF 2021)
IM = immediate management for BCR28 (PIF 2021)
MA = management attention for BCR28 (PIF 2021)
PR = planning and responsibility for BCR28 (PIF 2021)
[c] *NatureServe works with over 60 network organizations and over 1,000 conservation scientists to collect, aggregate, and standardize biodiversity statistics.*
[d] *Partners in Flight (PIF) is an international organization devoted to conserving bird populations in the Western Hemisphere.*
[e] *The bald eagle was federally delisted effective August 9, 2007.*
[f] *Under review for federal listing.*
[g] *A single specimen was captured in a mist net bordering the Clinch River in June 2013.*

Birds recorded on ORR and its boundary waters include the 228 species documented by Roy et al. (2014) plus the cackling goose (*Branta hutchinsii*), purple gallinule (*Porphyrio martinicus*), American bittern (*Botaurus lentiginosus*) and federally threatened wood stork (*Mycteria Americana*) for a total of 235 species. Most of these species are protected under the Migratory Bird Treaty Act (MBTA 1918) and Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds* (EO 2001). DOE's updated memorandum of understanding on migratory birds with the US Fish and Wildlife Service (FWS) (DOE-FWS 2013) strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and FWS.

Breeding bird surveys conducted along varying numbers of up to 10 routes on ORR provide data for the Partners in Flight Program. Public nature walks normally organized by ORNL did not take place in 2022 due to the COVID-19 pandemic. In previous years, these walks began in the late winter and carried through mid-summer, and covered topics such as the American woodcock (shown in Figure 1.4), birds of prey, frog calls, inventories of reptiles and amphibians, and the history of ORR. In past years ORR has been nominated for the Presidential Migratory Bird Federal Stewardship Award. A technical manuscript, *Oak Ridge Reservation Bird Records and Population Trends* (Roy et al. 2014), documents known ORR bird records since 1950 and population trends for 32 species of birds.

Several state-listed bird species such as the golden-winged warbler, cerulean warbler, and little blue heron are uncommon migrants or visitors to the reservation. The cerulean warbler, listed by the state as in need of management, often appears during the breeding season on ORR but is currently listed as a potential breeding bird on the reservation (Roy et al. 2014) as its actual breeding status is still uncertain.

Source: Sarah Darling, ORNL

Figure 1.4. American woodcock fledgling on ORR

The bald eagle (Figure 1.5), which was removed from the federal list of threatened and endangered species on August 9, 2007, is a year-round resident in Tennessee, though it can be difficult to find on the reservation from September through November. At least three bald eagle nests were confirmed on the reservation in 2022, all located along the Clinch River/Melton Hill Lake, between Gallaher Bend and Melton Hill Dam. One nest was first observed in 2011 near the mouth of Walker Branch and has remained active every year since, and another nest near Melton Hill Dam has been documented by an area nature photographer for several years. More than two dozen eaglets fledged in East Tennessee during 2017, according to bald eagle information published by the East Tennessee State University College of Arts and Sciences Biological Sciences department.

Other bird species of interest include the migratory wood thrush and barn swallow which have been observed nesting on the reservation. The Lincoln's sparrow (*Melospiza lincolnii*) (no listed status) was sighted on ORR in May 2014. Barn owls were documented nesting on the reservation in 2019.

Source: Kelly Roy, ORNL

Figure 1.5. Bald eagle photographed on ORR

Figure 1.6. Purple gallinule caught on a trail surveillance camera at ETTP in 2017

Uncommon birds for ORR recorded in recent years include several species associated with wetland habitats. Due to efforts in the early 2000s to mitigate ETTP's K1007 P-1 pond into high-quality wildlife habitat, Greater scaup (*Aythya marila*) and redhead (*Aythya americana*) made appearances in 2022. The common gallinule (*Gallinula galeata*), seen as recently as October 2022, is a fairly common migrant throughout Tennessee that is seldom seen on ORR. The least bittern (*Ixobrychus exilis*), an uncommon migrant and summer resident in Tennessee, was documented in 2022 at P-1 Pond on ETTP. While collaborating on detection methodologies for secretive marsh birds, researchers from ORNL and Charles Sturt University in New South Wales, Australia, photographed a purple gallinule (*Porphyrio martinicus*) on a trail camera at the Heritage Center Greenway Powerhouse Trail in 2017 (Figure 1.6). This was the first documented appearance of a purple gallinule on ORR.

ORNL increased monitoring of amphibians and reptiles over the past two years. The ORR contains some of the highest densities of state-listed four-toed salamanders (*Hemidactylium scutatum*) in eastern Tennessee, which are considered by the state as in need of management. Several of their largest subpopulations on the ORR occur in areas that are slated for development. ORNL has also documented what appear to be state-listed black mountain salamanders (*Desmognathus welteri*, considered by the state as in need of management) on the ORR, just south of the Horizon Center. Two state-listed reptiles have inhabited the ORR: the northern pinesnake (*Pituophis melanoleucus melanoleucus*, state-listed as threatened) and the eastern slender glass lizard (*Ophisaurus attenuatus longicaudus*, state-listed as in need of management). However, there is limited evidence to suggest the number of either species on the reservation.

Several fish species listed and noted for management concern are known to inhabit areas in and around the ORR. One fish species, the spotfin chub (*Erimonax monachus*), which is listed as threatened by both the state and the federal government, has been sighted and collected in the city of Oak Ridge and may be present on ORR. The tangerine darter (*Percina aurantiaca*), a species listed by the state as in need of management, has also been recorded in close proximity to ORR. The lake sturgeon (*Acipenser fulvescens*), state-listed as endangered, is known to inhabit the adjacent Clinch River. The Tennessee dace, listed by the state as in need of management, appears in the Bear Creek watershed, tributaries to the lower East Fork watershed, and Ish Creek. The Tennessee dace also occurs in some sections of Grassy Creek upstream of Scientific Ecology Group, Inc. and International Technology Corporation at Clinch River kilometer 23, south of west Bear Creek Road near Grassy Creek sampling point 1.9.

1.3.6.3. Threatened and Endangered Plants

Four plant species known to be on ORR (spreading false foxglove, Appalachian bugbane, tall larkspur, and butternut) have been under review for federal listing and were previously listed under the C2 candidate designation. FWS now informally refers to these as special concern species.

The state of Tennessee lists 16 plant species occurring on ORR as endangered, threatened, or of special concern; these are included in Table 1.2. An additional 10 threatened, endangered, or special concern species occur in the area and may be present on ORR, although currently unconfirmed. These are also included in Table 1.2. Other plant populations currently under study on ORR may be added to the table in future years (TDEC 2021, TDEC 2023b).

Table 1.2. Vascular plant species of special concern sighted or reported on or near ORR

Species	Common name	Habitat on ORR	Status/rank code[a,b]
Currently known to be or previously reported on ORR			
Aureolaria patula	Spreading false foxglove	River bluff	S, S3
Berberis canadensis	American barberry	Rocky bluff	S, S2
Bolboschoenus fluviatilis	River bulrush	Wetland	S, S1
Delphinium exaltatum	Tall larkspur	Barrens and woodlands	E, S2
Diervilla lonicera	Northern bush-honeysuckle	Rocky river bluff	T, S2
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S, S2
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S, S2
Eupatorium godfreyanum	Godfrey's thoroughwort	Dry woods edge	S, S1
Fothergilla major	Mountain witch-alder	Woods	T, S2
Helianthus occidentalis	Naked-stem sunflower	Barrens	S, S2
Juglans cinerea	Butternut	Lake shore	T, S3
Juncus brachycephalus	Small-head rush	Open wetland	S, S2
Liparis loeselii	Fen orchid	Forested wetland	T, S1
Panax quinquefolius	American ginseng	Rich woods	S, S3
Platanthera flava var. herbiola	Tuberculed rein-orchid	Forested wetland	T, S2
Spiranthes lucida	Shining ladies'-tresses	Boggy wetland	T, S1
Rare plants that occur near and could be present on ORR			
Agalinis auriculata	Earleaf false foxglove	Calcareous barren	E, S2
Allium burdickii[c]	Narrow-leaf Ramps	Moist woods	T, CE, S1
Allium tricoccum[c]	Ramps	Moist woods	S, CE, S1
Lathyrus palustris	Marsh pea	Moist meadows	S, S1
Liatris cylindracea	Slender blazing star	Calcareous barren	T, S2
Lonicera dioica	Mountain honeysuckle	Rocky river bluff	S, S2
Meehania cordata	Heartleaf meehania	Moist calcareous woods	T, S2
Pedicularis lanceolata	Swamp lousewort	Calcareous wet meadow	S, S1

Table 1.2. Vascular plant species of special concern sighted or reported on or near ORR (continued)

Species	Common name	Habitat on ORR	Status/rank code[a,b]
Pseudognaphalium helleri	Heller's catfoot	Dry woodland edge	S, S2
Pycnanthemum torreyi	Torrey's mountain-mint	Calcareous barren edge	E, S1

[a] State status codes (TDEC 2021):
CE = Status due to commercial exploitation
E = Endangered in Tennessee
S = Special concern in Tennessee
T = Threatened in Tennessee
[b] State conservation status (NatureServe 2023):
S1 = Critically imperiled
S2 = Imperiled
S3 = Vulnerable
[c] Ramps have been reported near ORR, but there is not sufficient information to determine which of the two species is present or whether the occurrence may have been the result of planting.
Acronym: *ORR = Oak Ridge Reservation*

1.3.6.4. Historical and Cultural Resources

Efforts continue to preserve ORR's rich prehistoric and historic cultural resources. Compliance with the National Historic Preservation Act of 1966 (NHPA 1966) is maintained in conjunction with the National Environmental Policy Act (NEPA 1969) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA 1980). The scope of proposed actions is reviewed in accordance with the Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee (DOE 2001). ORR has several facilities that were eligible for inclusion on the National Register of Historic Places (NRHP), a National Park Service program to identify, evaluate, and protect historic and archeological resources in the United States, as well as numerous facilities that were not eligible for NHRP inclusion. The reservation contains more than 44 known prehistoric sites (primarily archeological evidence of former structures), 254 historic pre-World War II structures, 32 cemeteries, and several historically significant structures from the Manhattan Project era.

The National Defense Authorization Act of 2015 (NDAA 2014), passed by Congress and signed into law on December 19, 2014, included provisions authorizing the Manhattan Project National Historical Park. An agreement by the Secretaries of Energy and Interior established the Manhattan Project National Historical Park on November 10, 2015 (DOE-DOI 2015). The Park includes facilities and lands in Los Alamos, New Mexico, and Hanford, Washington, as well as Oak Ridge. On ORR, the National Park includes the X-10 Graphite Reactor, Buildings 9731 and 9204-3 at the Y-12 Complex, and the K-25 Building Site at ETTP.

The X-10 Graphite Reactor building has been a National Historic Landmark since 1966, and has been open for public access in various ways since that time. Enhancing access and improving the visitor experience are important DOE objectives as it moves forward in implementing the National Park.

Occasional public access to Buildings 9731 and 9204-3 at the Y-12 Complex last occurred on November 12, 2015, when DOE facilitated public tours of both buildings to celebrate the establishment of the National Park. By helping to develop the National Park, DOE aims to enhance safe access to these buildings while protecting the agency's mission capabilities.

A memorandum of agreement signed in 2012 between DOE Oak Ridge Office, the State Historic Preservation Officer, the Advisory Council on Historic Preservation, the City of Oak Ridge, and the East Tennessee Preservation Alliance ensures consistent interpretation of site historic properties at ETTP. The memorandum of agreement is being implemented through the National Historic Preservation project that developed the K-25 History Center, and serves to highlight the historic aspects of ETTP and of the communities that were displaced during the construction of the site. On December 16, 2022, the US Army Corps of Engineers issued a solicitation for construction bids to select a contractor to build the K-25 Viewing Platform overseeing the building's original footprint. Exhibits inside the K-25 Viewing Platform will enrich the visitor experience by providing photos, facts, view scopes, and a scale model of the K-25 Building.

The K-25 History Center and Viewing Platform complement the Manhattan Project National Historic Park established in 2015, which includes the footprint of the former K-25 Building (DOE 2015). The National Park Service is assisting in historic interpretation of the site, although the K-25 Building site is already undergoing extensive historic interpretation activities separate and independent from the National Park. As part of the activities to establish the park, DOE launched the K-25 Virtual Museum which details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, which can be viewed **here**.

In addition to the X-10 Graphite Reactor, six additional historic ORR properties are listed individually in the planning for a History Center:

- Freels Bend Cabin
- New Bethel Baptist Church and Cemetery
- Oak Ridge Turnpike Checking Station
- George Jones Memorial Baptist Church and Cemetery
- Bear Creek (Scarboro) Road Checking Station
- Bethel Valley Road Checking Station

Although not yet included on the NRHP, an area known as the Wheat Community African Burial Grounds was dedicated in June 2000, and a memorial monument was erected.

ORNL and Y-12 programmatic agreements and memorandums of agreement among DOE, the State of Tennessee, the Advisory Council on Historic Preservation, and consulting parties serve to provide a system of review for projects that may potentially affect historic and archaeological resources on the ORR. The ORNL and Y-12 programmatic agreements are currently being updated to reflect new architectural building surveys and revisions to each site's Historic Preservation Plans. In 2022, a new memorandum of agreement was executed to address planned mitigation for the planned demolition of Buildings 3005, 3009, 3010, 3010A, 3107, and 9213 on the ORR. These historic contaminated buildings were determined to pose excessive environmental risks (DOE-TSHPO 2022).

1.4. Oak Ridge Sites

ORR includes a number of sites critical to the mission of DOE. Eight of these sites are described in this section: ORNL, the Y-12 Complex, ETTP, EMWMF, the Oak Ridge National Environmental Research Park, ORISE, NNSA OST AOEC, and the TWPC.

United Cleanup Oak Ridge LLC (UCOR) is the new lead DOE ORR cleanup contractor as of May 2022. The company is a new configuration of the former UCOR, and is now led by Amentum, Jacobs, and Honeywell. The new contract expands cleanup operations at ORNL and Y-12, in addition to the continuing final soil and groundwater remediation at ETTP. The TWPC also became a part of UCOR in October 2022.

The scope of UCOR activities includes characterization and cleanup of former production facilities, building pads, and impacted environmental media; management and maintenance of active ORR facilities; long-term management of inactive waste disposal sites; and water quality monitoring. The *2022 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2022) provides detailed information on UCOR activities at the ORR and is available **here**.

1.4.1. Oak Ridge National Laboratory

ORNL (shown in Figure 1.7) is managed for DOE by UT-Battelle, LLC, a partnership between the University of Tennessee and the Battelle Memorial Institute. The largest science and energy national laboratory in the DOE system, ORNL conducts basic and applied research to deliver transformative solutions to compelling problems in energy and security. The laboratory is home to several of the world's top supercomputers and is a leading neutron science and nuclear energy research facility that includes the Spallation Neutron Source and the High Flux Isotope Reactor. ORNL hosts a DOE leadership computing facility, home of the Frontier supercomputer; one of DOE's nanoscience centers, the Center for Nanophase Materials Sciences; one of DOE's energy research centers; and the Bio-Energy Science Center. UT-Battelle, LLC also manages the US ITER project (formerly the International Thermonuclear Experimental Reactor project) for DOE.

Formerly known as X-10, ORNL was established in 1943 to support the Manhattan Project. From an early focus on chemical technology and reactor development, ORNL's research and development portfolio broadened to include programs supporting DOE missions in scientific discovery and innovation, clean energy, and nuclear security. Today ORNL employs about 5,800 workers, and the laboratory's extensive capabilities in scientific discovery and innovation are applied to the delivery of mission outcomes for DOE and other sponsors.

Isotek Systems, LLC (Isotek) began processing operations on the remaining inventory of ^{233}U stored at ORNL in 2022. Crews began the campaign by transferring a canister of ^{233}U oxide from Building 3019 into an adjacent, newly upgraded hot cell facility for downblending processing. The heavily shielded hot cells protect workers and allow them to handle the material using remote manipulators. This upcoming phase will enable Isotek to enhance productivity by processing larger amounts of ^{233}U and extracting more medical isotopes than the previous phase that involved processing material in glove boxes. They also completed an operational readiness review that will allow for the processing and disposal of the remaining high-dose ^{233}U inventory stored at ORNL.

UCOR continued to carry out characterization and deactivation of former reactors and isotope production facilities in 2022, many which are slated for demolition in 2023. Deactivation activities took place at multiple facilities, including the Low Intensity Test Reactor, the Oak Ridge Research Reactor, and a group of buildings called "Isotope Row" that were constructed in the 1950s and early 1960s to process radioisotopes. This work focuses on asbestos, lead, and universal waste removal to eliminate high-risk contaminated structures and to open up space for future research missions at ORNL.

Demonstrating environmental excellence through high-level policies that clearly state expectations for continual improvement, pollution prevention, and compliance with regulations and other requirements is a priority at ORNL. Implementing an environmental management system (EMS) allows environmental impacts to be systematically measured, managed, and controlled. UT-Battelle's EMS is a fully integrated set of environmental management services for UT-Battelle activities and facilities. Services include pollution prevention, waste management, effluent management, regulatory review, reporting, permitting, and other environmental management programs.

Examples of environmental performance optimization during fiscal year (FY) 2022 include the following:

- The calculated energy use intensity was 234,194 Btu/gross square foot. This is a 2.8 percent decrease from 2021, and a cumulative reduction of 35.6 percent since the DOE baseline target year of FY 2003.

Figure 1.7. Aerial view of the Oak Ridge National Laboratory

- The diversion rate for municipal solid waste at ORNL was 70.8 percent in FY 2022. Sustainable Campus Initiative staff plan to work with Procurement staff to continue to employ terms and conditions within construction contracts to manage construction waste and recycling.
- UT-Battelle implemented 26 ongoing and new pollution prevention projects at ORNL during 2022, which eliminated more than 3.6 million kg of waste.
- Eighty-two percent of all ORNL vehicles are alternative fuel vehicles, with 90 percent of all replacements over the past two fiscal years being alternative fuel or electric vehicles. One hundred percent of light-duty vehicles operate on alternative fuels, exceeding DOE fleet management goals.

See Section 5.2.1.4 for additional details on ORNL environmental sustainability performance data for FY 2022.

1.4.2. Y-12 National Security Complex

The Y-12 Complex (shown in Figure 1.8) was originally constructed as part of the World War II Manhattan Project and began operations in November 1943. The first site mission was the separation of ^{235}U from natural uranium by an electromagnetic separation process. At its peak in 1945, more than 22,000 workers were employed at the Y-12 site.

Today, as part of the NNSA Nuclear Security Enterprise, the Y-12 Complex is a leader in materials science and precision manufacturing. As the main storage facility for the nation’s supply of enriched uranium, Y-12 serves as the nation’s only source of enriched uranium nuclear weapons components and provides enriched uranium for the US Navy. The Y-12 Complex also supports efforts to reduce the risk of nuclear proliferation and performs complementary work for other government agencies.

In December 2017, UCOR issued the *Construction Execution/Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee* (UCOR 2017). The Outfall 200 Mercury Treatment Facility is a vital piece of infrastructure that will open the door for demolition of Y-12's large, deteriorated, mercury-contaminated facilities and subsequent soil remediation by providing a mechanism to limit potential mercury releases into Upper East Fork Poplar Creek. The west end Y-12 storm drain system discharges to Upper East Fork Poplar Creek at Outfall 200, and mercury from historic operations is present at Outfall 200 where storm water enters Poplar Creek.

In FY 2022, progress continued on construction of the Outfall 200 Mercury Treatment Facility, DOE Environmental Management research in new remediation technologies to address mercury releases into the environment from past operations, and contracting for the first mercury remediation technology demonstration. Shoring and major excavations were completed at the headworks site. Crews continued placing concrete pads and walls of the treatment plant. Crews also began erecting structural steel and continued installing underground utilities. The new facility is slated to be operational in 2025. Scientists have also prepared a report titled *Mercury Remediation Technology Development for Lower East Fork Poplar Creek—FY 2021 Update* (Mathews et al. 2021) that provides findings from studies at the Aquatic Ecology Laboratory. As part of the technology demonstration initiative, an existing ORR facility is being evaluated for the necessary modifications to carry out the proposed demonstration of mercury treatment technologies.

In FY 2022, UCOR workers finished removing the remaining slabs at the now demolished Biology Complex, readying the land for transfer to Y-12. The land is expected to be the site of the new Lithium Processing Facility. Crews completed backfilling and seeding the portion of the site where the last two buildings (Buildings 9207 and 9210) once stood. Subsequently, slabs remaining from previous demolition of buildings at the location were removed and their footprints backfilled and graveled. Between removal of those slabs and the slabs at Buildings 9207 and 9210, more than 6,141 yd^3 of waste and debris were removed.

Y-12's environmental policy reflects a commitment to providing sound environmental stewardship practices through the implementation of its EMS. At the end of FY 2022, the Y-12 Complex had achieved seven of eleven established environmental targets driven by the EMS, and the remaining targets were carried into future years. Highlights of achievements include the following (further details and additional successes are presented in Chapter 4 of this report):

- **Clean air:** Y-12 completed a project to seal the Stack 11 basin and identified improved mission operations and improvements to air emissions.
- **Energy efficiency:** Y-12 completed a project to upgrade power lines to 13.8-kV service on Second and Third Street, as well as projects to upgrade cooling towers and heating, ventilation, and air conditioning systems in two areas.
- **Hazardous materials:** A project to disposition and ship legacy mixed waste according to the site treatment plan continued, and 50 items were shipped in FY 2022 to meet plan milestones. Unneeded materials and equipment were dispositioned from Building 9998 and two tanker trailers in FY 2022. Y-12 improved waste characterization processes and implemented real-time radiography to improve control and management of low-level radioactive waste.
- **Land, water, and natural resources:** Y-12 completed upgrading sanitary sewer networks in two areas as part of a project to protect the sanitary sewer lines from infill and infiltration. Y-12 also completed assessments on 34 aboveground inactive tanks and dikes in FY 2022.

Figure 1.8. Aerial view of the Y-12 National Security Complex

Y-12 continues to strive to reduce impacts on the environment through increased use of environmentally friendly products and processes and reductions in waste and emissions. In FY 2022, the Y-12 Complex implemented 107 pollution prevention initiatives that resulted in a reduction of more than 11.3 million lb of waste and projected cost efficiencies of more than $2.5 million. Also in 2022, Y-12 diverted 55.8 percent of municipal and 7.5 percent of construction and demolition waste from landfill disposal through reuse and recycle. In FY 2022, Y-12 diverted more than 3.6 million lb of municipal materials from landfill disposal through source reduction, reuse, and recycle. More than 4.7 million lb of construction and demolition materials were diverted from landfill disposal.

Compared to the FY 2003 baseline year, Y-12 has seen an energy intensity reduction of 50.93 percent as of FY 2022. During FY 2022, energy intensity was 205,343 Btu/gross square foot, a full 1.1 percent above the prior year (203,085 Btu/gross square foot). The upward trend in the site energy intensity figures is largely attributed to the height of the pandemic occurring during FY 2020 and then having a larger portion of the plant population returning to the site, thus increasing infrastructure use. Sustainability goals and performance status for the Y-12 Complex are listed in Chapter 4, Table 4.1.

1.4.3. East Tennessee Technology Park

ETTP (see Figure 1.9), originally named K-25, is the site of the nation's first gaseous diffusion uranium enrichment plant. It was established as part of the World War II Manhattan Project. Additional uranium enrichment facilities K-29, K-31, and K-33 were built adjacent to K-25 during the Cold War, and these facilities formed a complex officially known as the Oak Ridge Gaseous Diffusion Plant. Uranium enrichment operations at the site ceased in 1986, and restoration and decontamination and decommissioning activities began soon after in preparation for ultimate conversion of the site to a private sector industrial park to be called the Heritage Center. Reindustrialization of the site began in 1996, when it was renamed the East Tennessee Technology Park.

ETTP completed several soil remedial actions in 2022 that help protect groundwater. The site is divided into two cleanup regions: Zone 1, a 1,400-acre area outside the main plant area; and Zone 2, the 800-acre area that comprises the main plant area. The areas in these zones are divided into Exposure Units (EUs) that vary in size from 6 to 38 acres.

The EU-25 remedial action centered on the slab, foundation, and underlying soil of the former K-1413 Building, which was constructed in the 1950s and operated until the early 1980s for a range of chemical waste processing activities. This project was completed in 2022 with over 18,000 yd^3 of concrete and soil removed from the site.

EU-13 has several excavation areas for ongoing soil remediation at the sites of the former buildings designated as K-413, K-1131, and K-631. This area near Poplar Creek once housed many of the gaseous diffusion and uranium hexafluoride enrichment support facilities. Workers also removed the K-1131 ash pit and surrounding soils in that area, for a total of approximately 13,000 yd^3 in 2022.

Remediation was also underway within EU-21, an area that is located in the middle of the K-25 footprint, which is part of the Manhattan Project National Historical Park. Characterization sampling was performed as part of the overall cleanup of the ETTP site. Based on results of model calculations, workers are set to excavate 16,000 yd^3 of soil to eliminate risks to groundwater.

The EU-35 remedial action was conducted on the site of the former K-1407-K Building. This facility contained six 500-gal tanks and a system used for mixing chemical solutions. Four of the tanks were used to convert dry chemicals into solutions; two tanks were used to hold rinse water. Concrete and soil in the footprint of the former building were found to contain methylene chloride and tetrachloroethylene that exceed site groundwater screening levels. Approximately 800 yd^3 of soil and concrete was removed from the area.

The EU-42 area is the site of the former K-1004-J Building, a laboratory that was part of the now-demolished Centrifuge Complex. Remediation was performed on the former slab and soils remaining after demolition. Research conducted in the former facility resulted in discharges to drain lines and neutralization pits that contaminated the concrete and soil in the area with radioactive isotopes. Remedial actions in this EU removed more than 6,200 yd^3 of concrete and soil.

The UCOR EMS environmental sustainability principles incorporate the procurement of environmentally preferable products, recycling, and pollution prevention and waste minimization practices in work processes and activities at ETTP. UCOR recycles much of its universal waste, municipal solid waste, and scrap metal; reuses large amounts of construction and demolition debris; and encourages the reduction of waste wherever possible. In 2022, more than 226 metric tons of greenhouse gas emissions, 273,490 metric tons of waste, 282,000 gallons of wastewater, and $777,850 in travel costs were avoided as a result of ETTP projects implementing pollution prevention measures. In addition to lessening the impact on the environment, these pollution prevention measures also saved more than $1.6 million. UCOR's pollution prevention and waste minimization practices at ETTP are detailed further in Section 3.2.1.

DOE Oak Ridge Office of Environmental Management (OREM) continued to see significant momentum in the Reindustrialization Program at ETTP. The former government-owned uranium enrichment complex is being turned into a multiuse industrial park that includes national historic preservation and conservation and greenspace areas. To date, OREM has successfully transferred almost 1,300 acres at ETTP for beneficial reuse and is working to complete transfer of the remaining acreage at the site.

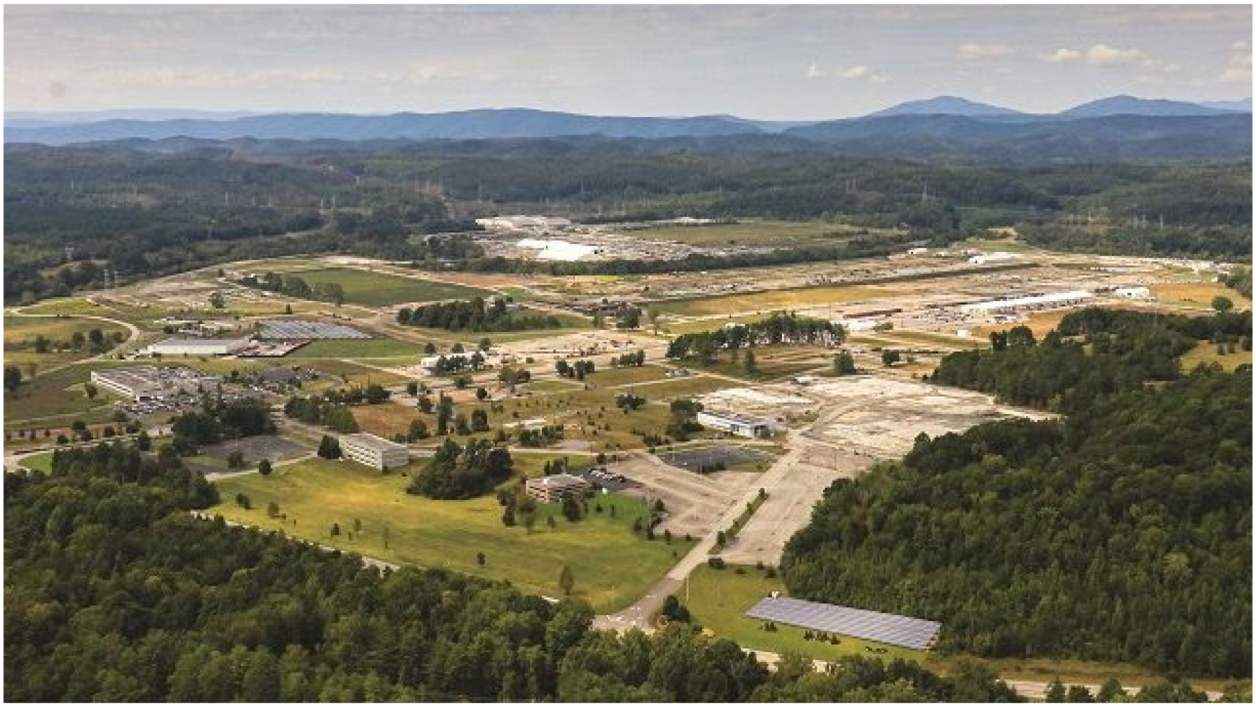


Figure 1.9. Aerial view of East Tennessee Technology Park

During 2022, the Reindustrialization team advanced the regulatory review of seven land transfer packages. This includes areas such as the former Powerhouse area, the Centrifuge area, and the K-1037 and the Toxic Substances Control Act Incinerator area. OREM and UCOR continued to partner with the Community Reuse Organization of East Tennessee to identify remaining available property, coordinate schedules, and support new businesses as they set up operations. DOE also continued to support the proposed general aviation airport project, which is in the planning stage.

1.4.4. Environmental Management Waste Management Facility

The EMWMF (shown in Figure 1.10) is located in eastern Bear Creek Valley near the Y-12 Complex and is managed by UCOR. The EMWMF was built for the disposal of waste resulting from CERCLA cleanup actions on ORR. The original design was for the construction, operation, and closure of a projected 1.3 million cubic meter (1.7 million cubic yard) disposal facility. The approved capacity was subsequently increased to 1.8 million cubic meters (2.4 million cubic yards) to maximize use of the footprint designated in a 1999 record of decision. The facility currently consists of six disposal cells.

The EMWMF is an engineered landfill that accepts low-level, mixed low-level, and hazardous wastes from CERCLA cleanup activities on ORR that meet specific waste acceptance criteria developed in accordance with agreements with state and federal regulators. Waste types that qualify for disposal include soil, dried sludge and sediment, solidified waste, stabilized waste, building debris, scrap equipment, and secondary waste such as personal protective equipment, all of which must meet land disposal restrictions. In addition to the solid waste disposal facility, the EMWMF operates a leachate collection system. In 2022, the facility collected, analyzed, and disposed of approximately 3.30 million gallons of leachate. The leachate is treated at the ORNL Liquids and Gaseous Treatment Facility, which is also operated by UCOR (UCOR 2022).

Figure 1.10. Aerial view of the Environmental Management Waste Management Facility

During FY 2022, the EMWMF received 7,172 waste shipments from cleanup projects at ETTP, ORNL, and Y-12. However, the EMWMF will reach its capacity before OREM completes its cleanup at Y-12 and ORNL, as the of 2.331 million yd^3 design capacity is now over 82 percent filled. Planning continued in 2022 for another disposal facility, the Environmental Management Disposal Facility (EMDF), which is needed to provide the capacity required to complete Oak Ridge's cleanup. The EMDF Record of Decision was signed on September 30, 2022. This major milestone for the project allows OREM to begin site preparation activities and finalize the facility's design. OREM continues to work with EPA and TDEC on follow-on regulatory documents related to the project, including the Focused Feasibility Study for Water Management for the Disposal of CERCLA Waste (DOE 2022). This approval followed the dispute resolution for radiological discharge limits. The Focused Feasibility Study provides an evaluation of landfill wastewater treatment alternatives, and its approval was a prerequisite for the EMDF Record of Decision signature by the Federal Facility Agreement parties. (UCOR 2022).

1.4.5. Oak Ridge Environmental Research Park

DOE established the Oak Ridge National Environmental Research Park (see Figure 1.11) in 1980. Managed for DOE by UT-Battelle, LLC, the research park serves as an outdoor laboratory to evaluate the environmental consequences of energy use and development and strategies to mitigate those effects. Its large blocks of forest and diverse communities of vegetation offer unparalleled resources for ecosystem-level and large-scale research. Major national and international collaborative research initiatives use it to address issues such as multiple stress interactions, biodiversity, sustainable development, tropospheric air quality, global climate change, innovative power conductors, solar radiation monitoring, ecological recovery, and monitoring and remediation.

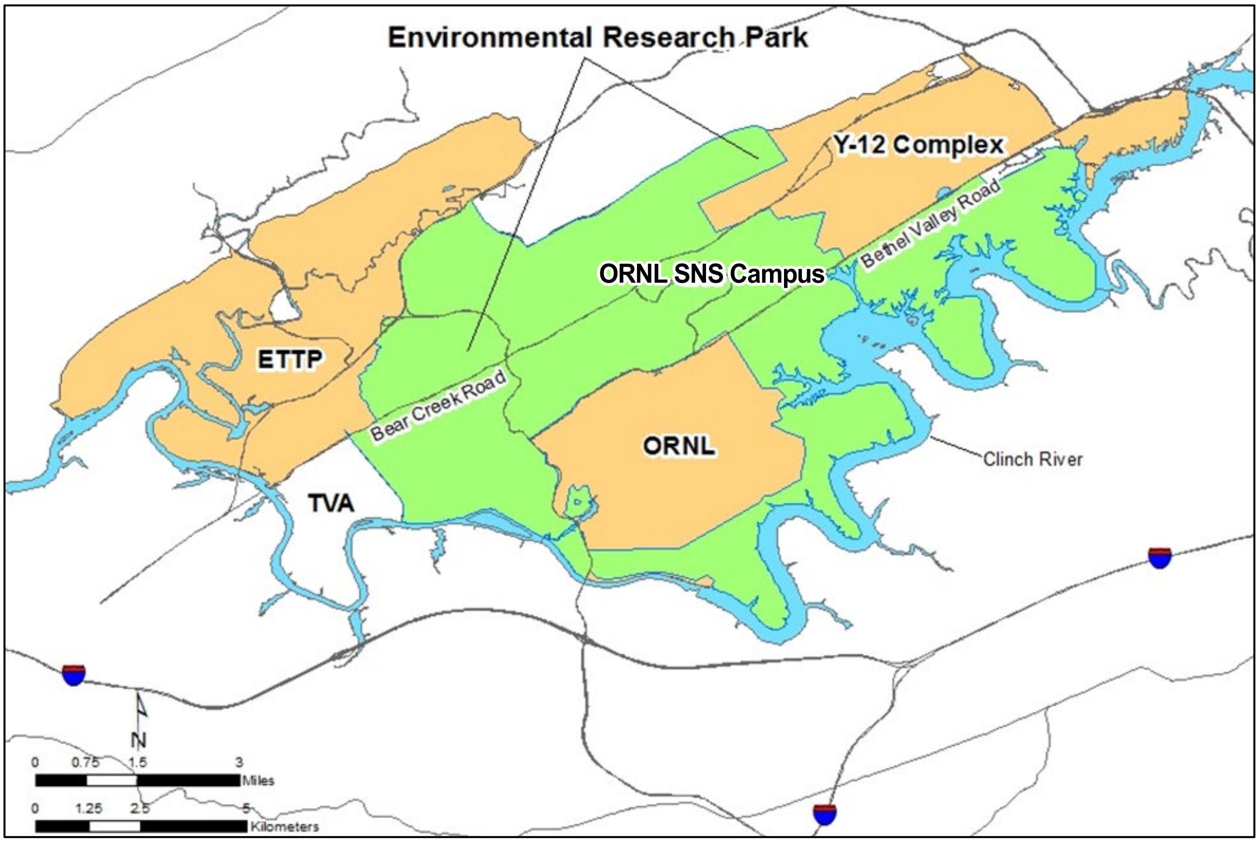


Figure 1.11. Location of the Oak Ridge National Environmental Research Park

Field sites at the research park provide maintenance and support facilities that permit sophisticated and well-instrumented environmental experiments. These facilities include elaborate monitoring systems that enable users to precisely and accurately measure environmental factors for extended periods. Because the park is under the jurisdiction of the federal government, public access is restricted and therefore experimental sites and associated equipment are not disturbed. National recognition of the research park's value has led to its use in both regional- and continental-scale research projects. Research Park sites offer opportunities for aquatic and terrestrial ecosystem analyses of topics such as biogeochemical cycling of pollutants resulting from energy production, landscape alterations, ecosystem restoration, wetland mitigation, and forest and wildlife management.

1.4.6. Oak Ridge Institute for Science and Education

ORISE is managed for DOE by Oak Ridge Associated Universities. The ORISE mission is to develop people and solutions to strengthen our nation's competitive advantage in science. ORISE accomplishes its mission by recruiting and preparing the next generation of our nation's scientific workforce; promoting sound scientific and technical investment decisions through independent peer reviews; facilitating and preparing for the medical management of radiation incidents in the United States and abroad; evaluating health outcomes in workers exposed to chemical and radiological hazards on the job; and ensuring public confidence in environmental cleanup through independent environmental assessments. ORISE creates opportunities for collaboration through partnerships with other DOE facilities, federal agencies, academia, and industry consistent with DOE objectives and the ORISE mission.

ORISE is located in an area on the southeastern border of ORR that was part of an agricultural experiment station owned by the federal government from the late 1940s to the mid-1980s. It was operated by the University of Tennessee until 1981. The site houses offices, laboratories, and storage areas for ORISE program offices and support departments.

1.4.7. National Nuclear Security Administration Office of Secure Transportation, Agent Operations Eastern Command

Beginning in 1947, DOE and its predecessor agencies moved nuclear weapons, weapons components, special nuclear materials, and other important national security assets by commercial and government modes of transportation. In the late 1960s, worldwide terrorism and acts of violence prompted a review of procedures for safeguarding these materials. As a result, a comprehensive new series of regulations and equipment was developed to enhance the safety and security of these materials in transit. Modified and redesigned transport equipment was created to incorporate features that more effectively enhance self-protection and deny unauthorized access to the materials. Also during this time, the use of commercial transportation systems was abandoned and a totally federal operation was implemented. The organization responsible for this mission within DOE NNSA is the Office of Secure Transportation, or OST.

The NNSA OST AOEC Secure Transportation Center and Training Facility is situated on about 723 hectares (1,786 acres) at ORR. It operates under a user permit agreement with the DOE Oak Ridge Office. NNSA OST AOEC performs its assigned mission transportation operations, maintains applicable fleet and escort vehicles, and continues extensive training activities for its federal agents.

1.4.8. Transuranic Waste Processing Center

The TWPC is located on an approximately 10.5-hectare (26-acre) tract of land in the Melton Valley area of ORNL about 120 feet west of the existing Melton Valley Storage Tanks. Management of this facility for DOE was transferred from North Wind Solutions, LLC to UCOR in October 2022. The TWPC's mission is to receive transuranic waste for processing, treatment, repackaging, and shipment to designated facilities for final disposal.

Transuranic waste consists of materials and debris that are contaminated with elements that have a higher atomic mass and are listed after uranium on the periodic table. The majority of Oak Ridge's inventory of transuranic materials originated from previous research and isotope production missions at ORNL. Waste determined to be non-transuranic (e.g., low-level radioactive waste or mixed low-level waste) is shipped to the Nevada National Security Site or other approved facilities. The TWPC has processed approximately 98 percent of the contact-handled transuranic waste and 98 percent of the remote-handled transuranic waste, and has also completed key regulatory milestones in the *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation* (TDEC 2020) on schedule.

Figure 1.12. Transuranic Waste Processing Center

Key progress for the project during 2022 included the following actions (UCOR 2022):

- TWPC continued certification and shipment of 59.3 m^3 of transuranic waste to the Waste Isolation Pilot Plant, 58.5 m^3 mixed low-level waste to treatment and disposal, and 2.7 m^3 of hazardous waste to treatment and disposal, eliminating 475 containers of the stored inventory.
- Construction of the Sludge Processing Mock Test Facility was completed in June 2022. OREM has been working since 2003 to process, repackage, and ship Oak Ridge's inventory of transuranic debris waste for permanent disposal at the Waste Isolation Pilot Plant. With that processing nearing completion, OREM is now working to address the site's 400,000-gallon inventory of transuranic sludge waste.

1.5. References

Birdwell 2011. Birdwell, Kevin Ray, "Wind Regimes in Complex Terrain of the Great Valley of Eastern Tennessee." PhD dissertation, University of Tennessee, May.

Broad 2007. Broad, William J, *Why They Called It the Manhattan Project*. New York Times, October 30, 2007. Available at https://www.nytimes.com/2007/10/30/science/30manh.html. Retrieved July 10, 2022.

CERCLA 1980. *Comprehensive Environmental Response, Compensation, and Liability Act.* Title 42 US Code Chapter 103.

CWA 1972. *Clean Water Act.* Title 33 US Code §1251 et seq.

DOE 2001. *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*. DOE/ORO-2085, US

Department of Energy Oak Ridge Operations Office, Oak Ridge, Tennessee, July.

DOE 2012. *Environment, Safety, and Health Reporting.* DOE Order 231.1B, June 27, 2011, US Department of Energy, Washington, DC.

DOE-DOI 2015. "Memorandum of Agreement Between the United States Department of the Interior and the United States Department of Energy for the Manhattan Project National Historical Park". Washington, DC, November 10, 2015.

DOE-FWS 2013. "Memorandum of Understanding between the United States Department of Energy and the United States Fish and Wildlife Service Regarding Implementation of Executive Order 13186, 'Responsibilities of Federal Agencies to Protect Migratory Birds'." US Department of Energy and US Fish and Wildlife Service, Washington, DC. Available at https://www.energy.gov/sites/prod/files/2013/10/f3/Final%20DOE-FWS%20Migratory%20Bird%20MOU.pdf. Retrieved August 18, 2023.

DOE 2022. "Focused Feasibility Study for Water Management for the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee." DOE/OR/01-2664&D4, US Department of Energy Oak Ridge Operations Office, Oak Ridge, Tennessee, June.

DOE-TSHPO 2022. "Memorandum of Understanding between the U.S. Department of Energy Oak Ridge Office of Environmental Management and the Tennessee State Historic Preservation Office Pursuant to 36 CFR § 800.6(B)(2) Regarding Demolition of National Priority List Excess Buildings 3005, 3009, 3010, 3010a, 3107 And 9213 on the Oak Ridge Reservation, Anderson And Roane Counties, Tennessee." Oak Ridge, TN, March 21, 2022.

East Tennessee Economic Council. *US Department of Energy FY 2020 Economic Impact in Tennessee*. Oak Ridge, Tennessee.

EO 2001. *Responsibilities of Federal Agencies to Protect Migratory Birds*. Issued January 10, 2001.

EPA 2022. *Tennessee Nonattainment/ Maintenance Status for Each County by Year for All Criteria Pollutants.* March 31, 2023. Available at https://www3.epa.gov/airquality/greenbook/anayo_tn.html. Retrieved April 23, 2023.

ESA 1973. *Endangered Species Act*. Title 16 US Code Chapter 35 §1531 et seq.

FWS 2011. *Birds of Management Concern and Focal Species*. US Department of the Interior, US Fish and Wildlife Service, Migratory Bird Program, Falls Church, Virginia. Available at https://www.fws.gov/sites/default/files/documents/Birds-of-Management-Concern-and-Focal-Species.2011_2.pdf. Retrieved July 30, 2022.

FWS 2021. *Birds of Conservation Concern 2021*. US Department of the Interior, US Fish and Wildlife Service, Migratory Birds, Falls Church, Virginia. Available at https://www.fws.gov/sites/default/files/documents/birds-of-conservation-concern-2021.pdf. Retrieved July 17, 2022.

Hogan 2021. Hogan, Colbi W, "Displaced to Save the World: Strategies for Using Historic Preservation and Education to Interpret Pre-1942 Communities in Oak Ridge, Tennessee." PhD dissertation, Middle Tennessee State University, August.

Johnson 2018. Johnson, Charles W. (March 1, 2018). *Oak Ridge*. The Tennessee Historical Society. Available at https://tennesseeencyclopedia.net/entries/oak-ridge. Retrieved May 26, 2022

Mathews et al. 2021. Mathews, T., M. Mayes, M., S. Brooks, C. DeRolph, A. Johs, S. Nair, L. Goñez-Rodríguez, L. Stevenson, P. Matson, J. Martínez Collado, K. Lowe, M. Larson, A. Duncan, T. Geeza, O. Alo, N. Jones. *Mercury Remediation Technology Development for Lower East Fork Poplar Creek—FY 2021 Update*. ORNL/TM-

2021/2207, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

MBTA 1918. *Migratory Bird Treaty Act.* Title 16 US Code §§703–712.

McCracken et al. 2015. McCracken, M.K., N.R. Giffen, A.M. Haines, and J.W. Evans, *Bat Species Distribution on the Oak Ridge Reservation.* ORNL/TM-2015/248, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

NatureServe 2023. NatureServe Network Biodiversity Location Data accessed through NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Available at https://explorer.natureserve.org/. Retrieved May 8, 2023.

NDAA 2014. *National Defense Authorization Act of 2015.* HR 3979, SEC. 3039.

NEPA 1969. *National Environmental Policy*. Title 42, US Code Chapter 55.

NHPA 1966. *National Historic Preservation Act*. Public Law 89-665; Title 54, US Code 300101 et seq.

Olwell 1999. *Help Wanted for Secret City: Recruiting Workers for the Manhattan Project at Oak Ridge, Tennessee, 1942–1946.* Tennessee Historical Quarterly, Spring 1999, 58(1): 52–69.

Parr and Hughes 2006. Parr, P.D. and J.F. Hughes, *Oak Ridge Reservation Physical Characteristics and Natural Resources.* ORNL/TM-2006/110, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

PIF 2021. Avian Conservation Assessment Database Scores. Bird Conservancy of the Rockies. Database updated February 21, 2021. Available at https://pif.birdconservancy.org/avian-conservation-assessment-database-scores/. Retrieved May 8, 2023.

Reed 2014. Reed, Bruce Cameron. *The History and Science of the Manhattan Project, Second Edition*. Springer-Verlag, New York.

Rosensteel 1996. Rosensteel, Barbara A., *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory, Oak Ridge, Tennessee*. ORNL/ER 350, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Rosensteel 1997. Rosensteel, Barbara A., *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee*. Y/ER-279, Y-12 National Security Complex, Oak Ridge, Tennessee.

Rosensteel and Trettin 1993. Rosensteel, Barbara A. and Carl C. Trettin*, Identification and Characterization of Wetlands in the Bear Creek Watershed.* Y/TS-1016, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Roy et al. 2014. Roy, W.K., N.R. Giffen, M.C. Wade, A.M. Haines, J.W. Evans, and R.T. Jett, *Oak Ridge Reservation Bird Records and Population Trends*. ORNL/TM-2014/109, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Souza 2001. Souza, Peter A., *Cultural Resource Management Plan: Department of Energy Oak Ridge Operations Office, Anderson and Roane Counties, Tennessee*. DOE/ORO 2085, US Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee, July 2001.

TDEC 2020. *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation*. TDEC-VER.24.2, Tennessee Department of Environment and Conservation, Nashville, Tennessee, May 13.

TDEC 2021. *Tennessee Natural Heritage Program Rare Plant List*. Tennessee Department of Environment and Conservation, Division of Natural Areas, Nashville, Tennessee.

TDEC 2023a. *Rules and Regulations for In Need Management, Threatened, and Endangered Species.* Chapter 1660-01-32, Rules of the Tennessee Wildlife Resources Agency, Biodiversity, Tennessee Department of Environment and Conservation, Nashville, Tennessee, April. Available at https://casetext.com/regulation/tennessee-administrative-code/title-1660-tennessee-wildlife-resource-agency/subtitle-1660-01-wildlife-resources/chapter-1660-01-32-rules-and-regulations-for-in-need-of-management-threatened-and-endangered-species/. Retrieved April 26, 2023.

TDEC 2023b. *Rare Species Dataviewer*. Tennessee Department of Environment and Conservation, Nashville, Tennessee. Available at https://dataviewers.tdec.tn.gov/dataviewers/f?p=9014:3:118904174220701. Retrieved July 17, 2022.

TVA 2023. Tennessee Valley Authority (@TVAnews), "Last year was the sixth year in a row with above-normal rainfall for the TN River basin, with 55 inches of precipitation - the average is 51"." *Twitter*. January 9, 2023. Available at https://twitter.com/TVAnews/status/1612498244000534529. Retrieved May 9, 2023.

UCOR 2017. *Construction Execution/Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee*. UCOR-4972/R3, UCOR, Oak Ridge, Tennessee, October 15.

UCOR 2022. *2022 Cleanup Progress: Annual Report to the Oak Ridge Regional Community, Oak Ridge, Tennessee.* OREM- 23-7632, UCOR, Oak Ridge, Tennessee.

Zurawski 1978. Zurawski, A., "Summary Appraisals of the Nation's Ground-Water Resources−Tennessee Region." US Geological Survey Professional Paper 813-L.

Migratory birds known to nest on the Oak Ridge Reservation, such as this summer tanager, are covered by the Migratory Bird Treaty Act. DOE and its partners follow a wildlife management plan to protect migratory birds and their habitats.

2

Compliance Summary and Community Involvement

Activities conducted on ORR must conform to environmental standards established by federal and state statutes and regulations, DOE orders, contract-based standards, and compliance and settlement agreements where applicable. The US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) are the principal regulating agencies that issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and enforce compliance with applicable regulations.

The following sections summarize the major environmental statutes and their 2022 status for DOE operations on ORR. Note that the DOE Reindustrialization Program, typically in coordination with the Community Reuse Organization of East Tennessee, has leased several facilities at ETTP and the Oak Ridge Science and Technology Park at ORNL to private entities over the past several years. This report does not discuss the compliance status of these lessee operations.

2.1. Laws and Regulations

Table 2.1, which begins on page 2-5, is a summary of the principal environmental standards applicable to DOE activities on ORR, their 2022 status, and the sections in this report that provide more detailed information.

2.2. External Oversight and Assessments

Table 2.2 (see page 2-10) lists the inspections of ORR environmental activities conducted by regulatory agencies for each of the major ORR sites (ETTP, Y-12, and ORNL) during 2022. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

2.3. Reporting of Oak Ridge Reservation Spills and Releases

Substances defined as hazardous under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) are considered harmful to human health and the environment. Because many are commonly used substances that are harmless in normal uses but can be dangerous when released, CERCLA establishes reportable quantities for hazardous substance releases. Neither ETTP, Y-12, nor ORNL had any spills exceeding CERCLA reportable quantity limits.

Certain releases of oil must be reported if they "cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines" (40 *Code of Federal Regulations* 110.3[b]). Neither ETTP, Y-12, nor ORNL had any reportable releases of oil to area waterways.

Neither ETTP, Y-12, nor ORNL had any reportable releases of extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-Know Act, in 2022. See Sections 3.3.12, 4.3.10, and 5.3.9 of this report for more information.

2.4. Notices of Violations and Penalties

ETTP had no notices of environmental violations or penalties in 2022.

In 2022, compliance with the Y-12 National Pollutant Discharge Elimination System (NPDES) water discharge permit limits was 100 percent; there were no Clean Air Act violations or exceedances. Personnel from the TDEC Division of Solid Waste Management conducted a Resource Conservation and Recovery Act hazardous waste compliance inspection of Y-12 on February 23, 2022. The inspections covered waste storage areas and records reviews. Eight issues were identified, including roof leak repairs that were not documented, one container that exceeded 90 days in a storage area, inadequate aisle space in one area, one facility that did not conduct daily inspections when hazardous waste activities occurred for a period of time, and two instances each of containers being inadequately labeled for hazards and improperly closed. Immediate corrective actions were taken where possible. The issues and their causes were reviewed at the time of the incident and all issues were resolved.

ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 100 percent in 2022, and there were no Clean Air Act violations by UT-Battelle, LLC (the ORNL managing contractor) or by other contractors who conducted activities at ORNL in 2022 (Isotek, North Wind, and UCOR). In October 2022, water from a potable water line break in the 7000 Area was released into White Oak Creek and caused aquatic species mortality (a total of 141 fish, 11 salamanders, and 13 aquatic worms). This incident was reported as a noncompliance with narrative criteria in the NPDES permit, which was reissued in December 2022.

2.5. Community Involvement and Resources

Public activities were still somewhat curtailed in 2022 due to COVID-19 and its applicable restrictions. In previous years, DOE and its contractors have provided or supported numerous community involvement activities on a range of subjects including ETTP historic interpretation efforts, Manhattan Project National Historical Park public meetings and public engagement efforts, Historic American Engineering Record activities, American Museum of Science and Energy community meetings hosted by the City of Oak Ridge, ETTP airport public meetings, public bus tours of ORR, public comment periods for draft environmental assessments, and Community Relations Council meetings. Public collaboration will resume when COVID-19 safety restrictions are lifted.

During 2022, organizations such as Big Brothers Big Sisters, the Boys & Girls Clubs, Discover Life in America, Dolly Parton's Imagination Library, East Tennessee Foundation, Foothills Land Conservancy, Friends of the Smokies, the United Way, and many other local charities benefited from DOE and its contractors' involvement in the community.

2.5.1. Environmental Justice

As part of ORR's evolving mission, DOE and its contractors integrate environmental justice elements contained in executive orders and other guidance into all programs and activities through a variety of initiatives. Sites promote career awareness and development to attract a diverse workforce as an investment in the future of ORR's mission and activities. Outreach to underserved communities through ORR partnerships, programs, and activities ensures they have equal representation in environmental decision-making.

2.5.2. Public Comments Solicited

To keep the public informed of comment periods and other matters related to cleanup activities on ORR, DOE publishes online notices at https://www.energy.gov/orem/services/community-engagement, conducts public meetings, and issues notices in local newspapers as appropriate. Information on environmental policy and DOE's commitment to providing sound environmental stewardship practices and keeping the public informed is available to the public through sponsored forums and public documents such as this report.

2.5.3. Oak Ridge Site Specific Advisory Board

The Oak Ridge Site Specific Advisory Board (ORSSAB) is a federally appointed citizens' panel that provides independent advice and recommendations to the DOE Oak Ridge Environmental Management Program. The board was formed in 1995 and is composed of up to 22 members chosen to reflect the diversity of genders, races, occupations, views, and interests of persons living near ORR. Members are appointed by DOE and serve on a voluntary basis without compensation.

Information on recommendations the board has made since its establishment, minutes of board and committee meetings, and other information are available on the ORSSAB website at http://www.energy.gov/ORSSAB. Videos of the first hour of recent board meetings are posted at https://www.energy.gov/orem/listings/oak-ridge-site-specific-advisory-board-meetings. Additional information may be obtained by calling 865-241-4583 or 865-241-4584.

2.5.4. DOE Information Center

The DOE Information Center, located at 1 Science.Gov Way, Oak Ridge, Tennessee, is a one-stop information facility that maintains a collection of more than 45,000 documents describing environmental activities in Oak Ridge.

The center is open Monday through Friday from 8 a.m. to 5 p.m. and can be reached by phone at 865-241-4780, or toll-free at 1-800-382-6938 (option 6). An online catalog that can be used to search for DOE documents by author, title, date, and other fields is available at https://www.energy.gov/orem/services/community-engagement/doe-information-center.

2.5.5. Other Resources

- Agency for Toxic Substances and Disease Registry: 1-800-232-4636, http://www.atsdr.cdc.gov
- DOE main website: http://www.energy.gov
- DOE Oak Ridge Public Affairs Office: 865-576-0885
- EPA Region 4: 1-800-241-1754, https://www.epa.gov/aboutepa/about-epa-region-4-southeast
- TDEC, DOE Oversight Division: 865-481-0995, https://www.tn.gov/environment/program-areas/rem-remediation/rem-oak-ridge-reservation-clean-up.html
- ETTP: https://www.energy.gov/orem/cleanup-sites/east-tennessee-technology-park
- Y-12 National Security Complex: http://www.y12.doe.gov/
- ORNL: https://www.ornl.gov/

Table 2.1. Applicable environmental laws and regulations and 2022 status

Regulatory program description	2022 status	Report sections
The Clean Air Act and State of Tennessee rules regulate the release of air pollutants through permits and quality limits. Emissions of radionuclides are regulated by EPA via National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities. Greenhouse gas emissions inventory tracking and reporting are regulated by EPA and by DOE.	In 2022 all activities on ORR were conducted in accordance with Clean Air Act requirements.	3.3.4 4.3.4 5.3.2
The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) provides a regulatory framework for remediation of the release or threat of release of hazardous substances from past practices on ORR.	ORR was placed on the EPA National Priorities List in 1989. The ORR Federal Facility Agreement, initiated in 1992 between EPA, TDEC, and DOE, established the framework and schedule for developing, implementing, and monitoring remedial actions on ORR. The on-site CERCLA Environmental Management Waste Management Facility (EMWMF) is operated by UCOR for DOE. Located in Bear Creek Valley, EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR. EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes, and combinations of these wastes, in accordance with specific waste acceptance criteria under an agreement with state and federal regulators. No CERCLA notices of violations were issued for ORR actions during 2022.	3.3.9 4.3.8, 4.3.12 5.3.7
The Clean Water Act seeks to protect and improve surface water quality by establishing surface water standards enabled by a system of permits. Wastewater discharges are regulated by National Pollutant Discharge Elimination System (NPDES) permits issued by TDEC.	Discharges to surface water at each of the three major ORR sites are governed by NPDES permits. In 2022, ETTP and Y-12 achieved a compliance rate of 100% with NPDES permit limits. In October 2022, water from a potable water line break in the 7000 Area at ORNL was released into White Oak Creek and caused aquatic species mortality (a total of 141 fish, 11 salamanders, and 13 aquatic worms). This incident was reported as a noncompliance with narrative criteria in the NPDES permit, which was reissued in December 2022. See Appendix D.	3.3.5 4.3.5 5.3.3
The Energy Independence and Security Act (EISA) Section 438 establishes requirements for federal agencies to reduce storm water runoff from development projects to protect water resources.	A variety of storm water management techniques, referred to as green infrastructure or low impact design practices, have been implemented on ORR to comply with EISA. The site sustainability plans and associated reporting provide data on sustainability projects and support EISA Section 438 compliance.	4.2.6 5.2.1.5

Table 2.1. Applicable environmental laws and regulations and 2022 status (continued)

Regulatory program description	2022 status	Report sections
The Emergency Planning and Community Right-to-Know Act (EPCRA), also referred to as the Superfund Amendments and Reauthorization Act Title III, requires reporting of emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	In 2022, DOE facilities on ORR operated in accordance with emergency planning and reporting requirements as defined by EPCRA. ETTP had no reportable releases of hazardous or extremely hazardous substances. Y-12 and ORNL had no reportable releases of extremely hazardous substances. In 2022, Y-12 reported 47 chemicals that were over Section 312 inventory thresholds and ORNL exceeded the reporting threshold and reported on the manufacture of nitrate compounds as by-products of on-site sewage treatment.	3.3.12 4.3.10 5.3.9
The National Environmental Policy Act (NEPA) requires consideration of how federal actions may impact the environment and an examination of alternatives to the actions. NEPA also requires that decisions include public input and involvement through scoping and review of certain NEPA documents.	During 2022, DOE planning and decision-making activities at ETTP, Y-12, and ORNL were conducted via site-level procedures that provide requirements for project reviews and NEPA compliance. In 2022, 60 NEPA reviews, six federal categorical exclusions (CXs) and eight "umbrella" CXs were completed at Y-12; three reviews and one CX were completed at ETTP; and 86 reviews were completed by UT-Battelle, LLC at ORNL. At Y-12, planning for three environmental assessments, began in 2021 and 2022.	3.3.2 4.3.2 5.3.1
The National Historic Preservation Act (NHPA) provides protection for the nation's historic resources by establishing a comprehensive national historic preservation policy.	ORR has several facilities eligible for inclusion in the National Register of Historic Places. Proposed activities are reviewed to determine potential adverse effects on these properties, and identify methods to avoid, mitigate, or minimize adverse effects or harm. During 2022, activities on ORR were conducted in compliance with NHPA requirements.	3.3.3 4.3.3 5.3.1
ORR Protection of Wetlands Programs are implemented to minimize the destruction, loss, or degradation of ORR wetlands and to preserve and enhance their beneficial value.	Surveys to determine the presence of wetlands are conducted as needed for projects or programs through NEPA and other reviews to facilitate compliance with TDEC and US Army Corps of Engineers requirements. Wetland protection on ORR is conducted according to 10 *Code of Federal Regulations* 1022 and Executive Order (EO) 11990, *Protection of Wetlands*. No new wetlands were delineated at ETTP or Y-12 in 2022. At ORNL, four wetlands were delineated in 2022.	1.3.6.1 5.3.11
The Resource Conservation and Recovery Act (RCRA) governs the generation, storage, handling, and disposal of hazardous wastes. RCRA also regulates underground storage tanks containing petroleum and hazardous substances, universal waste, and recyclable used oil.	Y-12, ORNL, and ETTP are defined as large-quantity generators of hazardous waste because each generates more than 1,000 kg of hazardous waste per month. Each site is also regulated as a handler of universal waste. In addition, several permits have been issued for hazardous waste management units on ORR. No notices of violation were issued for ETTP or ORNL in 2022. At Y-12, eight issues were identified including roof leak repairs that were not documented, one container that exceeded 90 days in a storage area, inadequate aisle space in one area, one facility that did not conduct daily inspections when hazardous waste activities occurred for a period of time, and two instances each of containers being inadequately labeled for hazards and improperly closed. Immediate corrective actions were taken.	3.3.8 4.3.7, 4.3.13 5.3.5, 5.3.6

Table 2.1. Applicable environmental laws and regulations and 2022 status (continued)

Regulatory program description	2022 status	Report sections
The Safe Drinking Water Act establishes minimum drinking water standards and monitoring requirements.	The City of Oak Ridge supplies potable water to the facilities on ORR and is responsible for meeting all regulatory requirements for drinking water. Sampling results in 2022 for residual chlorine levels, bacterial constituents, and disinfectant by-products in ORR's water system were all within acceptable limits.	3.3.7 4.3.6 5.3.4
The Toxic Substances Control Act regulates the manufacture, use, and distribution of a number of toxic chemicals.	PCB waste generation, transportation, disposal, and storage at ORR are regulated under EPA identification numbers TN1890090003 and TN0890090004. ETTP operated one PCB waste storage area in 2022 where nonradioactive PCB waste was stored in a facility that was not a RCRA-permitted storage facility (closed in May 2022). In 2022, UT-Battelle, LLC operated eight PCB storage areas. Seven were located at ORNL, and one was located at the Y-12 Complex. There were no other PCB storage areas at the Y-12 Complex. The ORR PCB Federal Facilities Compliance Agreement between EPA and DOE continues to provide a mechanism to address legacy PCB-use issues across ORR. The agreement specifically addresses the unauthorized use of PCBs, storage and disposal of PCB waste, PCB spill cleanup and decontamination, PCBs mixed with radioactive materials, PCB research and development, and ORR records and reporting requirements. EPA is updated annually on the status of DOE actions regarding management and disposition of legacy PCBs covered by the ORR PCB Federal Facilities Compliance Agreement.	3.3.11 4.3.9 5.3.8
The Bald and Golden Eagle Protection Act protects bald and golden eagles by prohibiting, except under specified conditions, the taking or possession of and commerce in such birds. The act imposes criminal and civil penalties for any such actions.	Bald eagles are known to frequent ORR year-round. Three active bald eagle nests on ORR are protected in accordance with this act. Eaglets have been successfully fledged from the Poplar Creek nesting location in the past.	1.3.6.2
The Endangered Species Act prohibits activities that would jeopardize the continued existence of an endangered or threatened species or cause adverse modification to a critical habitat.	ORR is host to several plant and animal species categorized as endangered, threatened, or of special concern, and these species are protected in accordance with this act.	1.3.6.2, 1.3.6.3
The Migratory Bird Treaty Act protects migratory birds by governing the taking, killing, possession, transportation, and importation of such birds, including their eggs, parts, and nests and any product, manufactured or not, from such items.	ORR hosts numerous migratory birds that are protected under this act.	1.3.6.2

Table 2.1. Applicable environmental laws and regulations and 2022 status (continued)

Regulatory program description	2022 status	Report sections
DOE Order 231.1B, *Environment, Safety, and Health Reporting,* ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues.	The *2022 Oak Ridge Reservation Annual Site Environmental Report* summarizes ORR environmental activities during 2022 and characterizes environmental performance.	All chapters
DOE Order 435.1, Change 1, *Radioactive Waste Management,* is implemented to ensure that all DOE radioactive waste is managed in a manner that protects workers, public health and safety, and the environment.	Waste certification programs that are protective of workers, the public, and the environment have been implemented for all activities on ORR to ensure compliance with this DOE order.	3.2.6 4.3.14, 4.7, 4.8.2 5.3.12, 5.7, 5.8
DOE Order 436.1, *Department Sustainability,* provides requirements and responsibilities for managing sustainability within DOE to ensure the department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges and advances sustainable, efficient, and reliable energy for the future.	DOE contractors on ORR have developed site sustainability plans and have implemented environmental management systems that are incorporated with the contractors' integrated safety management systems to promote sound stewardship practices and ensure compliance with this DOE order.	3.2 4.2 5.2
DOE Order 458.1, *Radiation Protection of the Public and the Environment,* issued in June 2011, canceled DOE Order 5400.5 and was established to protect members of the public and the environment from undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	In 2022, DOE Order 458.1 was the primary contractual obligation for radiation protection programs for UT-Battelle, LLC and Consolidated Nuclear Security LLC, and for all UCOR work scope areas where existing CERCLA decision documents do not specifically identify DOE Order 5400.5 requirements. A dose assessment was performed to ensure that the total dose to members of the public from all DOE ORR pathways did not exceed the 100 mrem annual limit established by this order. The assessment estimated the maximum 2022 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem. Therefore, the 2022 maximum effective dose was about 3% of the 100 mrem annual limit given in DOE Order 458.1. Clearance of property from ORNL, ETTP, and the Y-12 Complex was conducted in accordance with approved procedures that comply with DOE Order 458.1. There were no unplanned radiological air emission releases from the three major ORR sites in 2022. No limits were exceeded in 2022.	3.2.6 4.3.4, 4.3.14 5.3.12, 5.6.2 Chapter 6 Chapter 7

Table 2.1. Applicable environmental laws and regulations and 2022 status (continued)

Regulatory program description	2022 status	Report sections
DOE Order 5400.5, *Radiation Protection,* was established to protect members of the public and the environment against undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	DOE Order 5400.5 is the primary environmental surveillance radiological applicable, relevant, and appropriate requirement for most CERCLA activities across ORR. It will remain in force until the individual CERCLA decision documents are reissued or revised to incorporate DOE Order 458.1. A dose assessment, performed to ensure the total dose to members of the public from all ORR pathways did not exceed the 100 mrem annual limit established by this order, estimated the maximum 2022 dose to a hypothetical exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem.	Chapter 7
Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, identifies the responsibilities of federal agencies to promote the conservation of migratory bird populations.	A memorandum of understanding entered into by DOE and the US Fish and Wildlife Service meets the requirements under Section 3 of EO 13186. ORR hosts numerous migratory birds that are present either seasonally or year-round. This memorandum, which was updated in September 2013, strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and the US Fish and Wildlife Service.	1.3.6.2
Executive Order 13834, *Efficient Federal Operations*, directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.	EO 13834, *Efficient Federal Operations*, superseded EO 13693. Progress toward meeting the requirements of the EO and achieving DOE sustainability goals is summarized in this report. ORNL, Y-12, and ETTP all have sustainability processes and management systems to comply with the EO and subsequent federal instructions for implementing the EO.	3.2.1 4.2.6.3 5.2.1.4

Acronyms:

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CX = categorical exclusion
DOE = US Department of Energy
EISA = Energy Independence and Security Act
EMWMF = Environmental Management Waste Management Facility
EO = Executive Order
EPA = US Environmental Protection Agency
EPCRA = Emergency Planning and Community Right-to-Know Act
ETTP = East Tennessee Technology Park
NEPA = National Environmental Policy Act
NHPA = National Historical Preservation Act
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
UCOR = United Cleanup Oak Ridge LLC
Y-12 or Y-12 Complex = Y-12 National Security Complex

Table 2.2. Summary of external regulatory environmental audits, inspections, and assessments at ORR, 2022

Date	Reviewer	Subject	Issues
		East Tennessee Technology Park	
April 25	TDEC	ETTP NPDES Compliance Inspection	0
August 11	TDEC	ETTP Hazardous Waste Compliance Evaluation Inspection	0
		Y-12 National Security Complex	
February 15	TDEC	Quarterly ORR Landfill Inspection ILF-V and CDL-VII	0
February 23	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	8
March 11	TDEC	Quarterly ORR Landfill Inspection	0
March 24	TDEC	Quarterly ORR Landfill Inspection ILF-IV	0
May 5	TDEC	Quarterly ORR Landfill Inspection ILF-IV, ILF-V, and CDL-VII and first Semiannual Inspection of Post-Closure ILF-II	0
August 4	TDEC	Minor Permit Modification Approval ILF-V, Area 5 Buildout Design	0
August 9	TDEC	Quarterly ORR Landfill Inspection ILF-V and CDL-VII	0
August 24	TDEC	Quarterly ORR Landfill Inspection of ILF-IV and second Semiannual Inspection of Closed ILF-II	0
August 31	TDEC	Minor Permit Modification Approval CDL-VII, Seep Repairs	0
November 22	TDEC	Quarterly ORR Landfill Inspection of ILF-V and CDL-VII	0
December 1	TDEC	Quarterly ORR Landfill Inspection of ILF-IV	0
		Oak Ridge National Laboratory *(including UT-Battelle, LLC; UCOR; Isotek Systems, LLC; and North Wind Solutions, LLC activities)*	
March 9–11	TDEC	Hazardous Waste Compliance Evaluation Inspection (including UT-Battelle, Transuranic Waste Processing Center, and UCOR)	0
March 23	TDEC	Underground Storage Tank Inspection	0
March 31	City of Oak Ridge	CFTF Wastewater Inspection	0
April 26	TDEC	Hardin Valley Campus Hazardous Waste Compliance Evaluation Inspection	0
June 9	KCDAQM	Hardin Valley Campus Clean Air Act Inspection	0
July 21	City of Oak Ridge	CFTF Wastewater Inspection	0
July 28	TDEC	CFTF Clean Air Act Inspection	0
December 14	TDEC	Annual Clean Air Act Inspection for ORNL	0

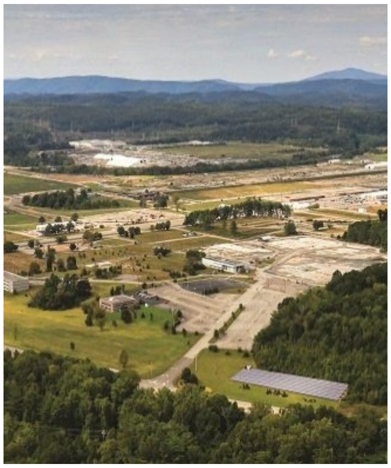
Acronyms:

CDL = Construction/Demolition Landfill
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
ETTP = East Tennessee Technology Park
ILF = Industrial Landfill
KCDAQM = Knox County Department of Air Quality Management
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
UCOR = United Cleanup Oak Ridge LLC

2.6. References

DOE 2020. *2020 Remediation Effectiveness Report for the US Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee, Data and Evaluations.* DOE/OR/01-2844&D1, US Department of Energy, Oak Ridge, Tennessee, March.

UCOR 2022. *2022 Cleanup Progress: Annual Report to the Oak Ridge Regional Community, Oak Ridge, Tennessee.* OREM-23-7632, UCOR, Oak Ridge, Tennessee.



The East Tennessee Technology Park has changed greatly in recent years as remediation projects have been completed.

3

East Tennessee Technology Park

ETTP was built during World War II as part of the Manhattan Project. Formerly known as the K-25 Site, its primary mission was to enrich uranium for use in atomic weapons. After the war, the mission changed to include the enrichment of uranium for nuclear reactor fuel elements and recycling of uranium recovered from spent fuel, and the name changed to the "Oak Ridge Gaseous Diffusion Plant" (ORGDP). In the 1980s, a reduction in demand for nuclear fuel resulted in the shutdown of the enrichment process and production. The emphasis of the mission then changed to environmental management and remediation operations. In 1996, the name changed to the "East Tennessee Technology Park."

Environmental management and remediation consist of waste management, the cleanup of outdoor storage and disposal areas, the demolition and cleanup of facilities, land restoration, environmental monitoring, and the proper disposal of waste generated from production operations. Beginning in the 1990s, reindustrialization (the conversion of underused government facilities for use by the private sector) became part of ETTP's mission. State and federally mandated effluent monitoring and environmental surveillance involve the collection and analysis of air, water, soil, sediment, and biota samples from ETTP and surrounding areas. Monitoring results are used to assess exposures to the public and the environment, evaluate the performance of treatment systems, and identify concerns within permitted standards for emissions and discharges. On November 10, 2015, DOE and the US Department of the Interior signed a memorandum of agreement (MOA) establishing the Manhattan Project National Historical Park (DOE 2015). The MOA defines agency roles and responsibilities in park administration and provisions for enhanced public access, management, interpretation, and historic preservation. The ORGDP footprint is included within the Manhattan Project National Historical Park. Details are available on the Manhattan Project National Historical Park page of the National Park Service website, **here**, and the K-25 Virtual Museum website details its history through narrative, interviews, and photographs, found **here**.

3.1. Description of Site and Operations

Construction of the K-25 Site (Figure 3.1) began in 1943 as part of the World War II Manhattan Project. The plant's original mission was the production of enriched uranium for nuclear weapons. Enrichment was initially carried out in the S-50 thermal diffusion process facility, which operated for one year, and the K-25 and K-27 gaseous diffusion process buildings. Later, the K-29, K-31, and K-33 buildings were built to increase the production capacity of the original facilities by raising the assay of the feed material entering K-27. Following the war years, the site became officially known as ORGDP.

After military production of highly enriched uranium was concluded in 1964, the two original process buildings, K-25 and K-27, were shut down. For the next 20 years, the plant's primary mission was the production of low enriched uranium fabricated into fuel elements for nuclear reactors throughout the world. Other missions during the latter part of this 20-year period included developing and testing the gas centrifuge method of uranium enrichment and laser isotope separation research and development.

By 1985, the demand for enriched uranium declined, and the gaseous diffusion cascades at ORGDP were placed in standby mode. That same year, the gas centrifuge program was canceled. The decision to permanently shut down the diffusion cascades was announced in late 1987, and actions necessary to implement that decision were initiated soon thereafter. Because of the termination of the original and primary missions, ORGDP was renamed the "Oak Ridge K-25 Site" in 1989. Figure 3.2 shows the ETTP site areas before the start of decontamination and decommissioning (D&D) activities. In 1996, the K-25 Site was renamed the "East Tennessee Technology Park" to reflect its new mission.

Figure 3.3 shows the ETTP areas designated for D&D activities through 2023. The ETTP mission is to reindustrialize and reuse site assets through leasing and/or transferring excess or underused land and facilities and by incorporating commercial industrial organizations as partners in the ongoing environmental restoration, D&D, and waste treatment and disposal. The site is undergoing environmental cleanup of its land, as well as D&D of most of its buildings. The cleanup approach makes land and various types of buildings (e.g., office, manufacturing) suitable for private industrial use and for title transfer to the Community Reuse Organization of East Tennessee (CROET) or other entities such as the City of Oak Ridge. The long-term DOE goal for ETTP is to transfer as much of the site property as practicable out of DOE ownership and into CROET's control for the development of a commercial business and industrial park. The facilities may then be subleased or sold, with the goal of stimulating private industry and recruiting businesses to the area. These transfers also reduce maintenance costs for DOE, which frees up additional money for environmental cleanup. The reuse of key facilities through title transfer is part of the site's closure plan.

UCOR, the lead environmental management contractor for ETTP, supports DOE in the reindustrialization program as part of the continuing effort to transform ETTP into a private-sector industrial park in addition to a national park and conservation area. Unless otherwise noted, information about non-DOE entities located on the ETTP site is not provided in this document.

Figure 3.1. The K-25 Site in 1946

Figure 3.2. East Tennessee Technology Park since the start of decontamination and decommissioning activities in 1991

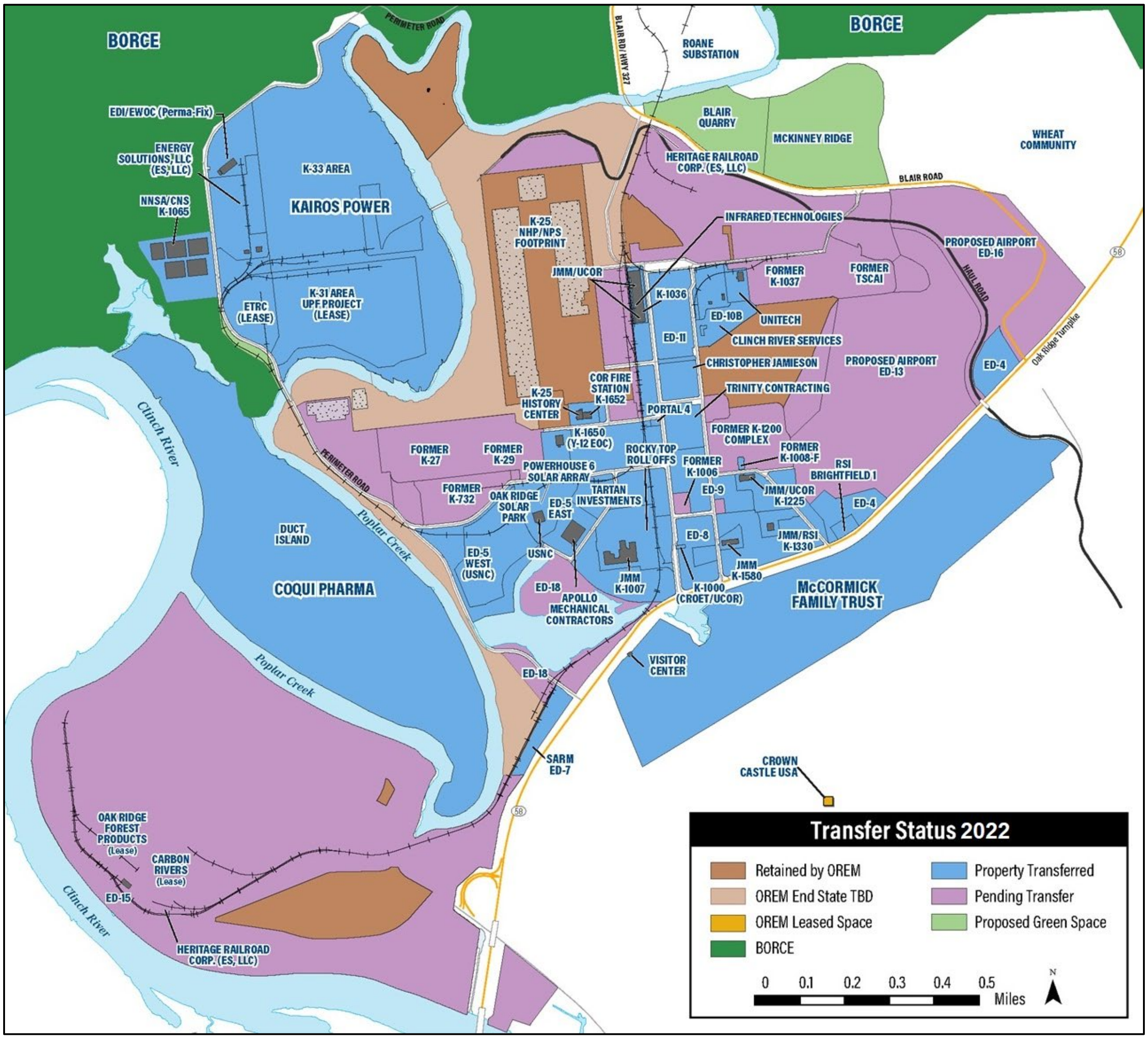


Figure 3.3. East Tennessee Technology Park in 2022, showing progress in reindustrialization

3.2. Environmental Management System

The UCOR Environmental Management System (EMS) is integrated with the UCOR Integrated Safety Management System. UCOR's EMS reflects the elements and framework contained in International Organization for Standardization (ISO) Standard 14001:2004, *Environmental management systems—Requirements with guidance for use* (ISO 2004). UCOR is committed to incorporating sound environmental management, protection, sustainability, and justice considerations in all business decisions, work processes and activities that are part of the DOE Environmental Management (EM) program in Oak Ridge, Tennessee. UCOR's environmental policy states, in part, "UCOR is committed to incorporating sound environmental management, protection, sustainability, and justice considerations in all our business decisions, work processes, and activities through the use of an EMS … and includes a commitment to continually improve the environmental performance of our operations … to protect and sustain human, natural, and cultural resources is inherent in our mission to complete environmental cleanup safely with reduced risks to the public, workers, and the environment." To achieve this, UCOR's environmental policy adheres to the following principles:

- **Leadership Commitment—**Integrate responsible environmental practices into project operations; factor environmental considerations and sustainability into project decisions that are appropriate for the nature and extent of our activities
- **Environmental Compliance—**Comply with all environmental laws, regulations and permits, including applicable or relevant and appropriate requirements
- **Sustainable Environmental Stewardship—** Minimize the effects of our operations on the environment through a combination of sustainable procurement improvements; increased waste reduction, reuse, and recycling; reduced greenhouse gas (GHG) emissions; sustainable, resilient remediation best management practices, and other science- and technology-based approaches
- **Partnership/Stakeholder Involvement—** Maintain partnerships through effective two-way communications with our client, suppliers, community, and other stakeholders

3.2.1. Sustainable Environmental Stewardship

Through a new UCOR Go Zero initiative designed to promote emission reductions and climate resilience, sustainability measures are being incorporated throughout UCOR's processes and activities via UCOR's EMS. The Go Zero initiative focuses on three primary goals: net zero GHG emissions; climate-ready operations and infrastructure; and education and partnerships to accelerate sustainability awareness and operational resilience.

3.2.1.1. Greenhouse Gas Emissions Reduction

UCOR is moving toward a net zero GHG emissions goal primarily through:

- Acquisition of electric vehicles
- Adoption of sustainable resilient remediation best management practices
- Transition to renewable and carbon-free energy
- Procurements that reduce Scope 3 GHG emissions
- Acquisitions that are increasingly sustainable through both systems and subcontract improvements
- A zero-waste goal for UCOR's occupied facilities and installations

In the area of renewable energy, Restoration Services, Inc. (RSI), in concert with UCOR, continued operations of ETTP's solar parks (Figure 3.4). Brightfield 1 is a 200-kW solar array located on a 0.405-ha (1-acre) tract purchased from CROET and built by RSI as part of UCOR's commitment to the revitalization of the former K-25 Site.

Figure 3.4. Oak Ridge Powerhouse Six Solar Farm

RSI self-financed the project using solar panels manufactured in Tennessee and partnering with other local small businesses for the installation. Power generated from Brightfield 1 is being sold to the Tennessee Valley Authority (TVA) through the City of Oak Ridge Electric Department using a TVA Generation Partners contract. The completed project was commissioned in April 2012 and is part of RSI's Brownfields to Brightfields initiative that works to develop restricted-use properties into solar farms. Brightfield 1 energy production in its first year was 110 percent more than projected, with no downtime due to maintenance issues. In calendar year (CY) 2022, Brightfield 1 produced 246, 500 kWh of energy.

In addition, through the cooperative efforts of DOE, UCOR, RSI, Vis Solis, Inc., CROET, and City of Oak Ridge, a second solar farm—the Powerhouse Six Solar Farm—was constructed on the west end of the park. It is a 1-MW solar farm that became operational in April 2015 and provides renewable energy, long-term lease income to CROET, and bolsters development at ETTP. This project continues to provide numerous benefits to the environment and the community at large, which include the following:

- Generates enough clean energy to power more than 100 homes
- Prevents pollution by removing the equivalent of 240 cars from the road annually (1,141 metric tons of CO_2)
- Provides brownfield reuse/redevelopment at ETTP
- Supports City of Oak Ridge renewable energy goals
- Supports TVA renewable energy initiatives
- Offers community economic development jobs and property tax income to City of Oak Ridge.
- Demonstrates benefits of ETTP reindustrialization.
- Supports DOE renewable energy goals.
- Demonstrates collaborative success between DOE and a public utility for renewable energy development

To steer the focus on the management of UCOR's upstream Scope 3 GHG emissions, UCOR initiated a Sustainable Supply Chain Council in fiscal year (FY) 2022. Through field-level testing of environmentally preferable product alternatives, sustainable procurement training and tools, expanded contract clauses, and other approaches, UCOR is incorporating sustainability and climate management into every aspect of its business and strengthening its resilience.

UCOR also continues to use environmentally sustainable products. Large quantity purchases are evaluated for less toxic alternatives. Other product purchases are first reviewed to determine if a recycled content material or biobased content alternatives are commercially available, and those alternatives are prioritized for purchase when feasible.

UCOR's exceptional electronics stewardship earned it an award in 2022 from the Global Electronics Council for its use of Electronic Product Environmental Assessment Tool™ methods and leadership in sustainable electronics procurement. This is the eighth consecutive year that UCOR has won an EPEAT™ award.

UCOR incorporates elements of Executive Orders (EOs) 14057 and 14008, climate science, source reduction, circularity, recycling, and pollution prevention (P2) and waste minimization practices in its work processes and activities. As an example, Figure 3.5 presents a selection of information on UCOR's 2022 P2 recycling activities related to solid waste reduction at ETTP. UCOR recycles much of its universal waste, municipal solid waste and scrap metal, reuses large amounts of construction and demolition debris, and encourages the reduction of waste wherever possible. UCOR's zero-waste program provides end-use avenues for products that are no longer useful to the current user, leading to a more circular economy. Products are reused or repurposed after use when possible. Products that cannot be reused or repurposed are recycled.

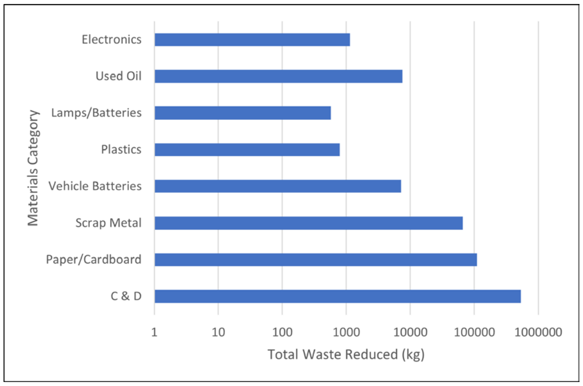


Figure 3.5. Pollution prevention recycling activities related to solid waste reduction at ETTP in FY 2022

In 2016, a significant improvement in the diversion of scrap metal was made, by petitioning and receiving agreement from the EPA and the Tennessee Department of Environment and Conservation (TDEC) to apply an unprecedented CERCLA screening process that allows noncontaminated scrap metal from CERCLA areas, previously excluded from commercial recycling services, to be safely shipped to commercial scrap-metal dealers for recycle. Effectively, the screening process removes the noncontaminated scrap metal from regulation under CERCLA; therefore, any non-CERCLA commercial scrap-metal recyclers can receive the material for recycle. This agreement continues to be successfully employed, allowing approximately 146,130 lb of scrap metal to be recycled in FY 2022 in lieu of land disposal and provides a path forward for additional waste diversion for the duration of the contract.

Some of the significant benefits of the scrap-metal recycling under this approval include:

- Provides funds from the recycling payments that are available to go back into the programs and support further actions in the Oak Ridge cleanup program
- Conserves valuable landfill space. As of FY 2022, 936,392 lb of scrap-metal recycled as a result of the screening process, diverting a valuable material from the landfill for reclamation, while saving capital cost, landfill capacity, historical operating costs, packing, and transportation
- Supports EPA, TDEC, and DOE programmatic environmental stewardship goals for waste diversion

The CERCLA screening process will continue to be used as more demolition and cleanup are continued at ETTP, ORNL, and Y-12.

3.2.1.2. Climate-ready Operations and Infrastructure

UCOR protects the DOE Oak Ridge Office of Environmental Management's (OREM) mission-critical assets by building climate-ready operations and infrastructure. The UCOR Vulnerability Assessment & Resilience Plan was developed to identify site-level risks to mission-critical assets and infrastructure posed by climate change. Current and projected climate hazards and trends were characterized using science-based resources. A risk matrix was prepared to help prioritize areas for focus for resilience solutions development and funding.

UCOR is more closely monitoring the impacts of weather events including performing post-weather event analyses to assess and trend the impacts to OREM's mission.

Sustainable resilient remediation best management practices are also being implemented to limit negative environmental impacts, maximize social and economic benefits, create resilience against increasing climate threats, and improve long-term risk management. UCOR is one of the DOE contractors having responsibilities for land management of portions of the ORR. The Natural Resources Management Team for ORR, centered at ORNL and partially funded by UCOR, is responsible for the creation and implementation of an Invasive Plant Management Plan. At ETTP, these efforts have included:

- Exposure Unit (EU)-29 demonstration field invasive plant control
- Powerhouse Trail privet control
- Wheat Church Vista invasive plant control

- Black Oak Ridge Conservation Easement kudzu and invasive plant control

For additional information, please see Chapter 6.

3.2.1.3. Education and Partnerships

Research has shown that the most sustainable outcomes come from a climate-aware workforce and community, and collaboration between stakeholders with mutual goals. UCOR is investing in specialized awareness and education efforts designed to develop a climate- and sustainability-focused workforce. Engaging activities featuring sustainability and climate management lessons are brought to the workers in the field. Other specialized training, such as a nine-month procurement-based climate foundations training was provided in FY 2022 to members of UCOR's supply chain management organization. These efforts are fostering a culture of sustainability and climate action throughout the workforce and developing resources to effectively implement OREM's sustainability goals.

In addition to building awareness and competency, UCOR is also leveraging partnerships to achieve its ambitious sustainability goals. These partnerships include other communities:

- Historic, predominantly minority Scarboro Community, focused on environmental justice and workforce development
- Historically Black Colleges and Universities and Minority Serving Institutions to increase awareness and access to environmental management careers
- Labor organizations to promote diversity in the workforce
- Oak Ridge High School mentorship program, educating local youth on sustainable practices

Additional collaborations have been established with public and private sectors, including:

- TVA for assistance in UCOR's renewable energy and electric vehicle transitions
- University of Tennessee for educational and opportunity awareness
- Other ORR contractors to develop the most efficient and collaborative approaches to accomplishing sustainability goals and climate resilience
- Suppliers to encourage efforts to reduce GHG emissions

UCOR reinforces good environmental stewardship and sustainability practices throughout the workforce with its Sustainability Leadership Awards, a competitive internal recognition program. Thirteen categories for nominations include topics such as energy management, acquisition and procurement, travel and commuting, and waste management. The program was expanded in 2023 to include a category for Diversity, Equity, and Inclusion to acknowledge that it is essential to sustainability and to encourage further development of these UCOR values. Four UCOR projects and one honorable mention were recognized in 2022, which are summarized below.

- The EU-21 Water Treatment System Team was recognized for treating trichloroethylene (TCE) using a Water Treatment System (WTS) to treat 282,000 gal of water on-site and saving $1,128,000 in water treatment off-site and 26.1 metric tons (MT) of greenhouse gas emissions for eliminating transportation, totaling a savings of $777,850 (i.e., operation of WTS vs. hauling/treating) since operating costs for the WTS totaled $357,665.
- The ORNL Waste Operations' Team was recognized for reusing the Activated-Carbon Free Granulated Activated Carbon (GAC) columns at Building 3608, converting the old GAC Feed Sump (F-1017) at Building 3608 to an unloading station for receipt of non-radiologically contaminated wastewater. Overall savings were $48,000 for diverting purchase of similar-sized Backwash Surge Tank, $40,000 by repurposing the GAC Feed Sump as a tanker unloading station, and conserving valuable landfill space at Environmental Management Waste

Management Facility (EMWMF) resulting in approximately 174 yd^3 in avoided disposal volume.

- The Heritage Center Area Project was recognized for transferring six large electrical transformers from ETTP to the City of Oak Ridge for reuse. This action eliminated the threat of a spill of the 23,000 gal of mineral oil contained in the transformers, avoided 0.05 MT of GHG emissions by recycling the copper within the transformers, and saved the disposal and transportation costs of disposing the transformers (weighing 273,316 lbs) in the landfill.
- The ORR Landfill Team was recognized for removing and storing 3,349 dump trucks of excess soil for reuse as landfill cover for both ILF-V and CDL-VII instead of disposing as waste. The project calculated a savings of $669,800 in clean fill material that would otherwise have been procured from an outside vendor, and saved space in the spoil area.
- The Scarboro Workforce Project was recognized for hosting the Scarboro Community Workforce Workshop for the historically African American community (called Scarboro), providing several opportunities for employment and the opportunity to sign up for the East Tennessee Apprenticeship Readiness Program to over 40 of its residents.

Together, the projects represented sustainability accomplishments in resource conservation, waste diversion, waste reduction, and P2. These accomplishments were the result of teamwork, leveraging a number of work control and management tools to save landfill space, reduce the use of virgin material, mitigate hazards to the environment and workers, and increase work efficiencies.

In 2022, the Sustainability Leadership Award winning projects saved more than 226 MT of GHG emissions, 273,490 MT of waste from landfills, and prevented 282,000 gal of wastewater generation. In addition to lessening the impact on the environment, these P2 measures also saved more than $1.6 million.

3.2.2. Environmental Compliance

UCOR maintains various layers of oversight to ensure compliance with legal and other requirements. The methods of evaluation include independent assessments by outside parties, assessments conducted by functional or project organizations, and routine field walkdowns conducted by a variety of functional and project personnel. Assessments are prioritized and scheduled based on risk management principles and performed in accordance with procedures. Records are maintained for all formal assessments and audits. Issues identified in assessments are handled, as required, by ISO 14001:2004, Section 4.5.3, “Nonconformity, Corrective Action, and Preventive Action” (ISO 2004). For additional information, see Section 3.4.

3.2.3. Environmental Aspects/Impacts

Using a graded approach appropriate for EMS includes an environmental policy that provides a unified strategy for the management, conservation, and protection of natural resources; the control and attenuation of risks; and the establishment and attainment of all environmental, safety, and health (ES&H) goals. UCOR works continuously to improve its EMS to reduce impacts from activities and associated effects on the environment (i.e., environmental aspects) and to communicate and reinforce this policy to its internal and external stakeholders.

3.2.4. Environmental Performance Objectives and Targets

UCOR conserves and protects environmental resources by: (1) incorporating environmental protection and the elements of an enabling EMS into the daily conduct of business; (2) fostering a spirit of cooperation with federal, state, and local regulatory agencies; and (3) using appropriate waste management, treatment, storage, and disposal methods.

UCOR has established a set of core company-level EMS objectives that remain relatively unchanged from year to year. These objectives are generally applicable to all operations and activities throughout UCOR's work scope. The core environmental objectives are based on compliance with applicable legal requirements and sustainable environmental practices contained in DOE Order 436.1, *Departmental Sustainability* (DOE 2011b), and include the following:

- Comply with all applicable environmental regulations, permits, regulatory agreements, and DOE orders.
- Reduce or eliminate the acquisition, use, storage, generation, and/or release of toxic, hazardous, and radioactive materials; waste; and GHG through acquisition of environmentally preferable products, conduct of operations, removal and safe disposition, waste minimization, and sustainable practices.
- Reduce degradation and depletion of environmental resources and potential impact on climate change through post-consumer material recycling, energy, fuel, and water conservation efforts, use or promotion of renewable energy, community engagement, and transfer for reuse valuable real estate assets.
- Reduce the environmental impact on surface water and groundwater resources.
- Reduce the environmental impact associated with project and facility activities.

The EMS objectives and targets reduce the environmental impact of UCOR activities and accomplish the DOE sustainability goals. Each year, ETTP reports its performance in the DOE Sustainability Dashboard, which collects data such as energy and water usage, GHG generation, sustainable buildings, facility metering, waste diversion, renewable energy, sustainable acquisitions, and electronic stewardship.

The Office of Management and Budget's Environmental Stewardship Scorecard is used to track and measure site-level EMS performance. During FY 2022, UCOR received a "green" for EMS performance, indicating full implementation of EMS requirements.

3.2.5. Implementation and Operation

UCOR protects the safety and health of workers and the public by identifying, analyzing, and mitigating aspects, hazards, and impacts from ETTP operations, and by implementing sound work practices. All UCOR employees and subcontractors are held responsible for complying with all ES&H requirements during all work activities and are expected to correct noncompliant conditions immediately. UCOR's internal assessments also provide a measure of how well EMS attributes are integrated into work activities through the Integrated Safety Management System. UCOR has embodied its program for the environmental compliance and the protection of natural resources in a companywide environmental management and protection policy. The policy is UCOR's fundamental commitment to incorporating sound environmental management practices in all business decisions, work processes, and activities.

3.2.6. Pollution Prevention/Waste Minimization/Release of Property

UCOR's work control process requires that all waste-generating activities be evaluated for source reduction and that product substitution be used to produce less toxic waste, when possible. The reuse or recycling of building debris and other generated wastes is evaluated in all cases.

The ETTP EMS program fosters P2 at every level of its operations, from routine office recycling of paper, cardboard, and plastics, to unique reuse and recycling at the project-field level. UCOR's P2 program is successful because it is tightly bound to its work control process. Thus, many original applications of material reuse and recycling have resulted, many of which have been captured through its internal P2 awards program. Each year, the projects that are recognized in the P2 internal awards program are often the source of

UCOR's national-level awards nominations (e.g., DOE Headquarters annual award program).

DOE Order 458.1, *Radiation Protection of the Public and Environment* (DOE 2011a), requires that a process be in place to ensure that radiologically contaminated materials are not released to the public or the environment, except in compliance with permit effluent requirements or other agreements with regulatory agencies. Materials and equipment may be released to the public through an approved pollution prevention/recycling program or through property sales (procedure PROC-PR-2032, *Disposition of Personal Property* [UCOR 2020a], governs the process of releasing personal property), and real property may be transferred to the public through CROET.

Materials and equipment that are to be recycled or reused may follow one of two paths. If process knowledge is sufficient to establish that the materials and equipment have never been in contaminated areas (for example, empty beverage cans from a specified break area or an office building), then the materials may be released for recycling or reuse. Materials and equipment that have been in radiologic areas must be examined by trained radiologic control technicians and the results documented before the materials and equipment may be released. Materials and equipment that fail to meet the free release criteria are either decontaminated to the point that they meet the free release criteria or are properly disposed of at an appropriate disposal facility. The release of property from radiologic areas is governed by procedure PROC-RP-4516, *Radioactive Contamination Control and Monitoring* (Table 3.1). In addition to the types and quantities of recycled materials and equipment shown above in Figure 3.5, 404,607 kg of office furniture, office supplies, electronics, electrical equipment, and building materials were released to the public through property sales.

Real property to be transferred must meet the release criteria established by DOE Order 458.1 (DOE 2011a) and the appropriate record of decision (ROD). DOE ensures that these requirements are met through independent verification by a third party. Currently, this verification is performed by Oak Ridge Associated Universities (ORAU) through a direct contract with DOE. The direct contract with DOE ensures that the evaluation is conducted independently of UCOR, DOE's cleanup contractor. ORAU reviews historic data, facility use history, verification strategies, methodologies, techniques, and equipment. When ORAU deems it appropriate, additional sampling and/or radiological surveys are undertaken. Results of the evaluation and verification are summarized in a report to DOE that is then submitted to DOE Headquarters for approval as part of the transfer package. Section 3.8 contains a summary of the real property releases to the public.

Table 3.1. Surface contamination values and DOE Order 458.1 authorized limits for surface activity

Radionuclide	Removable	Total (fixed + removable)
Natural Uranium, ^{235}U, ^{238}U, and associated decay products	1,000	5,000
Transuranic, ^{226}Ra,^{228}Ra,^{230}Th,^{228}Th,^{231}Pa,^{227}Ac,^{125}I,^{129}I	20	100/500
Natural Th, ^{232}Th,^{90}Sr,^{223}Ra,^{224}Ra,^{232}U,^{126}I,^{131}I,^{133}I	200	1,000
Beta-gamma emitters except ^{90}Sr and others noted above	1,000	5,000
Tritium and Special Tritium Compounds	10,000	
Hard to Detect: Pu-241, C-14, Fe-55, Ni-59, and Ni-63	10,000	50,000

Note: *Limits are shown in dpm/100 cm^2.*

3.2.7. Competence, Training, and Awareness

The UCOR training program and qualification process ensures that needed skills for the workforce are identified and developed and documents knowledge, experience, abilities, and competencies of the workforce for key positions requiring qualification. Completion and documentation of training, including required reading, are managed by the Local Education Administration Requirements Network, or LEARN.

3.2.8. Communication

UCOR communicates externally regarding environmental aspects through the UCOR public website, found **here**, which includes a link to its environmental policy statement in *Environmental Management and Protection,* POL-UCOR-007 (UCOR 2020c), and a list of environmental aspects.

A number of other documents and reports that address environmental aspects and cleanup progress are also published and made available to the public (e.g., the *Oak Ridge Annual Site Environmental Report* [ASER], DOE 2022d, DOE-SC-OSO/RM-2022-01] and the annual cleanup progress report [UCOR 2023, *2022 Cleanup Progress—Annual Report on Oak Ridge Reservation Cleanup,* OREM-23-7632]).

UCOR participates in a number of public meetings related to environmental activities at the site (e.g., Oak Ridge Site Specific Advisory Board meetings, which include community stakeholders, public permit reviews, and public CERCLA decision document reviews). Written communications from external parties are tracked using the weekly Open Action Report.

3.2.9. Benefits and Successes of Environmental Management System Implementation

An EMS program provides many benefits to an organization's success. Based upon the simplified model of Plan-Do-Act-Check, it provides a framework by which work incorporates mitigation of environmental hazards into its work control and planning. This translates into many returns to the organization. UCOR uses EMS objectives and targets, an internal P2 recognition program, environmentally preferable purchasing, work control processes, and a recycle program to meet sustainability and environmental stewardship goals and requirements. The approach is outlined in UCOR's *Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee* (UCOR 2022a, UCOR-4127/R10). The EMS program is audited by a third party triennially for conformance to the ISO 14001:2004 standard (ISO 2004) as required by DOE Order 436.1, *Departmental Sustainability, Attachment1 Contractor Requirements Document* (DOE 2011b), with the most recent having been conducted in 2021. The results of the audit were zero findings, two observations, and three proficiencies.

3.2.10. Management Review

A formal review/presentation with UCOR senior management is conducted once per year that addresses the ISO 14001:2004 (ISO 2004) required elements, including focus areas for the upcoming year. At least two of the senior managers are present for management reviews. The environmental policy is also reviewed during the annual EMS management review and revised, as necessary. Also, periodic reports are submitted to senior management on the status of EMS calendar year company-level objectives and targets.

3.3. Compliance Programs and Status

During 2022, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements. There were no National Pollutant Discharge Elimination System (NPDES) noncompliances, nor did ETTP receive any Notices of Violation in 2022. Figure 3.6 shows the trend of NPDES compliance at ETTP since 2012. The following sections provide more detail on each compliance program and the environmental remediation-related activities in 2022. In addition, ETTP is tracked on EPA's

Enforcement and Compliance History Online database (FRS ID 110002471094).

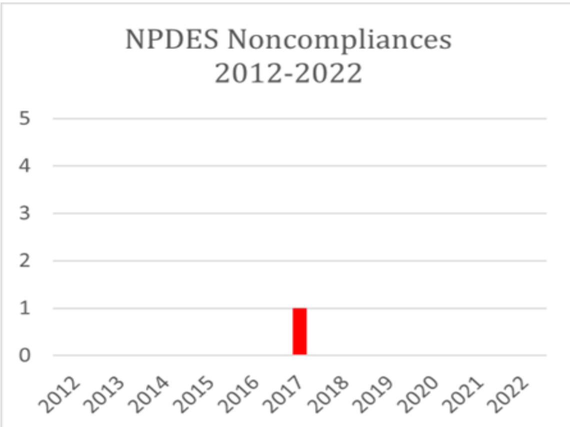


Figure 3.6. ETTP NPDES permit noncompliances since 2012

3.3.1. Environmental Permits Compliance Status

Table 3.2 contains a list of environmental permits that were in effect at ETTP in 2022. ETTP received no notices of environmental violations or penalties in 2022.

Table 3.3 presents a summary of environmental audits and oversight visits conducted at ETTP in 2022.

3.3.2. National Environmental Policy Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. ETTP maintains compliance with NEPA through the use of site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to ensure NEPA is a key consideration in the formative stages of project planning.

For many of the current operations at ETTP conducted under CERCLA, NEPA reviews are conducted concurrently with the CERCLA planning process to ensure that NEPA values are incorporated into CERCLA projects and documentation. These NEPA values include analysis of cumulative, off-site, ecological, and socioeconomic impacts. Opportunities for early public involvement are also provided early in the CERCLA process which meet the requirements of NEPA.

For non-CERCLA activities, a checklist incorporating NEPA and EMS requirements has been developed as an aid for project planners which document the potential for impacts on the environment. This checklist is used to collect necessary information to conduct a NEPA review. NEPA reviews identify new or changing environmental aspects associated with proposed activities. During 2022, three NEPA review reports were generated to document UCOR activities: cleanout of a facility in preparation for demolition, construction of a storage yard, and removal of power poles and feeder lines from an environmentally sensitive area.

To streamline the NEPA review and documentation process of non-CERCLA work, the DOE Oak Ridge Office has approved generic categorical exclusion (CX) determinations that cover certain proposed activities (i.e., maintenance activities, facility upgrades, personnel safety enhancements). A CX is a category of actions defined in 40 *Code of Federal Regulations* (CFR) Part 1508.4 (EPA 1978) that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required. One additional CX was developed in 2022 to cover UCOR structure demolition and site cleanup at ORNL.

3.3.3. National Historic Preservation Act

UCOR compliance with the National Historic Preservation Act (NHPA) on the ORR is achieved and maintained in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR Cultural Resource Management Plan (Souza et al. 2001).

Table 3.2. East Tennessee Technology Park environmental permits, 2022

Regulatory driver	Permit title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CWA	NPDES permit for groundwater and storm water discharges	TN0002950	02-04-2022	03-31-2020 Remained in effect through 3-31-2022; New permit became effective on April 1, 2022	DOE	UCOR	UCOR
CWA	SOP—waste transportation project; Blair Road and Portal 6 sewage pump and haul permit	SOP-05068	07-01-2014	02-28-2019 Remains in effect	TTS	TTS	TTS
RCRA	Hazardous waste corrective action document (encompasses entire ORR)	TNHW-164	09-15-2015	09-15-2025	DOE	DOE/All[a]	DOE/All[a]

[a] *DOE and ORR contractors that are co-operators of hazardous waste permits.*

Acronyms:
CAA = Clean Air Act
CWA = Clean Water Act
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
ID = identification (number)
NOA = Notice of Authorization
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
PBR = Permit-by-Rule
RCRA = Resource Conservation and Recovery Act
SOP = state operating permit
TDEC = Tennessee Department of Environment and Conservation
TTS = Turnkey Technical Services, LLC.
UCOR = UCOR, an Amentum-led partnership with Jacobs

Table 3.3. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2022

Date	Reviewer	Subject	Issues
April 25	TDEC	ETTP NPDES Compliance Inspection	0

Acronyms:
COR = City of Oak Ridge
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
NPDES = National Pollutant Discharge Elimination System
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

3.3.3.1. NHPA Compliance at ETTP

There were 135 facilities at ETTP eligible for inclusion on the National Register of Historic Places, a US National Park Service program to identify, evaluate, and protect historic and archeological resources in the United States, and numerous other facilities that were not eligible for inclusion on the National Register of Historic Places. More than 800 facilities were demolished at ETTP.

To commemorate the historic contributions of the ETTP K-25 gaseous diffusion plant, the first such uranium processing plant in the world, a final mitigation plan was developed by DOE in 2012 in exchange for the demolition of the facility. The mitigation plan called for the designation of a commemorative area around the building's perimeter from which future surface development would largely be restricted; the demarcation of the building's footprint; the construction of a viewing platform; an online virtual museum; and the development of a history center within the ETTP Fire Station #4. The final MOA was signed in August 2012 between DOE, the State Office of Historic Preservation, the Federal Advisory Council on Historic Preservation, the City of Oak Ridge, and the East Tennessee Preservation Alliance (DOE 2012). The K-25 History Center opened to the public on February 27, 2020.

On December 16, 2022, the U.S. Army Corps of Engineers, which is overseeing the construction of the K-25 Viewing Platform, issued a solicitation for construction bids to select a contractor to build the facility. UCOR will be providing engineering support to the Corps during construction and will also procure and manage the fabrication and installation of exhibits for the viewing platform. These exhibits will enrich the visitor experience to the Viewing Platform by providing photos, facts, view scopes, and a scale model of the K-25 Building.

The K-25 History Museum and Viewing Platform complement the Manhattan Project National Historic Park established in 2015, which includes the footprint of the former K-25 Building (DOI 2015).

3.3.3.2. NHPA Compliance Throughout the ORR

In accordance with Section 106 of the NHPA, UCOR works with OREM to provide a system of review for UCOR D&D projects that have the potential to affect historic and archaeological resources on the ORR. The review process is guided by ORNL and Y-12 Programmatic Agreements, which follow the approach outlined in each site's Historic Preservation Plan, and also MOAs between DOE, the state of Tennessee, the Advisory Council on Historic Preservation, and consulting parties.

Undertakings by UCOR that affect facilities identified as historical and cultural resources in the Historic Preservation Plans undergo a three-tier system of review: (1) Level One—programmatic exclusions (no adverse effect on historic properties); (2) Level Two—internal review by the UCOR NHPA coordinator and/or OREM and/or the OREM Cultural Resources Management Coordinator; and (3) Level Three—review by the Tennessee State Historic Preservation Officer. DOE activities involving ORR artifacts of historical and/or cultural significance are identified before demolition and are catalogued in a database to aid in historic interpretation. In 2022, 11 Level One and 9 Level Two reviews were conducted for UCOR D&D activities.

3.3.4. Clean Air Act Compliance Status

The Clean Air Act (CAA), passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation establishes comprehensive federal and state regulations to limit air emissions and includes five major regulatory programs: the National Ambient Air Quality Standards, State Implementation Plans, New Source Performance Standards, Prevention of Significant Deterioration permitting programs, and National Emission Standards for Hazardous Air Pollutants (NESHAPs). Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by EPA and the TDEC Division of Air Pollution Control.

Full compliance with CAA regulations and permit conditions was demonstrated in 2022. The ETTP ambient air-monitoring program, permitted source operations tracking, and record keeping provided documentation fully supporting a 100-percent compliance rate.

3.3.5. Clean Water Act Compliance Status

The objective of the Clean Water Act (CWA) is to restore, maintain, and protect the integrity of the nation's waters. This act serves as the basis for comprehensive federal and state programs to protect the waters from pollutants (see Appendix C for water reference standards). One of the strategies developed to achieve the goals of the CWA was EPA's establishment of limits on specific pollutants allowed to be discharged in US waters by municipal sewage treatment plants and industrial facilities. EPA established the NPDES permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the state of Tennessee.

In 2022, ETTP discharged storm water and groundwater to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges. Sewage discharges from routine breakrooms, restrooms, and change house showers were discharged to the City of Oak Ridge Rarity Ridge Wastewater Treatment Plant collection network.

3.3.6. National Pollutant Discharge Elimination System Permit Noncompliances

In 2022, compliance with ETTP NPDES storm water permit TN0002950 was determined by more than 120 laboratory analyses, field measurements, and flow estimates. The NPDES permit compliance rate for all discharge points for 2022 was 100 percent.

3.3.7. Safe Drinking Water Act Compliance Status

Since October 1, 2014, all water at the ETTP site is supplied by the City of Oak Ridge drinking water plant, located north of the Y-12 Complex in Oak Ridge, Tennessee. ETTP operations are in full compliance with this act.

3.3.8. Resource Conservation and Recovery Act Compliance Status

ETTP is regulated as a large-quantity generator of hazardous waste because the facility generates more than 1,000 kg of hazardous waste per month. At the end of 2022, ETTP had two hazardous waste Central Accumulation Areas, managed and operated by personnel of the Uranium Processing Facility, a Consolidated Nuclear Security, LLC owned project.

TNHW-164 is the hazardous waste corrective action document, which covers ORR areas of concern and solid waste management units.

In CY 2022, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2021 annual report of hazardous waste activities. This report identifies the type and amount of hazardous waste that was generated, shipped off site, or is staged for shipment. In 2022, ETTP was in full compliance with this act.

3.3.9. Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status

CERCLA, also known as "Superfund," was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act. Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA. ORR is on the National Priorities List and numerous CERCLA decision documents are approved for ETTP site cleanup actions for both facility demolitions and soil remediation. In 2022, ETTP was in full compliance with this act.

3.3.10. East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (DOE 1992, FFA-PM/18-011, DOE/OR-1014) is intended to coordinate the corrective action processes of Resource Conservation and Recovery Act (RCRA) required under the *Hazardous and Solid Waste Amendments* permit with CERCLA response actions.

3.3.11. Toxic Substances Control Act (TSCA) Compliance Status–Polychlorinated Biphenyls

On April 3, 1990, DOE notified EPA Headquarters (as required by 40 CFR Part 761.205, *Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions* [EPA 1979]) that ETTP is a generator with on-site storage, a transporter, and an approved disposer of PCB wastes.

In 2022, ETTP operated one long-term PCB waste storage area on-site where nonradioactive PCB waste was stored in a facility that was not a RCRA-permitted storage facility. This storage area was closed in May 2022. At this time, no PCB-contaminated electrical equipment is in service at ETTP.

Because of the age of many ETTP facilities and the varied uses for PCBs in gaskets, grease, building materials, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE Oak Ridge Office and EPA Region 4 consummated a major compliance agreement known as the *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement* (DOE 2018, ORR-PCB-FFCA), which became effective December 16, 1996, and was last revised on October 8, 2018, to Revision 6. The facilities that were included on the ORR-PCB-FFCA have been demolished and disposed.

ORR-PCB-FFCA specifically addresses the unauthorized use of PCBs in ventilation ducts and gaskets, lubricants, hydraulic systems, heat transfer systems, and other unauthorized uses; storage for disposal; disposal; cleanup and/or decontamination of PCBs and PCB items, including PCBs mixed with radioactive materials; and ORR records and reporting requirements. A major focus of the agreement is the disposal of PCB waste. As a result of that agreement, DOE and UCOR continue to notify EPA when additional unauthorized uses of PCBs, such as in paint, adhesives, electrical wiring, or floor tile, are identified at ETTP. This notification process is routinely incorporated into the CERCLA documentation for demolition and remedial actions (RAs).

The ETTP site prepares a PCB Annual Document Log (PCBADL) per 40 CFR Part 761.180(a) (EPA 1979). The written PCBADL is prepared by July 1 of each year and covers the previous calendar year. The PCBADL documents such things as container inventory, shipments, and PCB spills at the facility. Authorized representatives of EPA may inspect the PCBADL at the facility where they are maintained during normal business hours. The PCBADL must be maintained on-site for a minimum of three years. In 2022, ETTP was in full compliance with this act.

3.3.12. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA), which is also identified as Title III of the Superfund Amendments and Reauthorization Act, requires that facilities report inventory that exceed threshold planning quantities and releases of hazardous and toxic chemicals. The reports are submitted electronically and are available online for the local emergency planning committee, the state emergency response commission, and the local fire department. ETTP complied with these requirements in 2022 through the submittal of required reports as applicable under EPCRA Sections 302, 311, 312, and 313. ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by EPCRA, in 2022.

3.3.12.1. Chemical Inventories (EPCRA Section 312)

Inventories, locations, and associated hazards of hazardous and extremely hazardous chemicals were submitted in an annual report to state and local emergency responders, as required by EPCRA Section 312. Of the ORR chemicals identified for 2022, eight chemicals were located at ETTP. These chemicals were diesel fuel, unleaded gasoline, sulfuric acid (including large, lead-acid batteries), Chemical Specialties, Inc. Ultrapoles, Flexterra FGM erosion control agent, sodium polyacrylate, CETCO Quik-Solid, and various lubricating oils.

3.3.12.2. Toxic Chemical Release Reporting (EPCRA Section 313)

EPCRA Section 313 requires facilities to complete and submit a toxic chemical release inventory (TRI) form (Form R) annually. Form R must be submitted for each TRI chemical that is manufactured, processed, or otherwise used in quantities above the applicable threshold quantity. The reports address releases of certain toxic chemicals to air, water, land, and waste management, recycling, and P2 activities.

Threshold determinations and reports for each of the ORR facilities are made separately. Operations involving TRI chemicals were compared with regulatory thresholds to determine which chemicals exceeded the reporting thresholds based on amounts manufactured, processed, or otherwise used at each facility. After threshold determinations were made, releases and off-site transfers were calculated for each chemical that exceeded the threshold quantity. In 2022, there were no chemicals that met the reporting requirements.

3.3.12.3. Environmental Justice

UCOR strives to increase environmental justice efforts by advocating for and facilitating underserved and marginalized communities' involvement in environmental decision making. UCOR incorporates elements of EO 14008, Justice40 Initiative, and environmental justice initiatives into its community investment and commitment and workforce development programs. UCOR aspires to attract and maintain a diverse workforce that will promote the next generation of cleanup. This goal is achieved by increasing awareness and access to environmental management careers in minority and underserved communities; collaborating with labor organizations to promote diversity in the labor workforce; partnering with Historically Black Colleges and Universities and Minority Serving Institutions; and maintaining a culture of inclusion and accountability.

UCOR aims to create innovative tactics to bridge the gap between our work and the community. UCOR and DOE have partnered with the historic, predominantly minority Scarboro Community throughout its contract. The UCOR senior leadership team has cultivated relationships with Scarboro Community leaders and meet with them often to provide updates on environmental cleanup projects. A meeting was established with Scarboro Community members to best understand how benefits can be shared with the community. In this meeting, community leaders said they want to receive on-going information about economic benefits and opportunities for employment to help socio-economic growth in their area. UCOR sponsored a workforce workshop at the Scarboro Community Center. Information was presented on apprenticeships, careers at UCOR, and small business opportunities. The workshop is part of ongoing outreach effort to increase UCOR's environmental justice initiatives, identify barriers to employment, and build and maintain a skilled and diverse workforce. The workshop featured several UCOR staff augmentation companies, the American Job Center, the Knoxville Building & Construction Trades Council, and the Knoxville Urban League. The event allowed community members to speak to each vendor depending on their specific employment paths and interests.

UCOR keeps frequent communication establishing Environmental Justice E-mail Blast to the Scarboro Community. The email updates the community on available job opportunities and events at UCOR. This informal medium provides a direct pipeline of information to the community and facilitates opportunities for two-way communication with members of the community. The distribution reaches 80-plus key stakeholders in and around the Scarboro Community.

UCOR provided information about grant opportunities to an environmental non-profit organization, Socially Equal Energy Efficient Development, which provides pathways out of poverty for young adults through career readiness training, environmental education, and community engagement. Representatives of UCOR introduced environmental justice topics and initiatives and provided the organization with resources to apply for J40 and environmental grant opportunities.

UCOR has established formal Memoranda of Understanding with a Minority Serving Institution, Florida International University in Miami, Florida. The company hosted site visits with its HBCU Partnership schools, Tennessee State University in Nashville, Tenn., and Benedict College in Columbia, S.C., to grow DOE's future workforce. UCOR hosted two interns from the Mentorship for Environmental Scholars Program, which provides HBCU students with exposure to DOE EM careers. These actions support our mission and increase our environmental justice efforts.

3.4. Quality Assurance Program

Integrated Assessment and Oversight Program

Quality assurance (QA) program implementation and procedural and subcontract compliance are verified through the UCOR integrated assessment and oversight program. The program identifies the processes for planning, conducting, and coordinating assessment and oversight of UCOR activities, including both self-performed and subcontracted activities, resulting in an integrated assessment and oversight process. The program is composed of three key elements: (1) external assessments conducted by organizations external to UCOR, (2) independent assessments conducted by teams composed of UCOR personnel who are not directly involved with the project/function being assessed, and (3) management assessments and surveillances conducted as self-assessments and surveillances by the organization or on behalf of the organization manager.

Self-assessments are performed by the organization/function with primary responsibility for the work, process, or system being assessed. Organizations and functions within the company plan and schedule self-assessments. Self-assessments encompass both formal and informal assessments. The formal self-assessments include management assessments and surveillances, and subcontractor oversight. Informal self-assessments include weekly inspections and routine walkthroughs conducted by subcontractor coordinators, ES&H, and QA representatives, quality engineers, and line managers.

Conditions adverse to quality identified from internal and external assessments are documented, causal analyses are performed, and corrective actions are developed and tracked to closure. Analyses are conducted periodically to identify trends for management action. Senior management evaluates data from those processes to identify opportunities for improvement.

3.5. Air Quality Program

The state of Tennessee has been delegated authority by EPA to convey the clean air requirements that are applicable to ETTP operations. New projects are governed by construction and operating permit regulatory requirements. The owner or operator of air pollutant emitting sources is responsible for ensuring full compliance with any issued permit or other generally applicable CAA requirement. During 2022, ETTP DOE EM operations were under UCOR responsibility for regulatory compliance.

3.5.1. Construction and Operating Permits

UCOR ETTP operations are subject to CAA regulations and permitting under TDEC Air Pollution Control rules that are specific to stationary fossil-fueled reciprocating internal combustion engines for emergency use. TDEC originally issued an operating permit (069346P) covering six stationary emergency reciprocating internal combustion engine (e-RICE) units on March 3, 2015. An amended permit was issued on November 22, 2016, that removed one permanently shut-down unit. The last operating permit was amended on November 22, 2016, and covered four stationary e-RICE generators and one stationary e-RICE firewater booster pump. On July 19, 2018, TDEC provided a Notice of Authorization to UCOR for coverage under Permit-by-Rule for all of the ETTP stationary e-RICE (TDEC 2017b). During 2020 all generators and the firewater booster pump were either removed from the ETTP site or transferred to new owners; UCOR then surrendered its Permit-by-Rule authorization. No stationary e-RICE units were operated by UCOR at ETTP in 2022.

All other ETTP operations that emit low levels of air pollutants have been classified as insignificant under TDEC rules. Any planned stationary sources that may emit air pollutants are evaluated and compared against applicable pollutant emission limits to document this classification and pursue permitting if required under TDEC regulations.

3.5.1.1. Generally Applicable Permit Requirements

ETTP is subject to a number of generally applicable requirements that involve management and control. Asbestos, ozone-depleting substances (ODSs), and fugitive particulate emissions are specific examples.

Control of Asbestos

ETTP's asbestos management program ensures all activities involving demolitions and all other actions involving asbestos-containing materials (ACM) are fully compliant with 40 CFR Part 61, Subpart M, *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos" (EPA 1984, EPA 1990). This includes using approved engineering controls and work practices, inspections, and monitoring for proper removal and waste disposal of ACM. Most demolition and ACM abatement activities at ETTP are governed under CERCLA. Under this act, notifications of asbestos demolition or renovations, as specified in 40 CFR Part 61.145(b), are incorporated into CERCLA document regulatory notifications.

Non-CERCLA planned demolition or renovation activities were individually reviewed for applicability of the TDEC notification requirements of the rule. During 2022, one Notification of Demolition and/or Asbestos Renovation was submitted to TDEC for non-CERCLA ETTP activities. There were no regulated asbestos containing material demolitions during 2022.

The rule also requires an annual notification for all nonscheduled, minor asbestos renovations if the accumulated total amount of regulated or potentially regulated asbestos exceeds stipulated thresholds. For 2022, the total ETTP projected nonscheduled amounts were below thresholds that would require the submittal of an annual notification to TDEC. No releases of reportable quantities of ACM occurred at ETTP during 2022.

Stratospheric Ozone Protection

The management of ODSs at ETTP is subject to regulations in 40 CFR Part 82, Subpart F, "Recycling and Emissions Reduction" (EPA 1993); these regulations require preparation of documentation to establish that actions necessary to reduce emissions of Class I and Class II refrigerants to the lowest achievable level have been observed during maintenance activities at ETTP. The applicable actions include, but may not be limited to, the service, maintenance, repair, and disposal of appliances containing Class I and Class II refrigerants, such as motor vehicle air conditioners. In addition, the regulations apply to refrigerant reclamation activities, appliance owners, manufacturers of appliances, and recycling and recovery equipment. Figure 3.7 illustrates the historical on-site ODS inventory at ETTP. During 2022, the ODS inventory was zero.

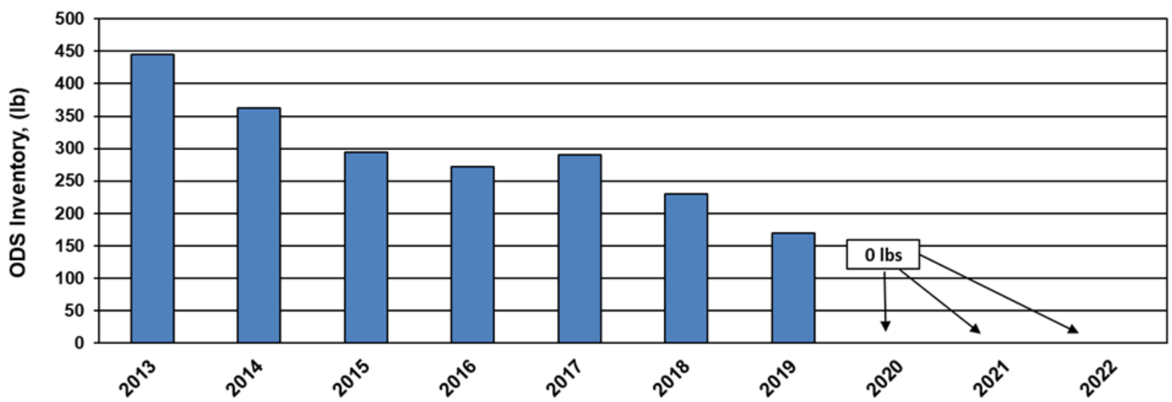


Figure 3.7. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history

3.5.1.2. Fugitive Particulate Emissions

ETTP has been the location of major building demolition activities, soil remediation activities, and waste debris transportation with the potential for the release of fugitive dust. All planned and ongoing activities include the use of dust control measures to minimize the release of visible fugitive dust beyond the project perimeter. This includes the use of specialized demolition equipment and water misters. Gravel roads in and around ETTP that are under DOE control are wetted with water, as needed, to minimize airborne dusts caused by vehicle traffic.

3.5.1.3. Radionuclide National Emission Standards for Hazardous Air Pollutants

Radionuclide airborne emissions from ETTP are regulated under 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP)* (EPA 1989). Characterization of the impact on public health of radionuclides released to the atmosphere from ETTP operations was accomplished by conservatively estimating the dose to the maximally exposed member of the public. The dose calculations were performed using the Clean Air Assessment Package (CAP-88) computer codes, which were developed under EPA sponsorship for use in demonstrating compliance with the 10 mrem/year effective dose National Emission Standards for Hazardous Air Pollutants for radionuclides (Rad-NESHAP) emission standard for the entire DOE ORR. Source emissions used to calculate the dose are determined using EPA-approved methods that can range from continuous sampling systems to conservative estimations based on process and waste characteristics. Continuous sampling systems are required for radionuclide-emitting sources that have a potential dose impact of not less than 0.1 mrem per year to any member of the public. The only ETTP Rad-NESHAP source that operated during 2022—the K-1407 Chromium Water Treatment System (CWTS) Volatile Organic Compound (VOC) Air Stripper is considered minor based on emissions evaluations using EPA-approved calculation methods. A minor

Rad-NESHAP source is defined as having a potential dose impact on the public that is less than 0.1 mrem/year. Compliance is demonstrated using data collected by the ETTP ambient air monitoring program.

Quarterly radiochemical analyses are performed on composited samples collected at all ETTP ambient air sampling stations. The selected isotopes of interest were ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U), with the ^{99}technetium (^{99}Tc) inorganic analysis results included as a dose contributor. The concentration for each of the nuclides at each monitoring station are presented in Table 3.4 for the 2022 reporting period. Only one radionuclide analyzed at ETTP ambient air locations was detected; that result was for ^{235}U at station K11 in the second quarter of 2022. Dose calculations using the concentration results are included in Chapter 7, Table 7.5.

Table 3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2022 through December 2022

Station	Concentration (µCi/mL)[a]			
	^{99}Tc	^{234}U	^{235}U	^{238}U
K11[b]	ND[c]	ND	2.5E-19	ND
K12[b]	ND	ND	ND	ND

[a] *µCi/mL = microcuries/milliliter*
[b] *K11 and K12 represent an on-site business exposure equivalent to half of a yearly exposure at this location.*
[c] *ND = not detectable*

3.5.1.4. Quality Assurance

QA activities for the Rad-NESHAP program are documented in the *Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge Tennessee* (UCOR 2018, UCOR-4257/R2). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114 (EPA 1989), for ensuring that the radionuclide air emission measurements from ETTP are representative of known levels of precision and accuracy and that administrative controls are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC regulation 1200-3-11-.08, *Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities*, TDEC 2018). The plan ensures the quality of ETTP radionuclide emission measurement data from continuous samplers and minor radionuclide release points. Only EPA preapproved methods are referenced through the *Compliance Plan National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE/ORO/2196, DOE 2020).

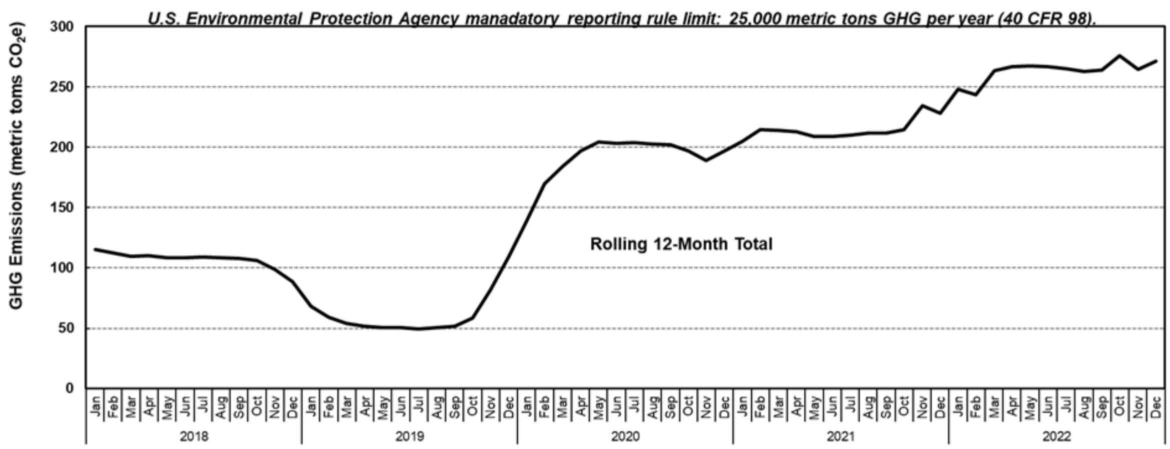
3.5.1.5. Greenhouse Gas Emissions

The EPA rule for mandatory reporting of GHGs (also referred to as the "Greenhouse Gas Reporting Program") was enacted October 30, 2009, under 40 CFR Part 98 (EPA 2009). According to the rule in general, the stationary source emissions threshold for reporting is 25,000 MT of CO_2 equivalent (CO_2e) or more of GHGs per year. The rule defines GHGs as:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons
- Perfluorocarbons
- Sulfur hexafluoride (SF_6)

A review was performed of ETTP processes and equipment categorically identified under 40 CFR

Part 98.2 (EPA 2009), whose emissions must be included as part of a facility's annual GHG report, starting with the CY 2010 reporting period. Based on total GHG emissions from all ETTP stationary sources during 2022, ETTP did not exceed the annual threshold limit and therefore was not subject to mandatory annual reporting under the GHG rule during this performance period. The total GHG emissions for any continuous 12-month period beginning with CY 2008 have not exceeded 12,390 MT CO_2e of GHGs. The most significant decrease in stationary source emissions was due to the permanent shutdown of the TSCA Incinerator in 2009. The remaining sources are predominantly comfort heating systems, hot water systems, and power generators. Figure 3.8 shows the five-year trend up through 2022 of ETTP total GHG stationary emissions. For CY 2022, GHG emissions totaled 264 MT CO_2e, which is 0.11 percent of the 25,000 MT CO_2e per year threshold for reporting.



Note: *Shown in carbon dioxide equivalent (CO2e)*
Acronyms:
CFR = Code of Federal Regulations GHG = greenhouse gas

Figure 3.8. East Tennessee Technology Park stationary source greenhouse gas emissions tracking history

The increase starting in 2020 resulted from the leasing of several large bays in Building K-1036; these bays are heated with natural gas.

EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, was published in the Federal Register on October 8, 2009. The purpose of this order was to establish policies for federal facilities that will increase energy efficiency; measure, report, and reduce GHG emissions from direct and indirect activities; conserve and protect water resources through efficiency, reuse, and storm water management; eliminate waste; recycle; and prevent pollution at all such facilities. While the order deals with a number of environmental media, only its applicability to GHG is considered here. The EO defines three distinct scopes for purposes of reporting:

1. Scope 1 is essentially direct GHG emissions from sources that are owned or controlled by a federal agency.
2. Scope 2 encompasses GHG emissions resulting from the generation of electricity, heat, or steam purchased by a federal agency.
3. Scope 3 involves GHG emissions from sources not owned or directly controlled by a federal agency, but related to agency activities, such as vendor supply chains, delivery services, and employee business travel and commuting.

One goal of this order was to establish a FY 2020 Scopes 1 and 2 reduction target of 28 percent, as compared to the 2008 baseline year.

EO 13693, *Planning for Federal Sustainability in the Next Decade,* was published in the Federal Register on March 25, 2015. This order superseded EO 13514 and established a new Scope 1 and Scope 2 federal-wide total reduction target of 40 percent by 2025, as compared to the 2008 baseline year. For reporting purposes, GHG emission data are compared to both goals.

EO 13834, *Efficient Federal Operations*, was published in the Federal Register on May 22, 2018. This order superseded EO 13693. It requires continued tracking and reporting of GHG emissions, but no specific federal-wide total reduction target.

The information reported here includes GHG emissions from the industrial landfills at Y-12 that are managed and operated by UCOR. The landfills are not part of the contiguous ETTP site; however, DOE requested that UCOR, as the operator, include landfill GHG emissions with ETTP reporting in the Consolidated Energy Data Report. To be consistent with reporting this information, the landfill emissions are also included with ETTP ASER data. Figure 3.9 shows the trend toward meeting both the original EO 13514 Scopes 1 and 2 GHG emissions reduction target of 28 percent by FY 2020 and the EO 13693 Scopes 1 and 2 GHG emissions reduction target of 40 percent by FY 2025.

Scopes 1 and 2 GHG emissions for FY 2022, including the landfills, totaled 15,676 MT CO2e, which is a 75 percent reduction from emissions in the FY 2008 baseline year.

Figure 3.10 shows the relative distribution and amounts of all ETTP FY 2022 GHG emissions for Scopes 1, 2, and 3, including the industrial landfills at Y-12. Total GHG emissions remain well below the levels first reported in the 2008 baseline year as demolition and remediation efforts continue at ETTP. Many of the early reductions were due to lower on-site combustion of fuels (stationary and mobile sources), lower consumption of electricity, and a smaller workforce. The total amount of GHG emissions for Scopes 1, 2, and 3, including landfills at Y-12, for FY 2022 was 21,614 MT CO_2e.

3.5.1.6. Source-Specific Criteria Pollutants

ETTP operations included one functioning minor stationary source, the CWTS, with a potential to emit any form of criteria air pollutant. This unit is equipped with an air stripper to remove VOCs from the influent stream. Potential total VOC emissions from the CWTS air stripper were calculated to be 0.005 ton/year in 2022, as compared to an emission limit of 5 tons/year.

A variety of minor pollutant-emitting sources released airborne pollutants from ETTP operations, such as vents, and fugitive and diffuse activities. The emissions from all stacks and vents are evaluated following approved methods to establish their low emissions potential. This is done to verify and document their minor source permit exempt status under all applicable state and federal regulations.

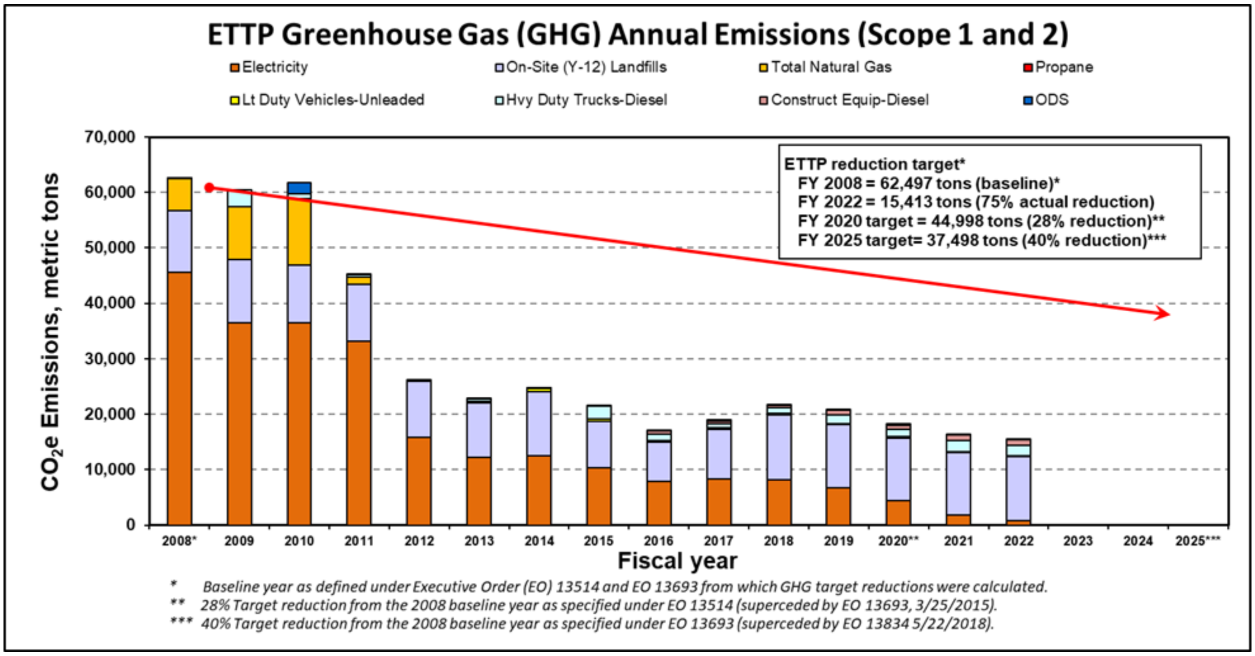
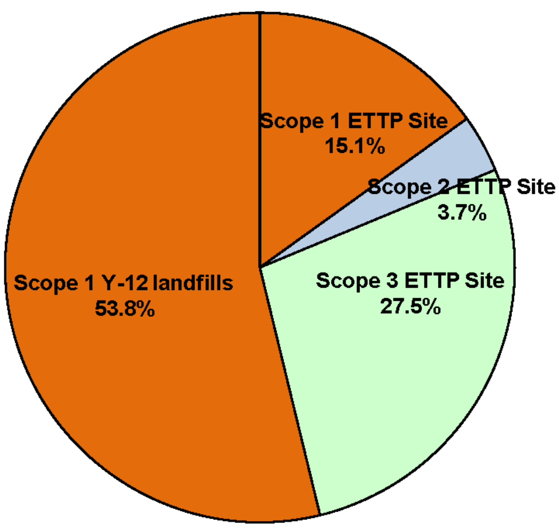


Figure 3.9. East Tennessee Technology Park greenhouse gas annual emissions (Scopes 1 and 2, including industrial landfills at Y-12)



ETTP FY 2022 Greenhouse Gas Emissions: 21,614 tons

Scope 1: ETTP Site Releases
Onsite stationary fossil fuel combustion, 264
Onsite fugitives and refrigerants, 10 tons
Onsite mobile source fuel combustion, 2,983 tons

Scope 1: Y-12 Industrial Landfills
Y-12 Industrial Landfills, 11,626 tons

Scope 2: Indirect GHG Releases
Electricity purchase, 793 tons

Scope 3: Indirect GHG Releases
Business air travel, 36 tons
Business ground travel, 10 tons
Employee commuting, 5,885 tons
Contracted wastewater treatment, 7 tons

Acronyms:
ETTP = East Tennessee Technology Park
GHG = greenhouse gas
Y-12 = Y-12 National Security Complex

Figure 3.10. Fiscal year 2022 East Tennessee Technology Park greenhouse gas emissions by scope

3.5.1.7. Hazardous Air Pollutants (Nonradionuclide)

Unplanned releases of hazardous air pollutants are regulated through the risk management planning regulations under 40 CFR Part 68 (EPA 1994). To ensure compliance, periodic inventory reviews of ETTP operations were performed that used monthly data obtained through the EPCRA Section 311 reporting program. This program applies to any facility at which a hazardous chemical is present in an amount exceeding a specified threshold. A comparison of the EPCRA 311 monthly Hazardous Materials Inventory System chemical inventories at ETTP with the risk management plan threshold quantities listed in 40 CFR Part 68.130 (EPA 1994) was conducted. This is an ongoing action that documents the potential applicability for maintaining and distributing a risk management plan and ensuring threshold quantities are not exceeded.

ETTP personnel have determined that there are no processes or facilities containing inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section 112(r), "Prevention of Accidental Releases." Therefore, activities at ETTP are not subject to the rule. Procedures are in place and implemented to continually review new processes, process changes, or activities with the rule thresholds.

3.5.2. Ambient Air

Compliance of fugitive and diffuse sources is demonstrated based on environmental measurements. The ETTP Ambient Air Quality Monitoring Program is designed to provide environmental measurements to accomplish the following:

- Tracking of long-term trends of airborne concentration levels of selected air contaminant species
- Measurement of the highest concentrations of the selected air contaminant species that occur in the vicinity of ETTP operations
- Evaluation of the potential impact on air contaminant emissions from ETTP operations on ambient air quality

The three sampling programs in the ETTP area are designated as the environmental compliance and protection (EC&P) program, TDEC program, and the ORR perimeter air monitoring program. Figure 3.11 shows an example of a typical EC&P program air monitoring station. Figure 3.12 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2022 reporting period.

The EC&P program consisted of two sampling locations throughout 2022. All projects are operating similar high-volume sampling systems. The EC&P, TDEC, and perimeter air monitoring samplers operate continuously with exposed filters collected weekly. The radiological monitoring results for samples collected at the one ETTP area perimeter air monitoring station are the responsibility of UT-Battelle, LLC. TDEC is responsible for the data collected from their samplers. UT-Battelle, LLC and TDEC results are not included with the EC&P data presented in this section. However, results from the other programs are requested periodically for comparison.

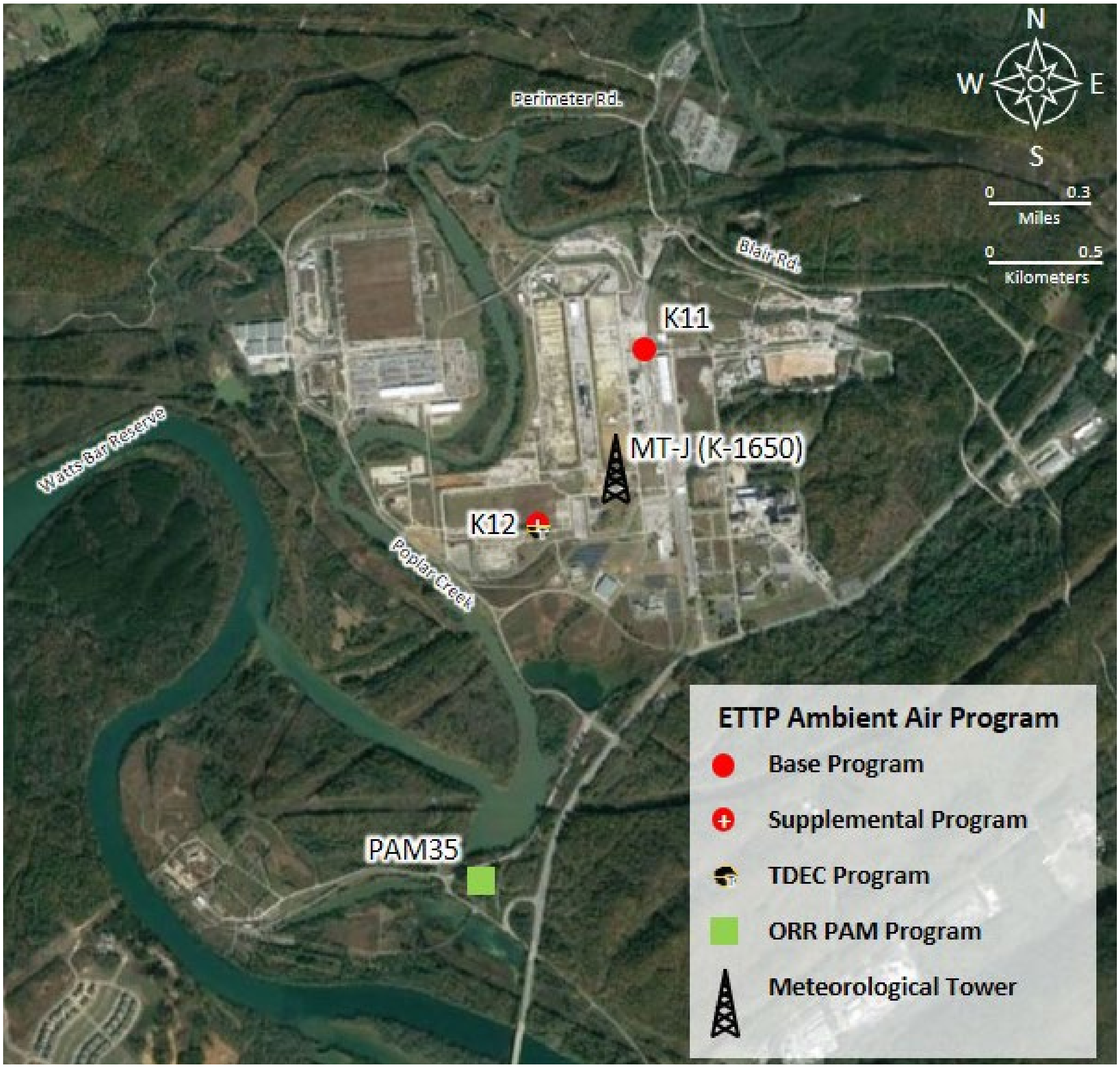
The analytical parameters were chosen with regard to existing and proposed regulations and with respect to activities at ETTP. The principal reason for EC&P program stations is to demonstrate that radiological emissions from the demolition of ETTP gaseous diffusion buildings, supporting structures, and associated remediation activities are in compliance with the annual dose limit to the most exposed members of the public that are either on-site (on ORR) or off-site. K11 and K12 were key sampling locations regarding the potential dose impact on the most exposed member of the public at an on-site business location during slab removals, small structures demolition, excavation and removal of contaminated soils, and other activities.

Changes of emissions from ETTP will warrant periodic reevaluation of the parameters being sampled. Ongoing ETTP reindustrialization efforts will also introduce new locations for members of the public that may require adding or relocating monitoring site locations. To ensure understanding of the potential impacts on the public and to establish any required emissions monitoring and controls, a survey of all on-site tenants is reviewed every six months through a request for the most recent ETTP reindustrialization map.

All EC&P program stations collected continuous samples for radiological analyses during 2022. These analyses of samples from the EC&P stations test for the isotopes ^{234}U, ^{235}U, ^{238}U, and ^{99}Tc.

Stations K11 and K12 are located to provide a conservative measurement of the impact to on-site members of the public.

Figure 3.11. East Tennessee Technology Park ambient air monitoring station



Acronyms:

ETTP = East Tennessee Technology Park
MT = meteorological tower
ORR = Oak Ridge Reservation
PAM = perimeter air monitoring
TDEC = Tennessee Department of Environment and Conservation

Figure 3.12. East Tennessee Technology Park ambient air monitoring station locations

3.6. Water Quality Program

Water quality is monitored via multiple programs at ETTP. Storm water monitoring is conducted through the NPDES Program (Section 3.6.1) and the Storm Water Pollution Prevention Program (Section 3.6.2). Surface water monitoring is conducted through the Environmental Monitoring Program (EMP) (Section 3.6.3). Groundwater monitoring is conducted through the Water Resources Protection Program (Section 3.6.4).

3.6.1. National Pollutant Discharge Elimination System Permit Monitoring

NPDES monitoring is conducted to demonstrate compliance with the ETTP NPDES Permit. The previous ETTP NPDES permit in effect during the first months of 2022 became effective on April 1, 2015, and expired on March 31, 2020, but the expired permit continued in effect until the new permit was issued by the state of Tennessee. The new permit was issued on February 4, 2022, and became effective on April 1, 2022. Under the new ETTP NPDES Permit in effect during 2022, 20 representative outfalls are monitored annually (Figure 3.13). All twenty (20) representative outfalls are sampled annually for total suspended solids (TSS), pH, and flow. Additionally, select outfalls are sampled annually for zinc (Outfall 142), oil and grease (Outfall 190), PCBs (Outfalls 280, 690), benzidine (Outfall 430), and semiannually for total chromium and hexavalent chromium (Outfall 170). There were no permit noncompliances in 2022.

Figure 3.13. Storm water outfall monitoring

3.6.2. Storm Water Pollution Prevention Program

In addition to the NPDES permit required monitoring, storm water is also monitored for a variety of substances, including radionuclides, metals, and organic compounds (UCOR-4028b, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee*, UCOR 2022). Routine storm water pollution prevention plan (SWPPP) monitoring is conducted at various locations that vary from year to year depending on activities going on within the drainage basins and historical monitoring results. SWPPP monitoring includes radiological monitoring, D&D and RA monitoring, CERCLA Phased Construction Completion Report (PCCR) monitoring, legacy contamination monitoring, and investigative monitoring.

3.6.2.1. Radiologic Monitoring of Storm Water

Radiological monitoring is conducted to determine compliance with applicable dose standards. Composite samples from five outfalls were collected following a rain event and analyzed for gross alpha activity, gross beta activity, and specific radionuclides. The estimated discharge of radionuclides from ETTP via the storm water drainage system was calculated based on the radiological monitoring results, daily rainfall data for CY 2022, and flow rates. Table 3.5 presents the total calculated discharge of radionuclides from storm water discharged to off-site waters from ETTP in CY 2022.

Table 3.5. Radionuclides released to off-site waters from the East Tennessee Technology Park storm water system in 2022

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level (curies)	0.008	0.00078	0.0061	0.049

3.6.2.2. Demolition and Remedial Action Monitoring of Storm Water

Demolition and RA monitoring is conducted to evaluate the effectiveness of Demolition and RAs and to ensure that storm water controls are preventing sediment and contaminants from discharging into receiving waters. Grab samples from select outfalls are collected prior to the start of demolition/RAs, following each 1-in. rain event during demolition/RAs, and after completion of demolition/RA activities.

3.6.2.3. K-25 Building ^{99}Tc Contaminated Soil Remedial Action Monitoring

Demolition of the K-25 Building was completed in 2014. The last section of the east wing that was demolished was contaminated with the radioactive isotope ^{99}Tc. Rain and dust control water that contacted the ^{99}Tc-contaminated piping and other building materials is believed to have caused the migration of ^{99}Tc into soils beneath the east wing debris pile during demolition. Remediation of the ^{99}Tc-contaminated soils within the K-25 footprint was completed in 2020. Storm water monitoring in Outfalls 190 and 490, located downgradient of the former K-25 Building, continued in 2022.

Outfall 190 is sampled quarterly. Except for the sample collected in July 2021, ^{99}Tc has not been detected in storm water samples from Outfall 190 since July 2013. Based on this data, it does not appear that ^{99}Tc-contaminated groundwater from the K-25 Building D&D project is discharging to Mitchell Branch via Outfall 190.

Outfall 490 is sampled semiannually. Technetium-99 was detected in the storm water samples from Outfall 490 in January 2022 and August 2022 but was well below the reference standard of 390,000 picocuries/liter (pCi/L). Outfall 490 discharges into the K-1007-P1 Pond. Discharges from the K-1007-P1 Pond to Poplar Creek are monitored routinely as an exit pathway location per the ETTP EMP. The ^{99}Tc data is evaluated to determine the contribution of ^{99}Tc from the Outfall 490 drainage area to the total ^{99}Tc discharge from the K-1007-P1 pond, as further discussed in Section 3.6.3, "Surface Water Monitoring."

3.6.2.4. K-1203 Sewage Treatment Plant Post-Demolition and Remedial Action Monitoring

Outfall 05A is located in the former K-1203 Sewage Treatment Plant (STP) area. Demolition of K-1203 was completed in 2019; RAs, including rerouting of the Outfall 05A discharge, were completed in 2020; and storm water monitoring continued through August 2022. Samples from the newly designated outfall (referred to as Outfall 05A-2 but officially listed on the ETTP NPDES Permit as Outfall 05A) are collected and analyzed for metals. Metal concentrations have fluctuated but continue to show an overall decrease over time.

3.6.2.5. EU-21 Remedial Action Monitoring

The EU-21 area is located between the east and west wings of the former K-25 Building and includes the slab associated with the former K-1024 Maintenance Shop. The K-1024 Maintenance Shop was used for the repair and calibration of instruments and equipment used in the K-25 uranium enrichment process. The maintenance shop used solvents, including TCE, for cleaning instruments and equipment. As an accepted practice at the time, solvents were frequently discharged into the floor drains, then entered the storm drain network. The main source of TCE in the EU-21 area is presumed to be from

Catch Basin 7097, located on the south side of the former K-1024 Building. Although TCE is the primary contaminant of concern for the EU-21 soil RA, mercury droplets were discovered during removal of buried pipe. K-1024 was also used for cleaning mercury from line recorder chemical traps between 1946 and 1947 and the equipment shop had a problem with spilled mercury and mercury vapors.

Prior to the soil RA, the storm drain system within the proposed excavation and clean layback footprints was isolated from the active system in order to prevent sediment and contaminants from discharging to Poplar Creek via Outfalls 230 and 240. Outfall 210 receives water from the storm drain system located on the east side of the K-25 east wing (well outside of the excavation and layback footprints). All of the catch basins located on the west side of the K-25 west wing were previously plugged under a separate program.

Baseline samples were not collected prior to the start of the soil RA due to dry conditions. Monitoring of Outfalls 210, 230, and 240 is being conducted during 1-in. rain events and analyzed for VOCs, metals, mercury, and TSS. TCE has not been detected in any of the samples collected from Outfalls 210, 230, or 240 in 2022. Several other parameters have been detected, but only PCBs, mercury and lead exceeded reference standards during the February 2022 and April 2022 rain events. Storm water monitoring will continue following each 1-in. rain event until the RA is complete. A final sampling event will be conducted once excavation and waste shipments have been completed.

3.6.2.6. Monitoring of Outfalls Designated in the CERCLA Phased Construction Completion Reports

When environmental restoration activities at ETTP are conducted in phases, progress may be documented in a CERCLA PCCR. When this occurs, a PCCR is prepared to document the completed work (e.g., demolition) and interim requirements for remaining slabs. If radiological surveys indicate that a slab exceeds the release criteria in DOE Order 5400.5, Chg. 2, *Radiation Protection of the Public and the Environment* (DOE 1993a), then interim access controls are implemented, the slab is posted, and the slab is included in the radiological surveillance and monitoring program. Environmental requirements in the radiological surveillance and monitoring program include sampling designated outfall(s) once every NPDES permit cycle for gross alpha activity, gross beta activity, uranium isotopes, and ^{99}Tc. The designated outfall(s) are selected based on the drainage area and proximity to the slab(s).

Two outfalls were designated for sampling in CERCLA PCCRs in 2022. Grab samples were collected from Outfalls 40 and 490 and analyzed for gross alpha activity, gross beta activity, uranium isotopes, and ^{99}Tc. The CERCLA PCCR monitoring results are presented in Table 3.6.

3.6.2.7. Legacy Mercury Contamination Monitoring of Storm Water

Legacy mercury contamination monitoring is conducted to evaluate mercury concentrations over time and to determine if non-representative outfalls are contributing mercury to site waterways.

Outfalls 180 and 190 discharge storm water from large areas on the north side of ETTP into Mitchell Branch. There were numerous historical mercury operations within Outfalls 180 and 190 drainage areas and the Mitchell Branch subwatershed. Due to contaminated sediment within storm water networks and potential infiltration into the piping, these are potential contributors to the continuing legacy mercury discharges to Mitchell Branch. As described in Section 3.6.2.2, Outfall 05A/05A-2 routes storm water runoff and groundwater infiltration from the former K-1203 STP area to the former discharge pipe used by the K-1203 STP and into Poplar Creek. Based on the decreasing concentrations of metals, including mercury, in the samples collected from Outfall 05A/05A-2, it appears that legacy contamination in the Outfall 05A/05A-2 area has been reduced due to demolition of the K-1203 STP, subsequent RAs, and revegetation of the K-1203 footprint.

The mercury concentrations detected in Outfalls 180, 190, and 05A/05A-2 during 2022 are presented in Table 3.7. The mercury concentrations over time in Outfalls 180, 190, and the K-1700 Weir on Mitchel Branch and 05A/05A-2 on Poplar Creek are presented in Figures 3.14 and 3.15, respectively. In 2022, only one mercury result from April 2022 at Outfall 180 exceeded the reference standard of 51 nanograms/liter (ng/L). The mercury concentrations at these outfalls fluctuate but show an overall decreasing trend over time.

Table 3.6. CERCLA PCCR monitoring results for 2022

Parameter	Reference standard	Outfall 240 (4/12/2022)	Outfall 490 (10/31/2022)
Associated Slab(s)		K-2500-H slab	K-101 slab
Alpha activity (pCi/L)[a]	15	**7.69**	**2.25 U**
Beta activity (pCi/L)	50	**7.5**	**49.8**
^{99}TC (pCi/L)	390,000	**4.91 U**	**84.3**
$^{233/234}$U (pCi/L)	1,200	**1.45**	**0.91 U**
$^{235/236}$U (pCi/L)	1,300	**-0.00966 U**	**0.18 U**
^{238}U (pCi/L)	1,400	**0.566 U**	**0.4**

[a] *pCi/L = picocuries/liter*

Note: *Results in bold exceed the reference standard. Reference standards for gross alpha and gross beta measurements correspond to the National Primary Drinking Water Standard (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G, EPA 1975). Reference standards for radionuclides equal the derived concentration standard (DCS) for ingested water (DOE-STD-1196-2021, Derived Concentration Technical Standard, DOE 2021b).*

Table 3.7. Mercury results for Outfalls 180, 190, and 05A/05A-2 in 2022

Sampling location	Reference standard (ng/L)[a]	1/10/2022 (ng/L)	1/24/2022 (ng/L)	4/12/2022 (ng/L)	4/28/2022 (ng/L)	8/8/2022 (ng/L)	11/1/2022 (ng/L)
Outfall 180	51	15.9	14.5	39.3	**95.2**	39.9	46.2
Outfall 190	51	-	6.1	-	5.12	3.94	4.5
		2/3/2022 (ng/L)	**6/7/2022 (ng/L)**	**8/11/2022 (ng/L)**			
Outfall 05 A/05A-2	51	6.54	6.47	7.4			

[a] *ng/L = nanograms/liter*

Note: *Results in bold exceed the reference standard. The reference standard for mercury corresponds to TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria.*

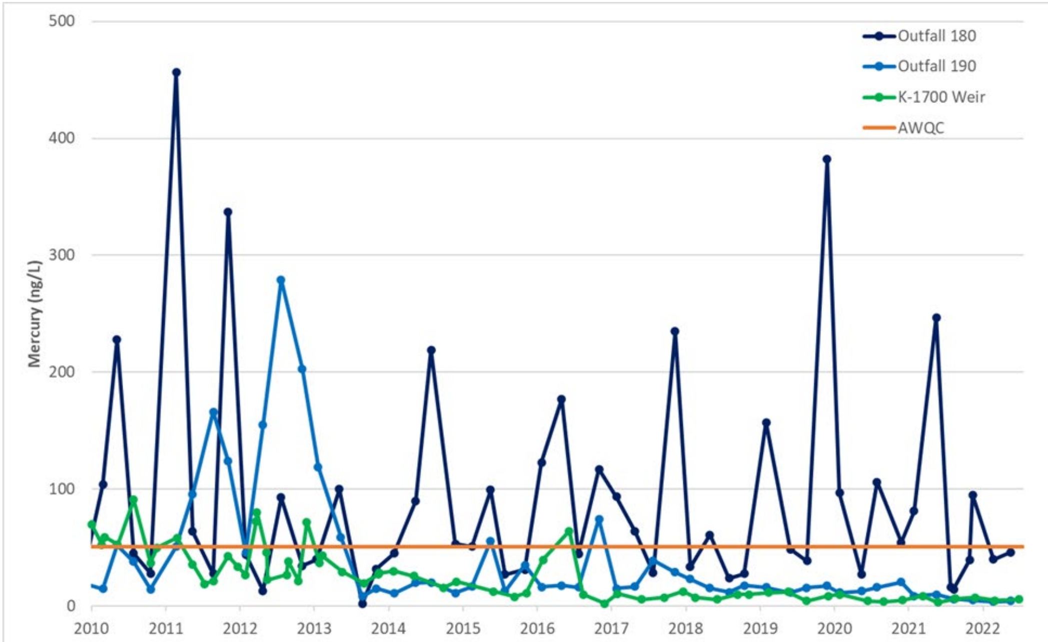
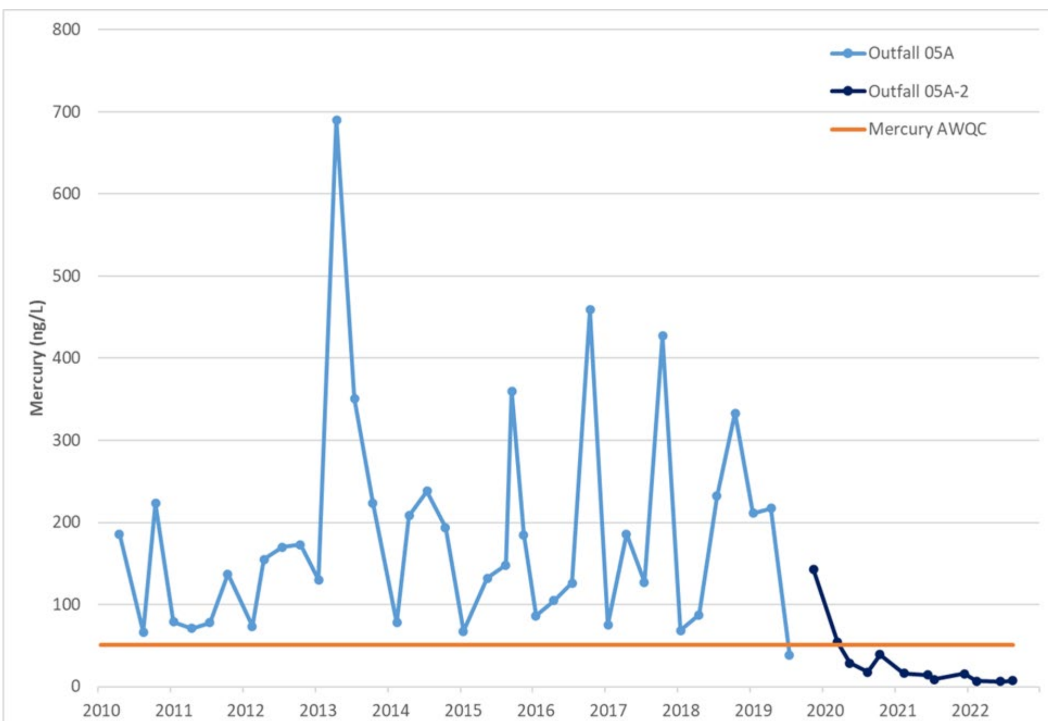


Figure 3.14. Mercury concentrations at Outfalls 180 and 190, and the K-1700 Weir



Acronym:
AWQC = ambient water quality criterion

Figure 3.15. Mercury concentrations at Outfall 05A/05A-2

3.6.2.8. Investigative Monitoring of Storm Water

Investigative monitoring is conducted based on elevated analytical results, CERCLA requirements, and/or changes in site conditions. Investigative monitoring was conducted at Outfall 690, as well as the Outfall 780 network in 2022.

Outfall 690. Outfall 690, was sampled to evaluate the current concentrations of PCBs and to evaluate the current contaminant trends observed at this outfall. Grab samples were collected when storm water runoff was observed discharging and analyzed for PCBs.

During the April 2022 sampling effort, PCBs were detected in Outfall 690. The result of 0.0354 J ug/L exceeded the reference standard of 0.00064 ug/L for PCBs. A sample was not taken during the third quarter of 2022 due to no flow conditions. In the fall of 2022, the oil water separator associated with Outfall 690 was filled in and the storm water system was modified to divert water to surface sheet flow via a newly installed bubbler. This action also removed the headwall of Outfall 690 and modified the system so that the outfall no longer discharges.

Outfall 780 Network. Outfall 780 is located in the Powerhouse Area. In 2018, a select group of non-representative outfalls was sampled to determine if they were contributing mercury and PCBs to site waterways. Outfall 780 had elevated concentrations of mercury and PCBs. Recent activities being conducted in the area were not suspected as the cause of the elevated mercury and PCB concentrations, although process knowledge indicated that they could be legacy contaminants. Outfall 780 once carried storm water runoff from former Buildings K-724 and K-725. These buildings were originally part of the S-50 Thermal Diffusion Plant; Building K-725 was later used for beryllium processing. It contained mercury traps that occasionally released mercury. In addition, mercury was reportedly "swept down the floor drains" and into the storm drain system during cleanup activities in the 1970s. Mercury may also have been present in the dust collection system and transported to the storm drain system via storm water runoff during demolition of K-725 in the 1990s. Outfall 780 also received storm water from the K-722 area, where approximately 1,000 gal of oil was landfarmed for dust suppression in the 1980s.

A commercial wood yard and chipping facility operates at the K-722 site. While it is doubtful that these operations caused an increase in mercury or PCBs in the Outfall 780 drainage network, in 2021 they appeared to discharge water from an unknown source. This discharge was dark brown and appeared in relatively small quantities on an ongoing basis. Before the facility began operation, Outfall 780 was dry and did not discharge water to the Clinch River except during substantial storm events. It is possible that the discharge from this facility may be mobilizing contaminants that have been dormant in the Outfall 780 network for years.

Outfall 780 was sampled in February 2022 for a wide variety of parameters. PCBs, copper, lead, and mercury were detected in elevated concentrations that exceeded their respective reference standards. Additional monitoring of legacy contaminants will be conducted as part of the SWPPP in 2023.

3.6.2.9. Chromium Water Treatment System and Plume Monitoring

The CWTS (Figure 3.16) was constructed to intercept a plume of contaminated groundwater before it enters Mitchell Branch.

The CWTS consists of interceptor wells, pumps, holding tanks, a treatment system, and an air stripper. Effluent is discharged through the pipeline that originally carried effluent from the Central Neutralization Facility (which was previously demolished). In CY 2022, monitoring was conducted at monitoring well 289 (TP-289), the chromium collection system wells, Outfall 170,

Figure 3.16. The Chromium Water Treatment System

and Mitchell Branch kilometer (MIK) 0.79. Figures 3.17 and 3.18 show the results for the analyses for total chromium and hexavalent chromium, respectively.

The analytical data indicate that both total and hexavalent chromium levels at TP-289 and the collection wells may fluctuate slightly but are relatively consistent over the long term. In 2022, levels of total chromium and hexavalent chromium at Outfall 170 and MIK 0.79 exhibited wider variability. After years of low concentrations, results for hexavalent chromium at Outfall 170 equaled or exceeded the ambient water quality criterion (AWQC) of 11 micrograms/liter (µg/L) in three of five samples collected in 2022. Results for total chromium at Outfall 170 were within historic ranges, and well below the AWQC in 2022. The levels of both hexavalent and total chromium at MIK 0.79 fluctuated in 2022, but remained below the AWQC for hexavalent chromium of 11 µg/L and well below the total chromium AWQC of 164 µg/L. These results demonstrate the continuing positive impact of the collection well system to minimize the release of chromium into Mitchell Branch.

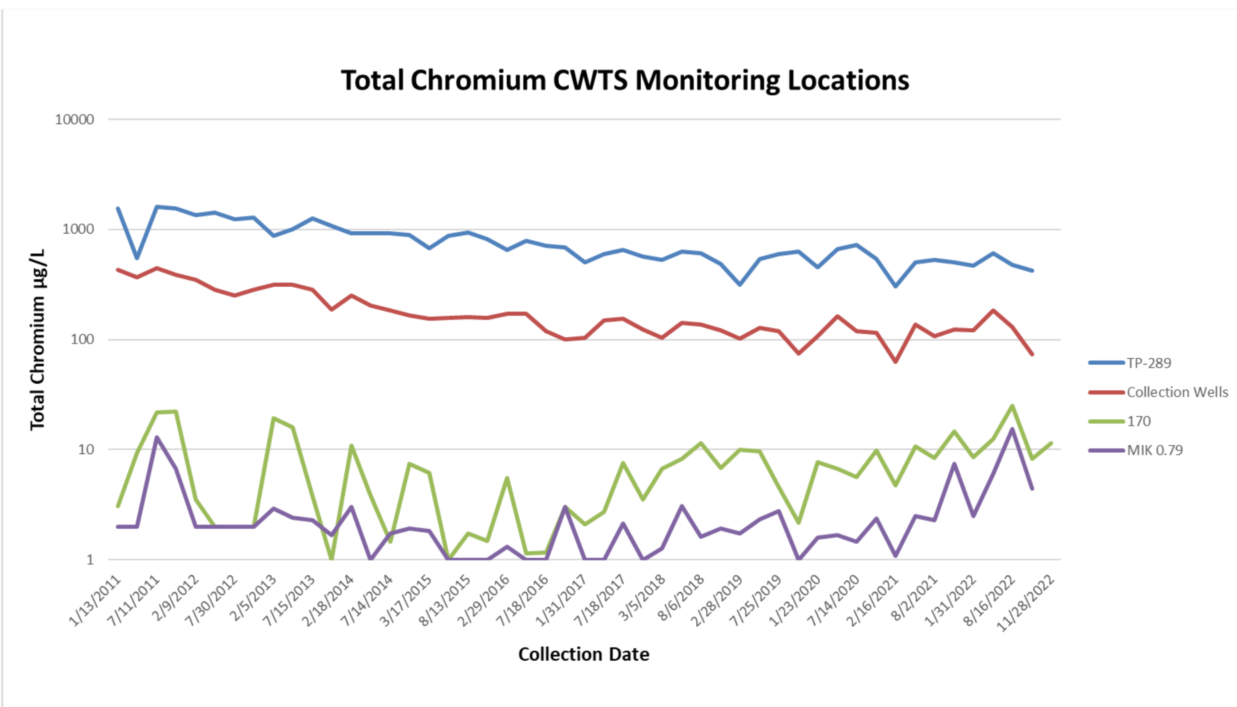


Figure 3.17. Total chromium sample results for the chromium collection system

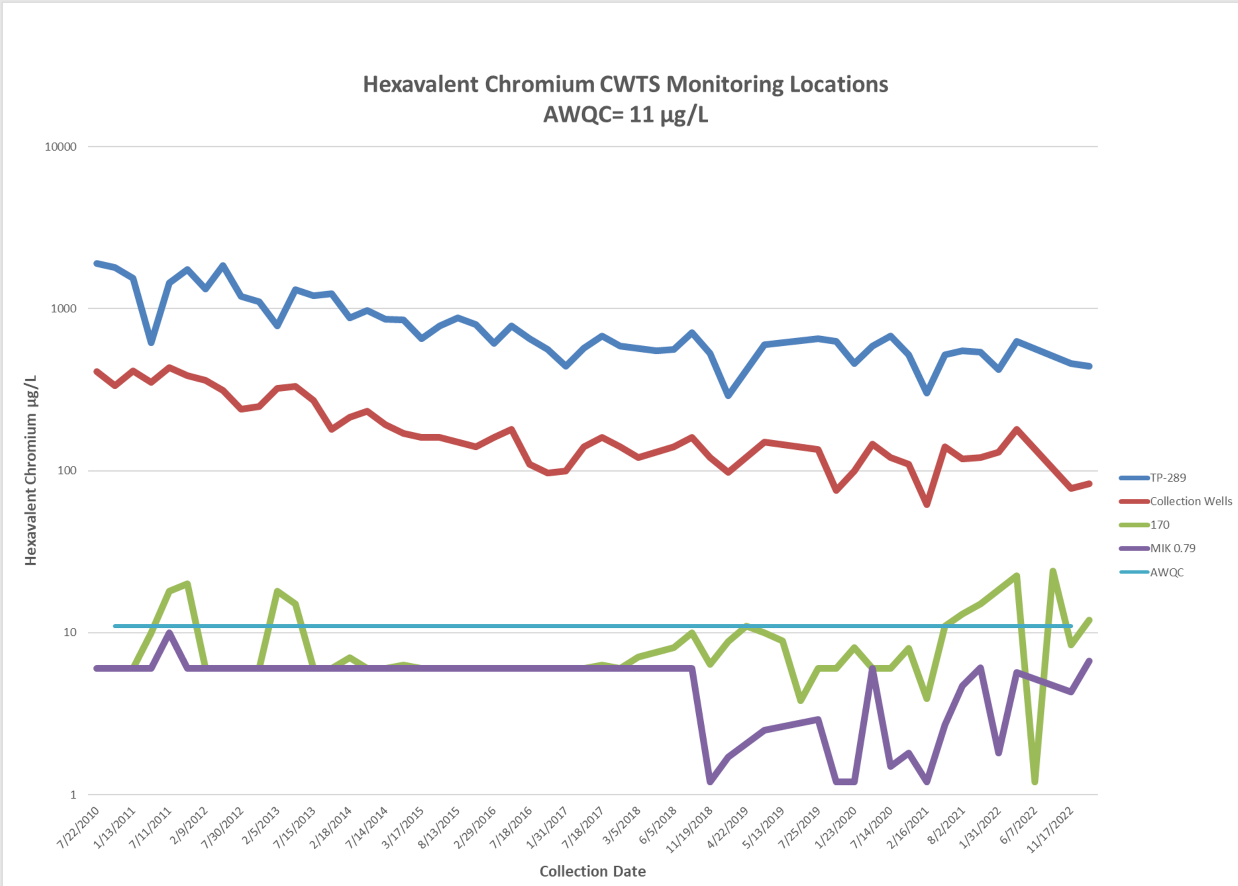
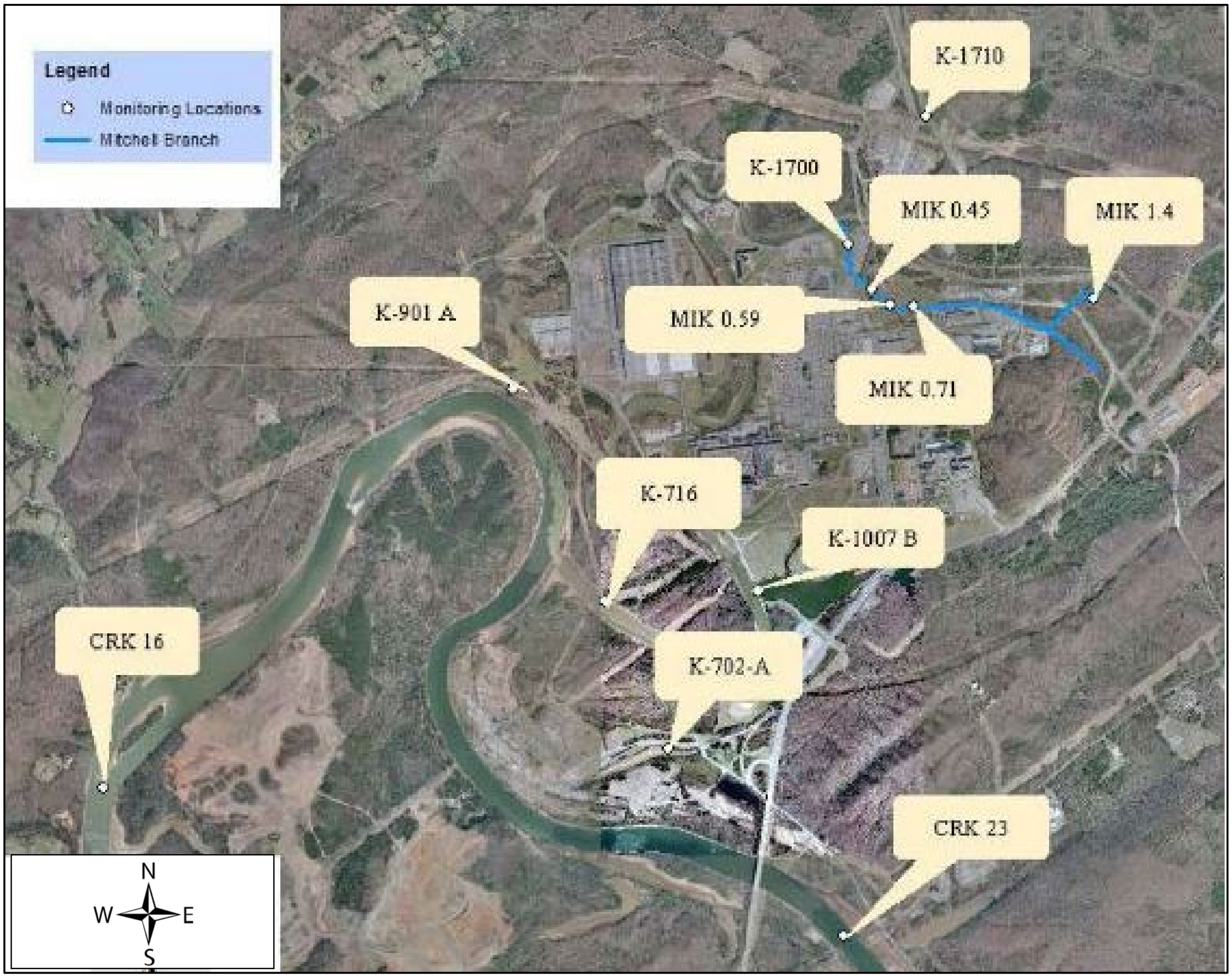


Figure 3.18. Hexavalent chromium sample results for the chromium collection system

3.6.3. Surface Water Monitoring

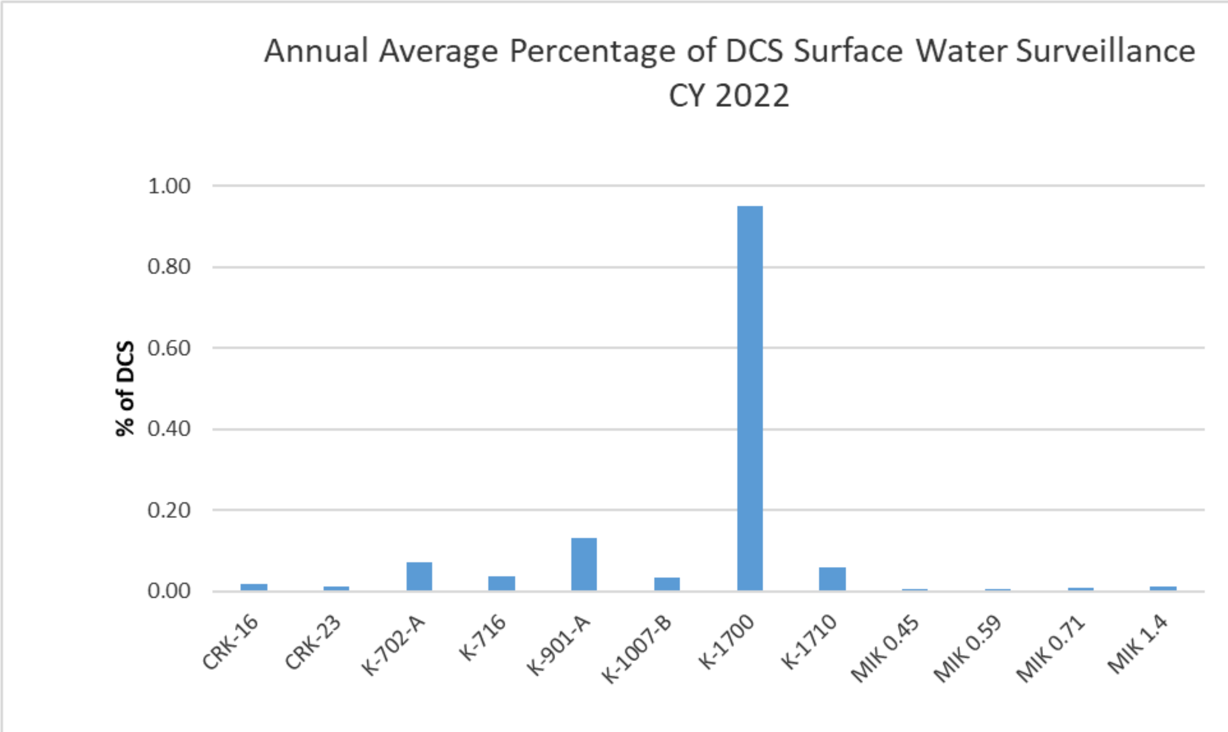
During 2022, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Figures 3.19 and 3.20) to monitor surface water conditions at watershed exit pathway locations (K-1700, K-1007-B, and K-901-A) or ambient stream conditions (Clinch River kilometers [CRKs] 16 and 23; K-1710; K-716; the K-702-A slough; and MIKs 0.45, 0.59, 0.71, and 1.4). Monitoring locations K-1700 and MIKs 0.45, 0.59, 0.71, and 1.4 were sampled quarterly; and monitoring locations CRKs 16 and 23, K-716, K-1007-B, K-901-A, and the K-702-A slough were sampled semiannually.

Figure 3.19. Surface water surveillance monitoring



Acronyms:
CRK = Clinch River kilometer *MIK = Mitchell Branch kilometer*

Figure 3.20. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations



Acronyms: *CRK = Clinch River kilometer DCS = derived concentration standard MIK = Mitchell Branch kilometer*

Figure 3.21. Annual average percentage of derived concentration standards at surface water monitoring locations, 2022

Results of radiological monitoring were compared with the derived concentration standard (DCS) values in DOE Standard 1196, *Derived Concentration Technical Standard* (DOE 2021b). Radiological data are reported as fractions of DCSs for reported radionuclides, and the fractions for all of the isotopes are added together to produce the sum of fractions (SOF) and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100 percent) for the year, a formal source investigation is required. Sources exceeding DCS requirements would need an analysis of the best available technology to reduce the SOF of the radionuclide concentrations to less than 1.0 (100 percent). In 2022, the monitoring results yielded SOF values of less than 0.01 (1 percent of the allowable DCS) at all surface water surveillance locations at ETTP (Figure 3.21). At K-1700, the annual average SOF was 0.0095 (0.95 percent). At MIKs 0.45, 0.59, and 0.71, quarterly monitoring is conducted for ^{99}Tc only.

EMP surface water monitoring results show that conditions in the ETTP waterways usually meet Ambient Water Quality. There was one exception during the third quarter of 2022: a failure to meet the minimum required level of dissolved oxygen (5.0 mg/L).

Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2022, 1834 analytical results and 169 field readings were collected under the EMP. The vast majority of these results were well within the appropriate AWQC. There was one exception during the third quarter of 2022: a failure to meet the minimum required level of dissolved oxygen (5.0 milligrams/liter [mg/L]). Dissolved oxygen levels were measured at 4.5 mg/L at K-901-A. This reading was collected at a time of elevated temperatures and very low flow due to the drought conditions, which favor high biological activity and the resulting depletion of dissolved oxygen. This reading was within historic ranges at this location.

Figure 3.22 illustrates the concentrations of TCE from the Mitchell Branch monitoring locations. Although VOCs are routinely detected at K-1700 and MIK 0.45, they are rarely detected at other surface water surveillance locations across ETTP. In the samples collected on November 22, 2016, results for several VOCs, including TCE and cis-1,2-dichloroethene, at several of the Mitchell Branch monitoring locations were reported at levels significantly higher than seen in recent monitoring. It should be noted that the November 22, 2016, sample date was at the end of an extended dry weather period that began in August 2016. Furthermore, even at the increased levels, the results are still well within the AWQC. Concentrations of TCE and total 1,2-dichloroethylene (1,2-DCE) are below the AWQCs for recreation, organisms only (300 µg/L for TCE and 10,000 µg/L for trans-1,2-DCE), which are appropriate standards for Mitchell Branch. In addition, vinyl chloride has sometimes been detected in Mitchell Branch water. VOCs have been detected in groundwater in the vicinity of Mitchell Branch and in building sumps discharging into storm water outfalls that discharge into the stream; these compounds have generally not been detected in storm water during the monitoring of network discharges. It appears that the primary source of these compounds is contaminated groundwater.

Since CWTS was installed, chromium levels in Mitchell Branch have dropped dramatically, with levels of total chromium being routinely measured at less than 6 µg/L (Figure 3.23). In 2022, hexavalent chromium levels in Mitchell Branch were all below the AWQC of 11 µg/L.

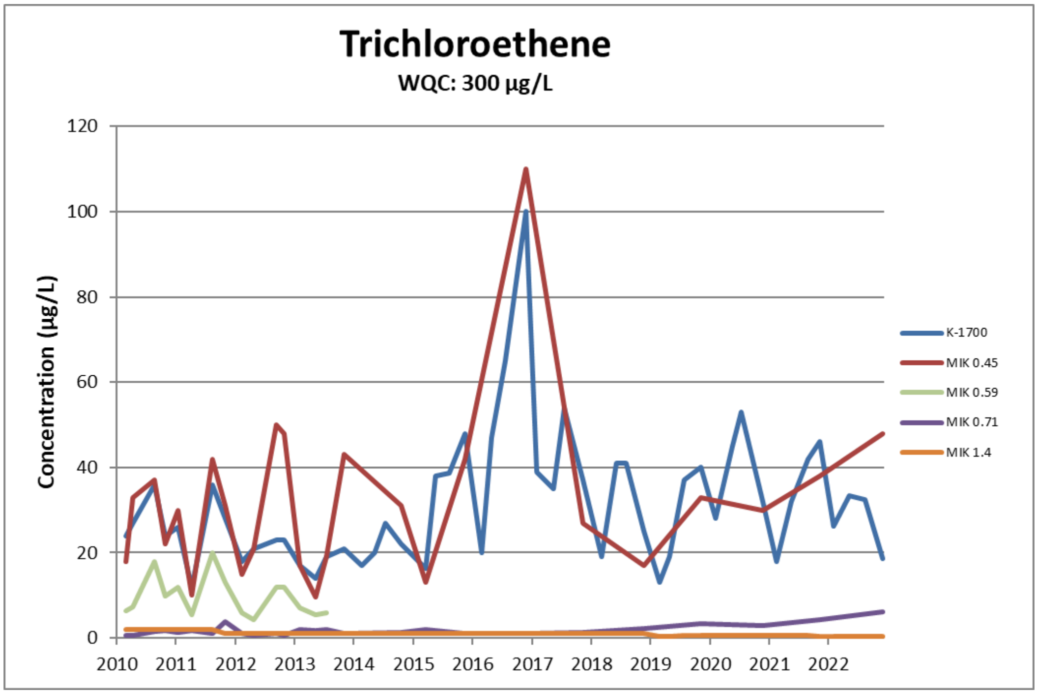
In CY 2022, ETTP did not conduct surface water monitoring for per- and polyfluoroalkyl substances (commonly known as "PFAS"). Instead, groundwater was sampled for these compounds. See Section 3.6.4 for details.

3.6.4. Groundwater Monitoring at ETTP

ETTP was divided into two zones to complete the primary source RA work. Zone 1 comprises 1290 acres outside the ETTP main plant area, and Zone 2 comprises 806 acres of the ETTP main plant area. Actions have been ongoing to characterize and address soil, buried waste, and subsurface structures for protection of human health and the environment and to limit further groundwater contamination through source reduction or removal.

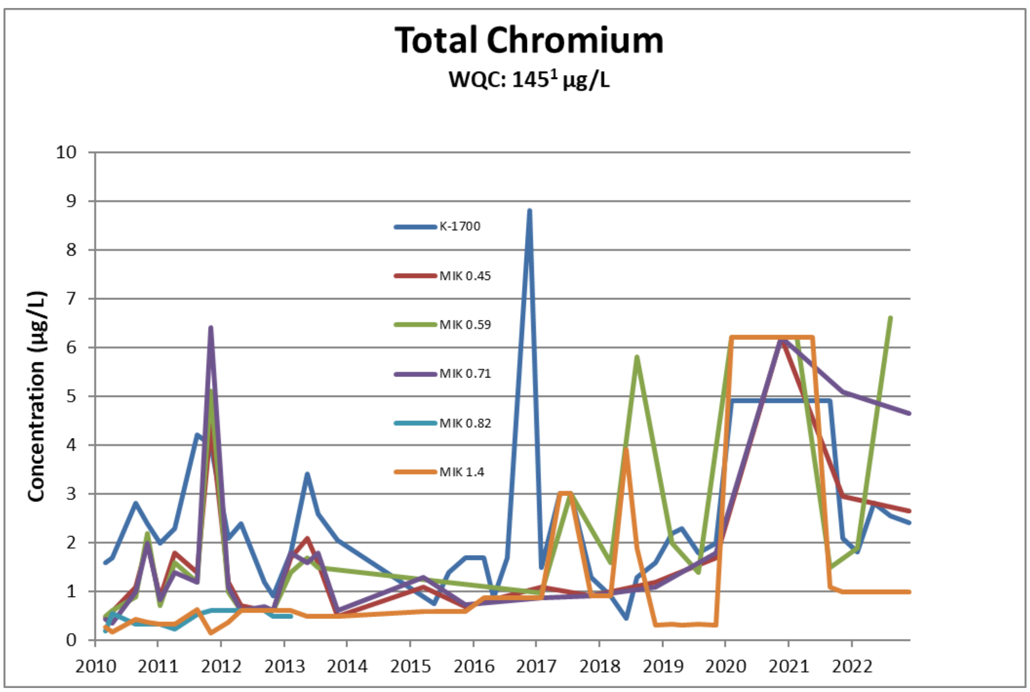
In FY 2022, planning for the ETTP continued as follows:

- The *East Tennessee Technology Park Main Plant Groundwater Focused Feasibility Study, Oak Ridge, Tennessee* (DOE 2021a) and the *Proposed Plan for an Interim Record of Decision for Groundwater in Main Plant Area at East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 2022b) were submitted to EPA and TDEC for review, and comments were received.



Acronym: *MIK = Mitchell Branch kilometer*

Figure 3.22. Trichloroethene concentrations in Mitchell Branch



Note: *(1) The AWQC for Cr(III), which is hardness-dependent, is 145 µg/L, based on a hardness of 227 mg/L in the receiving waters. The AWQC for Cr(VI) is 11 µg/L.*
Acronyms: *AWQC = ambient water quality criterion MIK = Mitchell Branch kilometer*

Figure 3.23. Total chromium concentrations in Mitchell Branch

- The *Remedial Investigation/Feasibility Study Report for the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2893&D2, DOE 2021d) was approved by EPA and TDEC through an erratum, and the *Proposed Plan for the Record of Decision for Groundwater in the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2922&D1, DOE 2022c) was submitted to EPA and TDEC for review, and comments were received.
- The *Zone 1 Groundwater Plumes Remedial Investigation Work Plan, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2903&D2, DOE 2021c) was submitted to EPA and TDEC for review and comments were received.

The data screen and trend assignments show contaminant concentration trends are highly variable across the site. Maximum contaminant levels (MCLs) are used as screening levels for groundwater and are not performance standards. A summary of the groundwater sampling follows:

- VOC concentrations in wells monitored downgradient of K-1070-C/D show a broad area is affected by past-disposal releases of liquid VOCs at the G-Pit. While trend evaluations for data collected within the most recent 5 years indicate stable, indeterminate, or decreasing concentrations, the persistent, high concentrations of these VOCs in nearby wells suggest an ongoing contaminant source release.
- In the K-31/K-33 area, chromium and nickel continue to be measured periodically at levels slightly greater than the MCL and Tennessee groundwater criteria at two wells (BRW-030 and UNW-043). However, in FY 2022, concentrations of chromium exceeded the MCL only at well UNW-043 and nickel concentrations were below Tennessee groundwater criteria.
- At the K-27/K-29 area, groundwater contamination migrates toward Poplar Creek in both north and south directions from area facilities. Alpha activity and total uranium concentrations in BRW-016 continued to decline in FY 2022 after well cleanout was conducted for BRW-016. This well was inundated by water from D&D runoff in FY 2019. Vinyl chloride (VC) exceeds the MCL in the northern portion of the K-27/K-29 area north exit pathway. Nickel equaled or exceeded its Tennessee groundwater criteria screening concentration (0.1 mg/L) in the unfiltered samples from two wells (UNW-038 and UNW-096) in the south/west exit pathway. TCE also exceeded the MCL screening concentration (0.005 mg/L) in these two wells. The five-year TCE trends in the K-27/K-29 southern area are stable to increasing.
- Monitoring results from wells in the K-1407-B/C Ponds area are generally consistent with results from previous years and show several-fold concentration fluctuations in seasonal and long-term periods. The detection of VOCs at concentrations above 1000 µg/L and the relatively steady concentrations over recent years suggest the presence of dense non-aqueous phase liquid in the vicinity of the former K-1407-B Pond.
- VOCs are present in groundwater at the now-remediated K-1070-A Burial Ground in the northwestern portion of ETTP. Groundwater contaminated primarily with TCE discharges at downgradient spring 21-002. Although TCE concentrations fluctuate above and below the MCL screening concentration of 5 µg/L, 8 of the last 12 samples collected at spring 21-002 have exceeded the MCL for TCE.

Groundwater beneath the K-720 Fly Ash Pile in EU Z1-11 is contaminated with metals. The potential surface water discharges are dependent upon the soil cover that is in place as a protective action. Activities conducted at the K-720 Ash Pile in FY 2022 included inspections for changes in features, such as presence of any new seepage areas on the periphery or downgradient of the ash pile, changes in conditions at the surface water monitoring locations, changes in the northern drainage ditch or other surface water drainages, changes in appearance or dimension of the sluice pond, evidence of rodent damage, changes in the seep directly south of the covered ash pile, evidence of visible subsidence or settlement of the soil cover, inspections of the vegetative cover and wetland, and inspections of warning signs. An existing seep on the south side remains unchanged. Also, bottom ash is visible along the northern ditch and banks of the pond on the west side, but there is no change from previous inspections. A maintenance request was initiated on December 1, 2021, to assess a beaver dam at the end of the northern ditch and a possible culvert blockage. It was noted on the April 21, 2022, inspection that pH at the seep collector is 6.61.

The K-1407-B Pond, constructed in 1943, was primarily used for settling metal hydroxide precipitates generated during neutralization and precipitation of metal-laden solutions treated in the K-1407-A Neutralization Unit. It also received discharge from the K-1420 Metals Decontamination Building, K-1420 plating wastes that generated F006 hazardous wastes pond sludge, and wastes from the K-1501 Steam Plant. The K-1407-C Pond, constructed in 1973, was primarily used to store potassium hydroxide scrubber sludge generated at ETTP. It also received sludge from the K-1407-B Pond. When the K-1407-B Pond reached maximum sludge capacity, it was dredged, and the sludge was transferred to the K-1407-C Pond. The *Remedial Action Report for the K-1407-B Holding Pond and the K-1407-C Retention Basin, Oak Ridge, Tennessee* (DOE/OR/01-1371&D1, DOE 1995) proposed semiannual groundwater monitoring for nitrate, metals, VOCs, and selected radionuclides, including gross alpha and beta activity, ^{99}Tc, ^{90}Sr, ^{137}Cs, ^{230}Th, ^{232}Th, ^{234}U, and ^{238}U. Target concentrations for these parameters were not established (DOE/OR/02-1125&D3, DOE 1993b; DOE/OR/01-1371&D1, DOE 1995). However, as recommended by EPA with concurrence from TDEC, monitoring for the constituents listed for the K-1407-B Pond is conducted in wells UNW-003, UNW-009, and the Mitchell Branch Weir (K-1700 Weir), shown on Figure 3.24. The primary groundwater contaminants in the K-1407-B/C Ponds area are VOCs. VOCs are widespread and persistent in this portion of ETTP, including contaminant sources upgradient of the ponds. Figure 3.24 presents the combined unconsolidated and bedrock plume boundaries for total VOCs.

DOE has compiled analytical data from groundwater monitoring well UNW-003 to evaluate concentration trends for regulated contaminants. Data are compared to EPA's National Primary Drinking Water Regulations MCLs or maximum contaminant level derived concentrations (MCL-DCs) for radionuclides, for screening purposes and for identifying constituents and wells for trend analysis. The MCLs and MCL-DCs are not criteria identified in the K-1407-B/C Ponds ROD.

In recent years, large seasonal variations in VOC concentrations have been measured at well UNW-003. DOE suspects a dense non-aqueous phase liquid source exists somewhere beneath the former pond site based on persistent high VOC concentrations in both shallow and deeper groundwater wells. Data are consistent in showing significant decreasing contaminant concentration trends for four VOCs at this location over the past 10 years. However, stable trends are present for the annual maximum concentration evaluations over the past 10 years for three of these four VOCs (i.e., tetrachloroethene [PCE], TCE, and VC). The FY 2022 results from UNW-003 remain consistent with the plume boundary depicted in Figure 3.24.

No other analytes were detected in wells UNW-003 or UNW-009 at concentrations greater than or equal to 80 percent of their respective MCLs or MCL-DCs in FY 2022. It is important to note that VOCs are generally not detected at UNW-009, located downgradient of the K-1407-C Pond. Since 2017, only low, estimated concentrations of cis-1,2-DCE have been detected at this well.

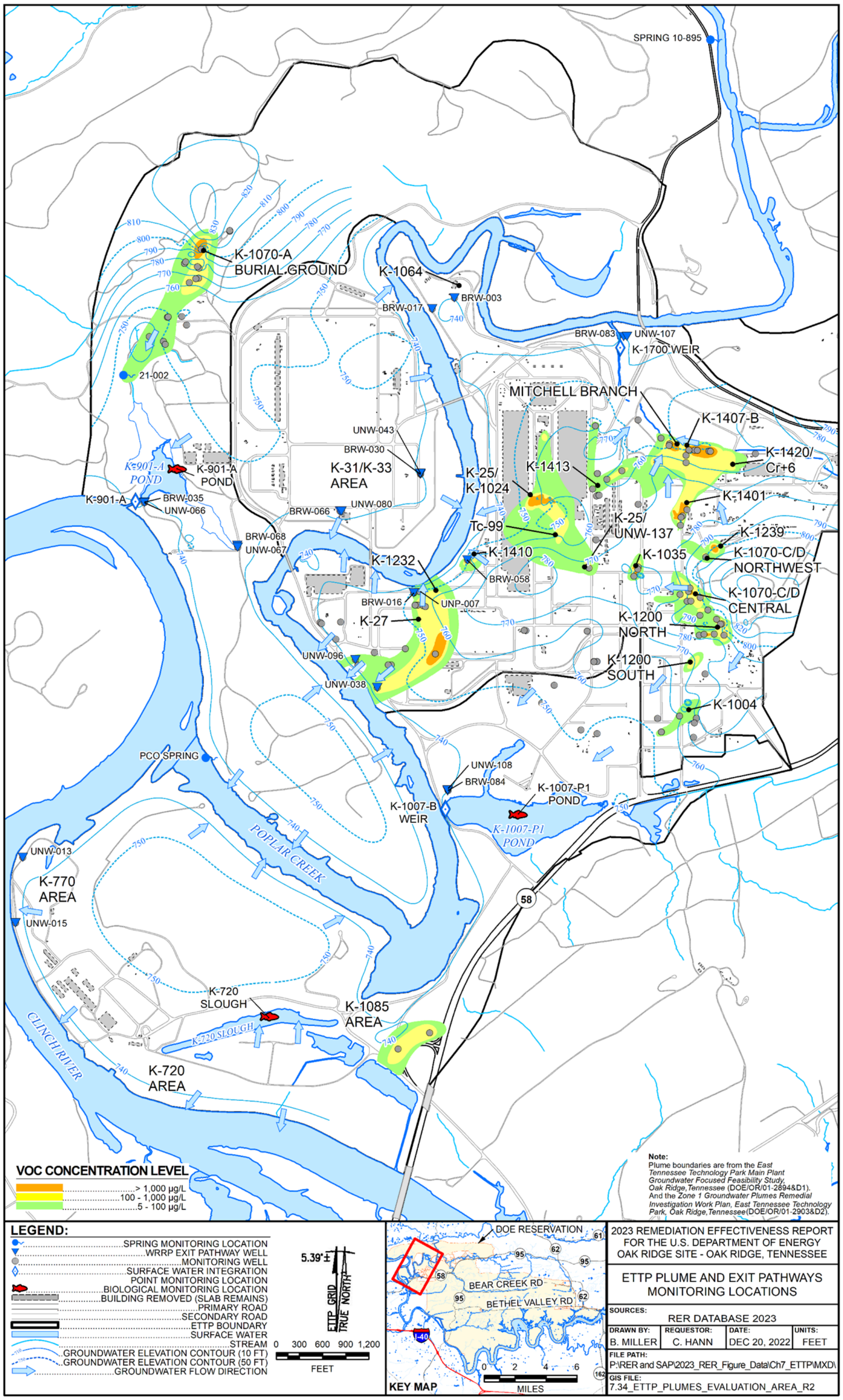


Figure 3.24. East Tennessee Technology Park volatile organic compound and ^{99}Tc plumes

The K-1070-C/D G-Pit was the primary source of organic contaminant releases to soil and groundwater in the area immediately west of the K-1070-C/D Waste Disposal area. The K-1071 Concrete Pad, located in the southeastern portion of the K-1070-C/D area, was determined to pose an unacceptable health risk to workers from future exposure to soil radiological contaminants (DOE/OR/02-1486&D4). The contents of the pit were excavated and a soil cover was placed over the concrete pad earlier. Residual contaminated groundwater in the K-1070-C/D G-Pit and Burial Ground area will be addressed in a future decision. Monitoring locations, analytical parameters, and cleanup levels were not specified for groundwater monitoring at the K-1070-C/D Burial Ground, although the primary contaminants of concern (COCs) in that area are VOCs. Semiannual samples collected at wells and surface water locations outside the perimeter (downgradient) of the K-1070-C/D Burial Ground are analyzed for VOCs and general water quality parameters. Monitoring at the site focuses on providing data for evaluating changes in contaminant concentrations near the source units or potentially discharging to surface water within the ETTP boundaries.

Following G-Pit remediation, monitoring wells UNW-114, TMW-011, and UNW-064 (see Figure 3.24) were selected to monitor the VOC plume leaving the K-1070-C/D Burial Ground because they were located in the principal known downgradient groundwater pathway. Well monitoring results show elevated VOC concentrations. The VOC concentrations at these three wells began to decrease prior to excavating the G-Pit contents (during FY 2000) and continue to decrease. Although 1,1,1-TCA was formerly present at concentrations far greater than its 0.2-mg/L MCL, natural biodegradation and advective groundwater processes within the monitoring zone have reduced 1,1,1-trichloroethane (1,1,1-TCA) concentrations to less than the drinking water standard. Several direct-push technology monitoring points were installed to the west of UNW-114 during investigations conducted in 2005. The purpose of these monitoring points was to investigate groundwater contamination in an area along potential geologically controlled seepage pathways that may have connected the G-Pit contaminant source to the former SW-31 spring. DOE continues to monitor to measure VOC concentrations and their fluctuations downgradient of G-Pit.

DOE has compiled analytical data from K-1070-C/D groundwater monitoring to evaluate concentration trends for regulated contaminants. Data are compared to EPA's National Primary Drinking Water Regulations MCL, for screening purposes; however, MCLs are not identified as criteria in the ROD (DOE/OR/02-1486&D4). Groundwater contaminant trends in the area downgradient of the G-Pit source are mostly stable to indeterminate, with decreasing trends for PCE and TCE at well UNW-114 for the 10-year evaluation period. No contaminants exhibit an increasing trend over the past 5- and 10-year periods. Seasonal variations in VOC concentrations are very commonly observed. The FY 2022 results from UNW-114, UNW-064, and TMW-011 remain consistent with the plume boundary.

Well UNW-114 is closest to the source area and has a 10-ft screened interval placed in weathered bedrock material at an elevation of 774.95 ft above mean sea level (AMSL). Monitoring data for well UNW-114 show concentrations of most VOCs have been variable since 2005.

Well UNW-064 (10-ft well screen placed just above bedrock at an elevation of 783.87 ft AMSL) is located slightly further downgradient from the contaminant source area than UNW-114 and its monitoring data exhibit a slightly different behavior. Similar to the overall trend observed at UNW-114, the majority of VOC concentrations at UNW-064 decreased from about 2002–2005. Trend evaluations for VOCs in well UNW-064 for a 10-year period indicate no significant trend for 1,1-DCE and TCE and a stable trend for VC. The most-recent five-year period trends indicate a stable trend for 1,1-DCE; a decreasing trend for TCE, with a stable trend for the annual maximum concentrations; and no trend for VC.

Well TMW-011 (10-ft well screen placed just above bedrock at an elevation of 762.8 ft AMSL) is located furthest from the contaminant source area near the base of the hill below K-1070-C/D. VOC concentrations at TMW-011 tend to fluctuate in a fashion similar to those at UNW-064, except the seasonal signature is reversed, with higher concentrations in summer than during winter. This relationship suggests groundwater recharge during winter tends to dilute the VOCs near TMW-011 rather than cause a pulse of higher concentration groundwater, as was observed at the mid-slope location near UNW-064.

Overall, throughout the monitoring period of record, there have been decreases in the parent VOC (1,1,1-TCA and TCE) concentrations, with slight increases in concentrations of some of the degradation pathway compounds (e.g., 1,1-dichloroethane and VC) in the vicinity of the source (UNW-064 and UNW-114). The FY 2022 increase in VC concentrations at UNW-064 and UNW-114, which generally correlate to TCE and other precursor compound (i.e., cis-1,2-DCE) concentration decreases, likely represents the result of natural biodegradation from intrinsic dehalogenating bacteria in groundwater in the vicinity of these wells.

Figure 3.24 presents the current sitewide contaminant plume map for the sum of VOC plumes from the Main Plant Area Focused Feasibility Study (FFS) (DOE 2022b), K-31/K33 Remedial Investigation/Feasibility Study (DOE 2021d), and Zone 1 Remedial Investigation Work Plan (DOE 2021c). Figure 3.24 also shows the locations of exit pathway monitoring wells throughout the ETTP site that are routinely sampled by the Water Resources Restoration Program (WRRP) for known COCs, inferred groundwater flow directions in plume areas, and direction of surface water flow. As shown, the inferred groundwater flow directions are based on the water table piezometric surface contours. Shallow groundwater plumes generally flow in conformance to the local gradients, although in some areas, especially where geologic structures such as bedrock folding, fracturing, and karst development occur, groundwater may flow through secondary porosity features in directions oblique to inferred gradients.

For each of these exit pathway wells, DOE has compiled analytical data for groundwater contaminants for the past 10 years. The compiled data are compared to EPA's National Primary Drinking Water Regulations MCLs or MCL-DCs for radionuclides. The summary of M-K trend evaluations for the exit pathway wells in increments of the past 10 years and the last 5 years of monitoring show that, in general, contaminants that have exceeded their respective MCL concentrations have decreased in concentrations based on maximum measured concentrations in each monitoring interval evaluated and compared to FY 2022 data. The assignment of M-K trends shows mixed results of statistically significant decreases in some cases, increasing trends in other cases, and some instances in which trends are indeterminate or stable. Some metals (e.g., chromium and nickel) tend to be measured at or above MCL concentrations, with a tendency for particle-associated metals to lead to these MCL exceedances based on often-lower metal concentrations in filtered sample aliquots.

The Mitchell Branch groundwater exit pathway is monitored using surface water data from the K-1700 Weir on Mitchell Branch and wells BRW-083 and UNW-107.

Wells BRW-083 and UNW-107, located near the mouth of Mitchell Branch, have been monitored since 1994. Detection of VOCs in groundwater near the mouth of Mitchell Branch is considered an indication of the migration of the Mitchell Branch VOC plume complex. The intermittent detection of VOCs in this exit pathway is thought to be a reflection of variations in groundwater flowpaths that can fluctuate with seasonal hydraulic head conditions, which are strongly affected by rainfall and long-term and short-term Watts Bar Reservoir fluctuations. During FY 2022, no VOCs were detected in semiannual samples from either of these monitoring wells. In addition, no concentrations of VOCs in the 10-year or 5-year evaluation periods exceeded 80 percent of their respective MCLs. Gross alpha activity was not equal to nor exceeded 80 percent of the MCL in FY 2022.

Exit pathway wells BRW-003 and BRW-017 monitor metals and VOCs in groundwater at the K-1064 Peninsula Burn area. Metals detected in groundwater at the site include antimony, zinc, and arsenic; however, only arsenic concentrations were equal to or exceeded 80 percent of its MCL. Arsenic was detected in unfiltered samples collected in FY 2022 from both wells, with a maximum concentration of 0.008 mg/L in well BRW-003, which equals 80 percent of the MCL. The maximum concentration for filtered samples for arsenic collected in 2022 from well BRW-003 was only half (0.004 J mg/L) of the maximum unfiltered concentration. Arsenic concentrations in both unfiltered and filtered samples from well BRW-003 have shown long-term decreases during the period between 2004–2022. Historically, VOC contaminants exceeded MCLs in wells BRW-003 and BRW-017; however, regulated VOC concentrations have declined to below screening levels, with the exception of TCE, which has not exceeded its 0.005-mg/L MCL within the past 10 years and was not equal to nor exceeded 80 percent of the MCL during FY 2022.

Groundwater is monitored in four wells (BRW-066, BRW-030, UNW-080, and UNW-043) that lie between the K-31/K-33 area and PC. VOCs are not COCs in this area; however, within the past 10 years, five metals (antimony, arsenic, chromium, lead, and nickel) have exceeded 80 percent of their MCLs. During FY 2022, only chromium and nickel were detected at concentrations equal to or exceeding 80 percent of the MCL. Chromium was detected in FY 2022 in filtered and unfiltered samples from BRW-030, UNW-080, and UNW-043, with concentrations above its MCL screening concentration (0.1 mg/L) in UNW-043 filtered and unfiltered samples. Trend evaluations for chromium in wells BRW-030 and UNW-043 indicate significant upward trends for the 5-year and 10-year evaluation periods for both unfiltered and filtered samples from BRW-030 and for filtered samples from UNW-043. However, chromium concentrations for unfiltered samples from BRW-030, where historical concentrations have exceeded the MCL, were below the MCL in the FY 2022 sample results. Chromium concentrations for unfiltered samples from UNW-043 show a downward trend over the 10-year period, with no determinate trend in the annual maximum concentrations, and an upward trend for the five-year period. Chromium concentrations in UNW-080 were less than 80 percent of the MCL in FY 2022. Nickel was detected in FY 2022 in filtered samples from UNW-043 at concentrations above 80 percent of the MCL screening concentration (0.1 mg/L), but below the MCL. In unfiltered samples from UNW-043, nickel was not detected above 80 percent of the MCL screening concentration. Trend evaluations for nickel in UNW-043 indicate declining 5-year and 10-year concentrations trends at this well. Nickel was detected in FY 2022 below 80 percent of the MCL screening concentration in UNW-080 filtered and unfiltered samples.

Groundwater discharges toward PC in both a northward pathway beneath the K-1232 area and in a south-to-westward pathway, as shown earlier on Figure 3.24. Two wells (BRW-016 and BRW-058) in the northern plume near K-27/29 and two wells (UNW-038 and UNW-096) in the south/western plume have been designated for exit pathway monitoring.

During FY 2019, a high alpha activity result occurred in well BRW-016 in September 2019. This result was likely caused by infiltration of water down the well bore associated with D&D activities in the area. DOE redeveloped the well to remove residual infiltrated contamination to the extent practical. The well was pumped and swabbed to remove as much sediment and contaminated water as possible and was returned to service. A subsequent sample collected in March 2020 showed large reductions in contaminant concentrations compared to the levels measured prior to well redevelopment, and the August 2020 alpha activity decreased further but remained greater than the 15-pCi/L MCL screening concentrations. Alpha activity remained lower in FY 2022 with a concentration of 110 pCi/L but remained greater than the MCL screening concentration. VOCs have exceeded MCLs in the K-27/K-29 area northern pathway. However, in FY 2022, VC was the only VOC detected above its MCL screening concentration (0.002 mg/L), with a maximum detected concentration of 0.011 mg/L in well BRW-058. Trend evaluations for well BRW-058 indicate significant upward trends for the prior 10-year period and a stable trend over the five-year period for VC at this well. TCE concentrations were less than 80 percent of the MCL in FY 2022, and cis-1,2-DCE was detected at low levels in samples from well BRW-058 at concentrations greater than 80 percent of the MCL screening concentration, but less than the MCL. The presence of cis-1,2-DCE and VC in the area is indicative that a small degree of intrinsic degradation of the parent TCE is occurring in this part of the ETTP site.

In the south/west exit pathway from the K-27/K-29 area, TCE is persistent in the exit pathway wells, with stable trends at well UNW-038 and increasing trends at well UNW-096 over the 10-year and 5-year periods. Chromium concentrations were greater than 80 percent of the MCL in samples from well UNW-096, but less than the MCL in FY 2022. Nickel concentrations equaled or exceeded the Tennessee MCL of 0.1 mg/L in wells UNW-038 and UNW-096 in unfiltered FY 2022 samples, with maximum concentrations of 0.1 and 0.13 mg/L, respectively. In well UNW-096, nickel concentrations in filtered FY 2022 samples also exceeded the Tennessee MCL with a maximum concentration of 0.13 mg/L.

Wells BRW-084 and UNW-108 are exit pathway monitoring locations at the northern edge of the K-1007-P1 Holding Pond (Figure 3.24). No regulated contaminants have equaled or exceeded 80 percent of their respective MCLs in the FY 2022 samples. Alpha activity was present at levels less than 80 percent of the 15-pCi/L MCL screening concentration in samples from well UNW-108 in FY 2022, and TCE was detected below 80 percent of the MCL screening concentration (0.005 mg/L) in FY 2022 at BRW-084.

Exit pathway groundwater in the K-901-A Holding Pond area (Figure 3.24) is monitored by four wells (BRW-035, BRW-068, UNW-066, and UNW-067) and two springs (21-002 that flows into the K-901-A Holding Pond, and PC-0 that discharges into PC on the west side of Duct Island). No regulated contaminants equaled or exceeded 80 percent of the MCL at any of the four wells in FY 2022 samples.

TCE is the most significant groundwater contaminant detected in the springs. Spring PC-0 was added to the sampling program in 2004. During April–October each year, spring PC-0 is submerged beneath the Watts Bar Lake level. In the late winter of 2012, DOE installed a sampling pump in the spring mouth to allow year-round sampling. The contaminant source for spring PC-0 is presumed to be legacy waste disposed of at the former K-1070-F located on Duct Island. The TCE concentrations in spring PC-0 have varied between non-detectable levels and 26 µg/L and have decreased from their highest measured value in 2006. During FY 2022, the maximum TCE concentration in spring PC-0 quarterly samples was 11 µg/L measured in a sample collected in November 2021. The TCE concentrations in the remaining FY 2022 samples were all below the MCL screening concentration of 5 µg/L.

TCE that originates from the now-remediated K-1070-A Burial Ground is the principal contaminant detected at spring 21-002 (Figure 3.24).

The conceptual behavior of this contaminant plume is described by higher concentration, but lower flow, during the dry season with apparently subdued effects of rainfall on spring TCE concentrations. During the wet season, the overall TCE concentrations at spring 21-002 are lower; however, wet-season, increased rainfall-driven, groundwater-flow pulses push TCE concentration pulses through conduits that discharge at spring 21-002. Eight of the last 12 samples collected at spring 21-002 have exceeded the MCL screening concentration of 5 µg/L. Because water that discharges from the springs monitored in the ETTP area originates mostly from shallow flow systems, the flow rates and dissolved contaminant concentrations are highly variable. For this reason, no contaminant trend direction can be confidently assigned to the spring data.

Exit pathway groundwater monitoring is also conducted at the K-770 area, where wells UNW-013 and UNW-015 are used to assess radiological groundwater contamination along the CR (Figure 3.24). Alpha activity measured in samples from well UNW-015 has exceeded the

15-pCi/L MCL once within the past 10 years. During FY 2022, the maximum alpha activity was 8.6 pCi/L, which is below 80 percent of the 15-pCi/L MCL, and no other regulated contaminants exceeded 80 percent of their MCLs.

3.7. Biological Monitoring

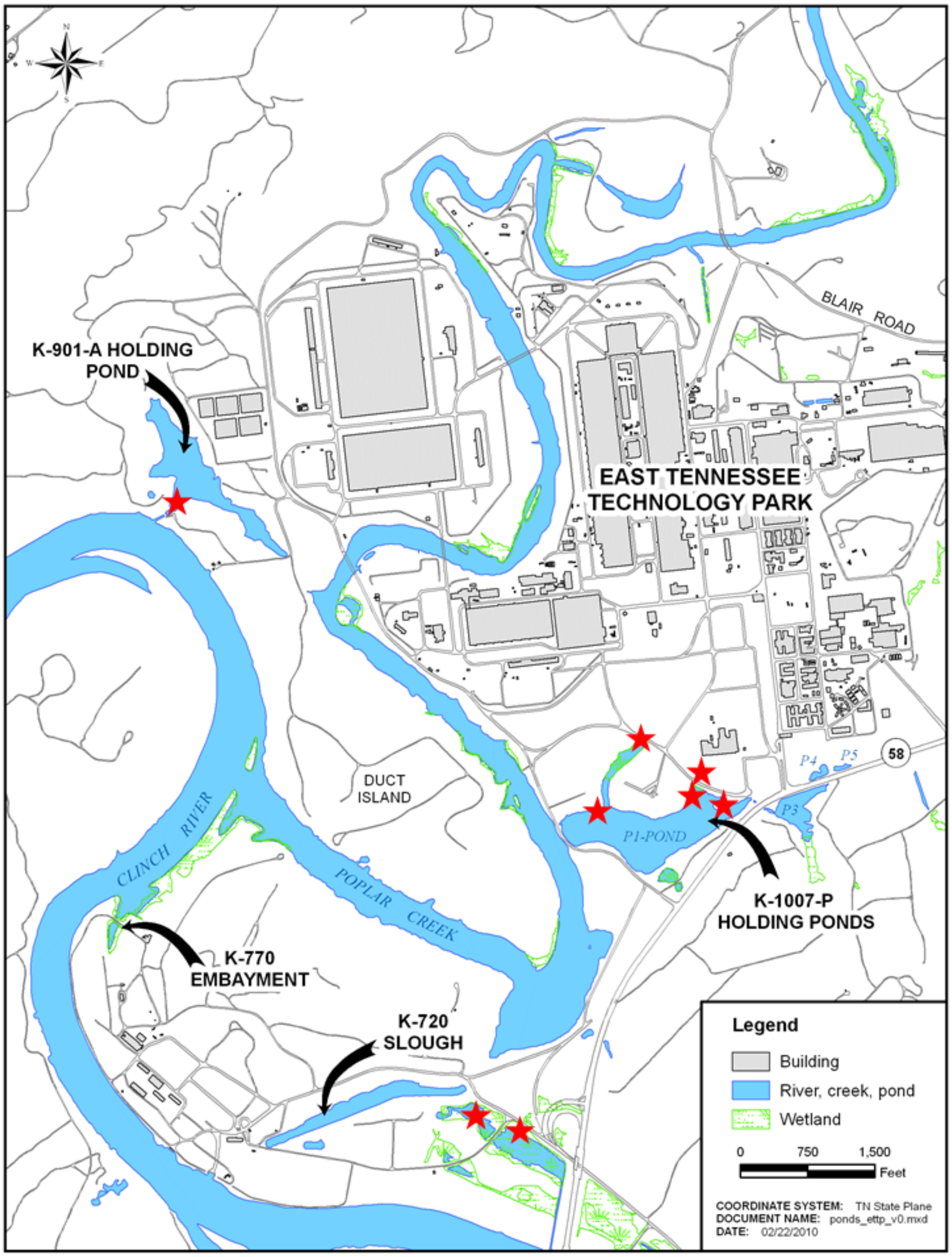
The ETTP Biological Monitoring and Abatement Program (BMAP) consists of two tasks designed to evaluate the effects of ETTP legacy operations on the local environment, identify areas where abatement measures would be most effective, and test the efficacy of the measures. The results from this program will support future CERCLA cleanup actions. These tasks are: (1) bioaccumulation studies, and (2) instream monitoring of biological communities. Figure 3.25 shows the major water bodies at ETTP and Figure 3.26 shows the BMAP monitoring locations along Mitchell Branch.

3.7.1. Task 1: Bioaccumulation Monitoring

Bioaccumulation monitoring for the ETTP BMAP has focused on evaluating the impact of PCB discharges into the environment because of historical operations at the ETTP complex. It was previously assumed that mercury (Hg) flux into Poplar Creek and the Clinch River originated largely from Y-12 Complex discharges into East Fork Poplar Creek. However, more recent monitoring has shown that water in ETTP storm drains and biota from lower Mitchell Branch have elevated mercury concentrations. Mercury bioaccumulation monitoring is routinely conducted in the watersheds adjacent to ETTP by the Y-12 and ORNL BMAPs, both on and off ORR. The available Hg bioaccumulation monitoring data will be presented in the following subsections with long-term trends in PCB contamination in resident fish and caged clams from ETTP waters.

Because the consumption of contaminated fish represents the largest dose of Hg and many other bioaccumulative contaminants to humans, fish fillet concentrations are relevant to assessing human health risks, whereas whole body fish are relevant to assessing ecological risks. Largemouth bass (*Micropterus salmoides*) and various sunfish species are used to monitor Hg and PCB fillet concentrations, and gizzard shad (*Dorosoma cepedianum*) and bluegill (*Lepomis macrochirus*) are used to monitor whole body concentrations at various locations over time. Largemouth bass are larger, upper trophic level predatory fish and are, therefore, susceptible to Hg and PCB bioaccumulation. Fillet concentrations in these fish represent the near maximum potential dose to humans, if eaten. Largemouth bass tend to live in larger, deeper pools of water and are collected in the ponds at ETTP (K-1007-P1 Pond, K-901-A Pond, and K-720 Slough) as well as in off-site river and reservoir locations. Sunfish are short-lived and have small home ranges, so fillet Hg and PCB concentrations in these fish are representative of exposure at the site of collection. These fish are used in long-term studies to monitor changes in bioaccumulation at a given site over time. Collections of sunfish are restricted to sizes large enough to be taken by sport anglers (generally 50–150 g total weight) to minimize effects of covariance between size and contaminant concentrations, as well as for spatial and temporal comparability. The target sunfish species for bioaccumulation studies in Mitchell Branch and other ORR stream sites is redbreast sunfish (*Lepomis auritus*), but where these fish are not present, other species with similar feeding habits (e.g., bluegill sunfish [*Lepomis macrochirus*]) are collected. For bioaccumulative contaminants such as Hg and PCBs, fish bioaccumulation data have become important measures of compliance for both the CWA and CERCLA.

For Hg, the EPA National Recommended Water Quality Criterion for Hg in fish (0.3 micrograms/gram [μg/g]) is used as the trigger point for fish consumption advisories in Tennessee, the target concentration for NPDES permit compliance, and the threshold for impairment designations that require a Total Maximum Daily Load (TMDL) assessment. In addition to fish Hg limits, the state of Tennessee continues to use the statewide AWQC for Hg of 51 ng/L in water, based on organisms only, and 50 ng/L for recreation-water and organisms. Regulatory guidance and human health risk levels have varied more widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criteria for individual Aroclors and total PCBs are both 0.00064 µg/L under the recreation designated use classification and are the target for PCB-focused TMDLs, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudon). However, most conventional PCB water analyses have detection limits much higher than the PCB AWQC.

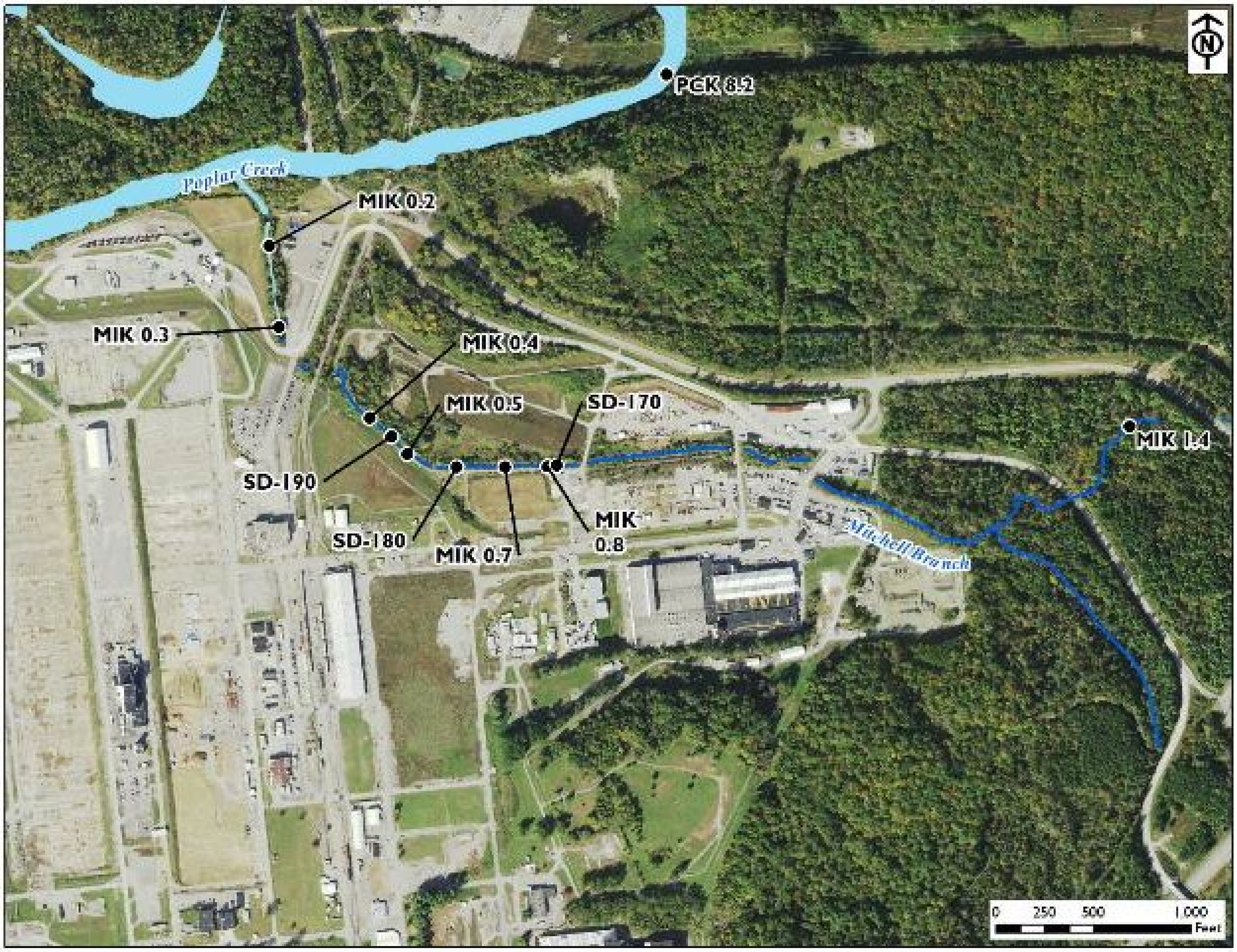


Note: *Red stars indicate clam sampling locations in and around the ETTP complex in 2022 (Mitchell Branch sites not shown).*

Acronyms:

CRM = Clinch River mile PCK = Poplar Creek kilometer MIK = Mitchell Branch kilometer SD = storm drain

Figure 3.25. Water bodies at the East Tennessee Technology Park



Acronyms:
BMAP = Biological Monitoring and Abatement Program
MIK = Mitchell Branch kilometer
SD = storm drain/storm water outfall

Figure 3.26. Major storm water outfalls and biological monitoring locations on Mitchell Branch

Therefore, in Tennessee and in many other states, assessments of impairment for water body segments, as well as public fishing advisories for PCBs, are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2 µg/g in fish fillet was used for PCB advisories; then for many years in Tennessee, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillet at the ETTP K-1007-P1 Pond is 1 µg/g. Most recently, the water quality criterion that has been used by TDEC to calculate the fish tissue concentration triggering a determination of impairment and a TMDL, and this concentration is 0.02 µg/g in fish fillet. The fish PCB concentrations at and near ETTP are above this most conservative concentration.

In addition to monitoring for human health and ecological risks as well as long-term trends, bioaccumulation monitoring also includes investigations of sources of contamination to ETTP waterways. Caged Asiatic clams (*Corbicula fluminea*) are used as bioindicators of contaminant sources in Mitchell Branch and other sites around ETTP. These clams are collected from an uncontaminated reference site (Little Sewee Creek in Meigs County, Tennessee) and are divided into groups of 10 clams of equal mass. In 2022, clams were placed in baskets to be deployed at strategic locations around ETTP (i.e., in and around storm drains) for a four-week exposure period (May 12–June 9, 2022). Two clam baskets were placed at each site with 10 clams in each basket.

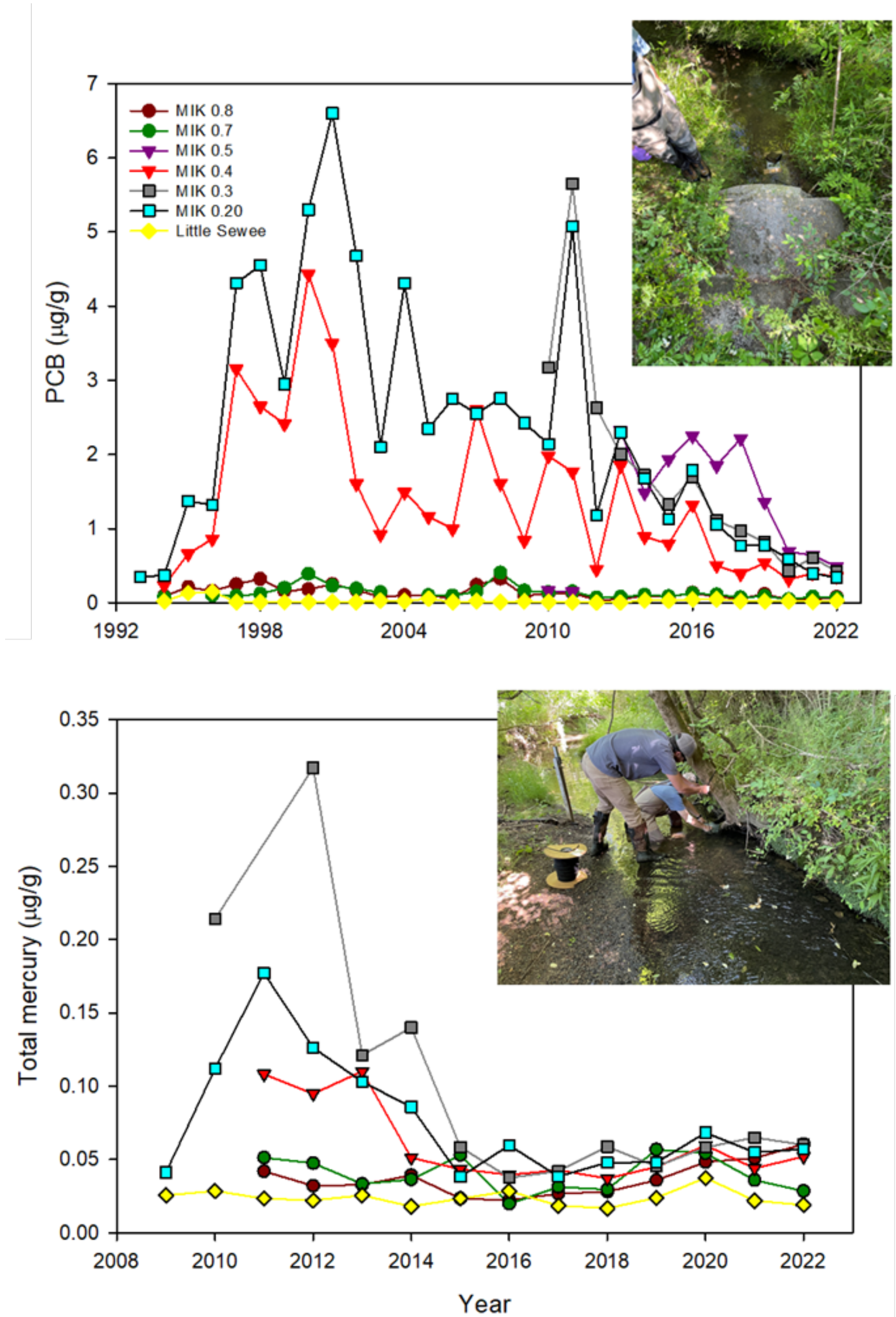
Because these animals are sedentary filter feeders, they accumulate contaminants that are present in the water and in suspended particles at a given site. They are useful indicators of the bioavailable (and therefore potentially toxic) portion of contaminants that enter the environment at a given location, and they provide spatial resolution of contamination on a finer scale than is possible with fish bioaccumulation studies. Caged clams have been used for more than 25 years to evaluate the importance of storm drains and other inputs of PCBs into the waterways around ETTP and for the past 10 years to monitor total mercury (Hg_T) and methylmercury (MeHg) inputs to Mitchell Branch. Whereas most of the Hg in the environment is inorganic mercury (Hg^{2+}), a small fraction of Hg^{2+} is converted to the more toxic and bioaccumulative MeHg. Because MeHg biomagnifies in aquatic systems, increasing in concentration as it moves up through the food chain, more than 90 percent of the Hg in upper trophic level fish is MeHg. Clams, which feed on periphyton and detritus at the base of the food chain, have a much smaller proportion of MeHg in their tissues but are still good indicators of MeHg hot spots and sources. The soft tissues of the clams from each cage were homogenized, and aliquots were taken for PCB and Hg analysis.

To assess spatial and temporal variability in exposure to PCBs following remediation activities, water samples have been collected for analysis of aqueous PCBs and TSS from the outfalls of K-1007-P1 and K-901-A, upper and lower storm drain (SD)-100, and an uncontaminated reference site (upper First Creek, ORNL). Samples are collected four times each year (March/April, June, July, and August).

3.7.1.1. Mitchell Branch

Figure 3.27 shows long-term monitoring results in caged clams deployed at various sites in Mitchell Branch. The lower portion of this stream (MIK 0.5, SD-190, MIK 0.2) has historically been a hot spot for both Hg and PCB contamination. In 2022 PCB concentrations in biota in this stretch of the creek continued to be slightly elevated (~0.3–0.5 µg/g) with respect to other Mitchell Branch and reference sites. Although there is considerable interannual variability, PCB concentrations in clams placed in lower Mitchell Branch appear to be generally trending downward since peak years in 2000–2001. While there was a slight bump up in PCB concentrations at Mitchell Branch sites in 2016, concentrations since then have dropped back down, continuing the overall decreasing trend. PCB concentrations in the upper portion of Mitchell Branch were similar to previous years' concentrations and were slightly elevated (0.08 µg/g) with respect to the reference site (0.02 µg/g).

Mercury concentrations in clams deployed in Mitchell Branch in 2022 were generally similar to concentrations seen in 2021 and were only slightly elevated in Mitchell Branch relative to the reference site (Figure 3.28). Within the Mitchell Branch system, the highest Hg concentrations were seen in clams deployed at SD180 (0.13 µg/g). Mercury concentrations in clams deployed at the K-1007-P1 and K-901-A Ponds were again comparable to reference site concentrations. Clams deployed at the north Beaver Pond had Hg concentrations similar to those of the reference site (clams deployed at the south Beaver Pond experienced complete mortality). Unlike in fish tissue, MeHg in the soft tissues of clams generally made up a small proportion of Hg_T (Figure 3.28). MeHg concentrations in clams mostly remained low in 2022, comparable to or slightly lower than concentrations in 2021, with the exception of a slight increase at MIK0.2 (0.03 µg/g). Clams deployed at the Oxbow lake had similar PCB concentrations and slightly higher Hg concentrations than the reference site.

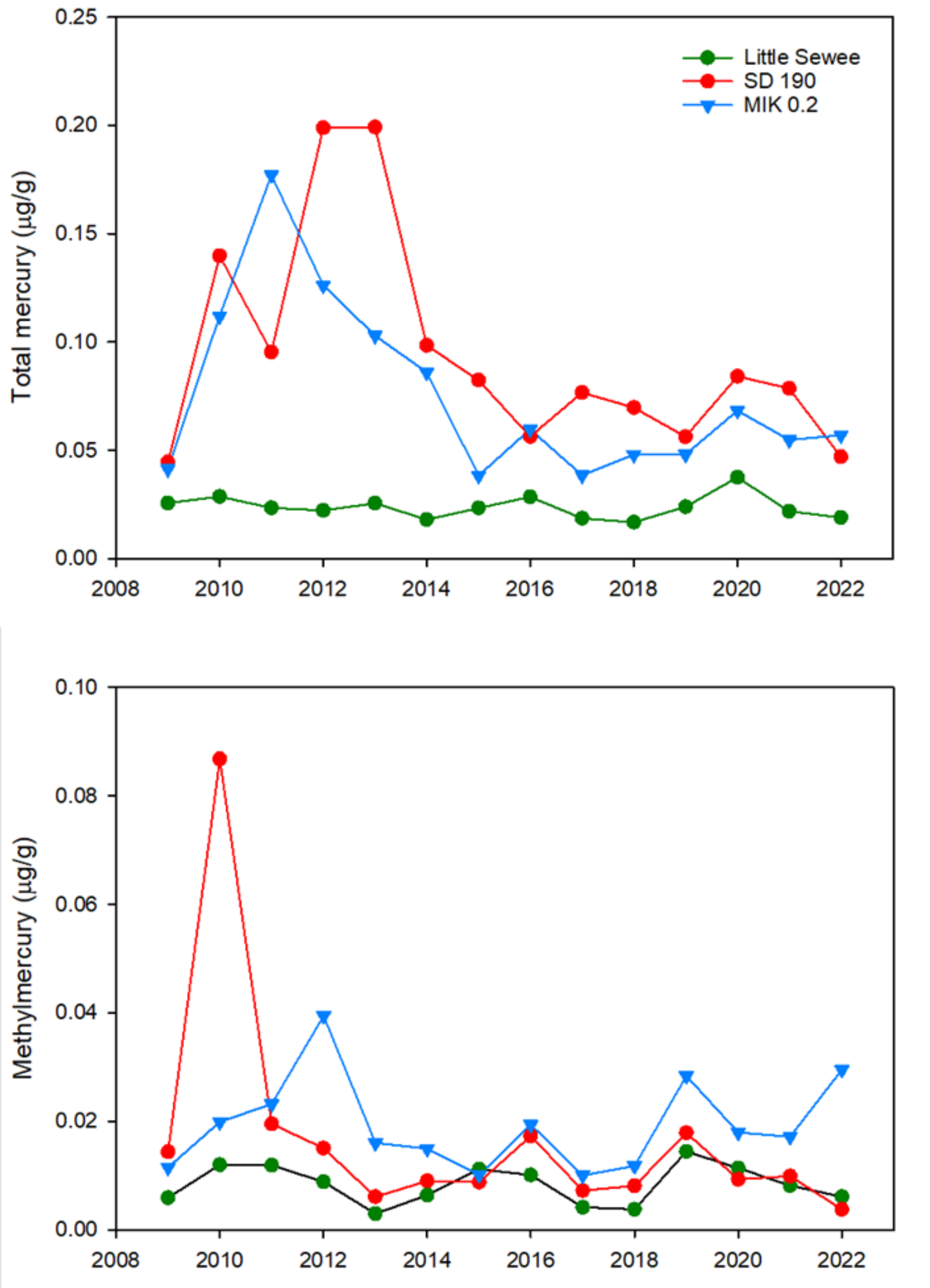


Notes:

1. *N = 2 composites of 10 clams each per year.*
2. *Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Meigs County, Tenn.).*
3. *Total PCBs is defined as the sum of Aroclors 1248, 1254, and 1260.*

Acronyms: *MIK = Mitchell Branch kilometer PCB = polychlorinated biphenyl*

Figure 3.27. Mean total PCB (Top: µg/g, wet wt; 1993–2022) and mercury (Bottom: µg/g wet wt; 2009–2022) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch



Notes:

1. *N = 2 composites of 10 clams each per year.*
2. *Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee)*

Acronyms: *MIK = Mitchell Branch kilometer SD = storm drain*

Figure 3.28. Total (top panel) and methylmercury (bottom panel) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2022)

Figure 3.29 shows long-term monitoring results in redbreast sunfish (*Lepomis auritus*) at MIK 0.2. Average PCB concentrations in fish collected at MIK 0.2 in 2022 (0.71 ± 0.1 µg/g) were higher than those seen in 2021 (0.59 ± 0.4 µg/g) but remained comparable to concentrations seen at this site in recent years. Although there is not a regulatory limit for PCBs in fish, the level most often used in practice to issue fish consumption advisories in the state of Tennessee, as previously stated, is 1 µg/g. In 2022, the mean PCB concentration in sunfish fillets collected from MIK 0.2 was below this limit. While the observed fish tissue concentrations in Mitchell Branch are lower than they have historically been, they are still two to three orders of magnitude higher than concentrations seen in the same species at the Hinds Creek reference site in Anderson County.

Total mercury has been monitored more sporadically in redbreast sunfish fillets at MIK 0.2. Figure 3.29 shows long-term trends in Hg_T concentrations (µg/g) in these fish. A rapid increase in fillet Hg_T concentrations was observed in the early 1990s and concentrations have generally remained elevated, with mean concentrations exceeding the AWQC (0.3 µg/g) in most years. Similar to the PCB concentrations in fish from this site, Hg_T concentrations at MIK 0.2 have been oscillating around the EPA's recommended AWQC for the past several years. Mean mercury concentrations in redbreast at this site remained just above the mercury tissue criterion, averaging 0.33 + 0.06 µg/g in 2022.

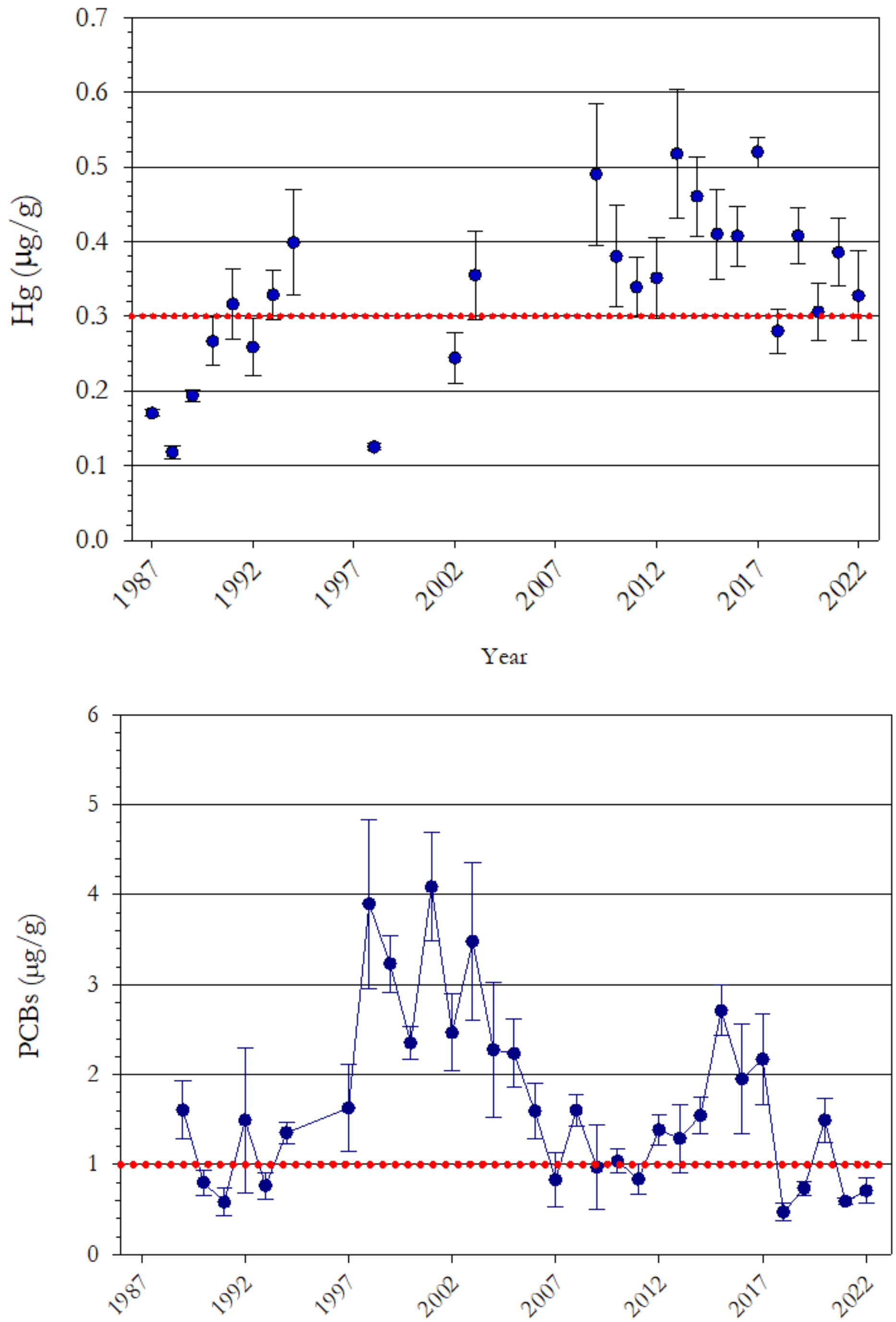
3.7.1.2. 1007-P1 Pond

Over the past decade, mean aqueous PCB concentrations in the K-1007-P1 Pond have fluctuated significantly but have generally been lower than concentrations seen before 2009 remediation activities (e.g., 36 ng/L in 2022 compared with 161 ng/L in 2007; Figure 3.30). Concentrations in 2022 were slightly higher than in 2021, but, still were also comparable to the lowest recorded average PCB concentration since remediation (26 ng/L in 2015). As hydrophobic contaminants, PCBs tend to be particle associated and are positively correlated with TSS. The fluctuations in PCB and TSS concentrations in water in the K-1007-P1 Pond could be related to fluctuations in aquatic plant coverage, which can affect sediment stability. The aqueous PCB concentrations measured in the K-1007-P1 Pond are above concentrations seen at the First Creek reference site (0.76 ng/L in 2022) and are above the state of Tennessee water quality criterion for the protection of fish and wildlife (14 ng/L).

PCB concentrations in clams placed at lower and upper SD-100 locations have fluctuated significantly since remediation actions in 2009, and were on an overall decreasing trajectory until the significant increases seen in 2017 and 2018 (Figure 3.31). Concentrations in clams deployed in upper and lower SD100 in 2022 were higher than the increased levels in 2017-2018. Both upper and lower SD100 concentrations remained elevated with respect to the reference site. PCB concentrations in clams placed at the K-1007-P1 outfall were also higher since the increase in 2017, but have been steadily falling since then, and in 2022, were comparable to concentrations seen just after remediation actions in this pond (Figure 3.31).

Similar trends have been observed in fish tissue PCB concentrations in the K-1007-P1 Pond (Figure 3.32). Since 2009, the target species for bioaccumulation monitoring in the K-1007-P1 Pond has been bluegill sunfish (*Lepomis macrochirus*). As in previous years, fillets from 20 individual bluegill and 6 whole body composites (10 bluegill per composite) from the K-1007-P1 Pond were analyzed for PCBs in 2022 to assess the ecological and human health risks associated with PCB contamination in this pond.

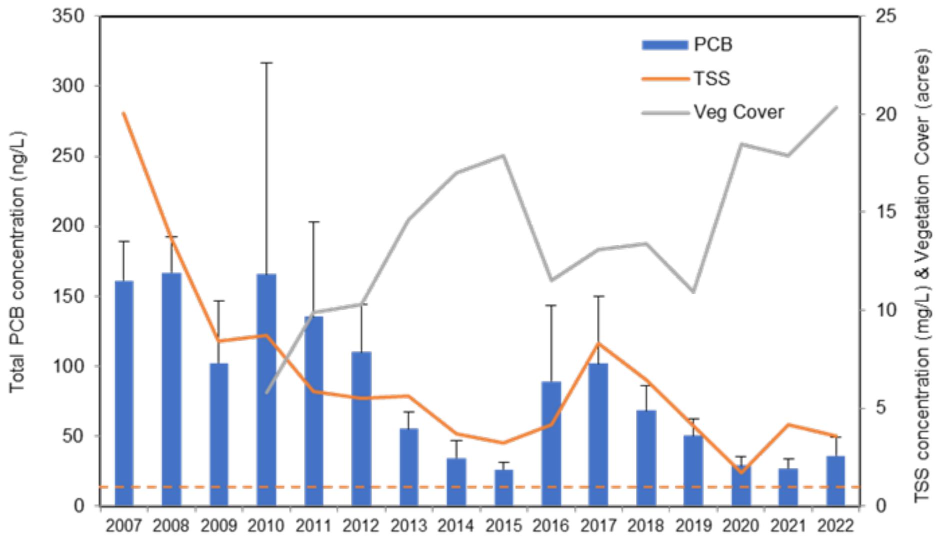
While PCB concentrations in fish and in caged clams at K-1007-P1 Holding Pond have been fluctuating for the past few years, in 2022 biota concentrations decreased such that both fillets and whole-body concentrations in bluegill were below the targets for this pond. Mean PCB concentrations in bluegill fillets in the K-1007-P1



Notes:
1. *1989–2022 N = 6 fish per year.*
2. *Shown in red is the fish advisory level for PCBs (1 µg/g) and mercury concentration (0.3 µg/g).*

Acronyms:
Hg = mercury MIK = Mitchell Branch kilometer PCB = polychlorinated biphenyl

Figure 3.29. Mean PCB (top panel) and mercury (bottom panel) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2), 1989–2022

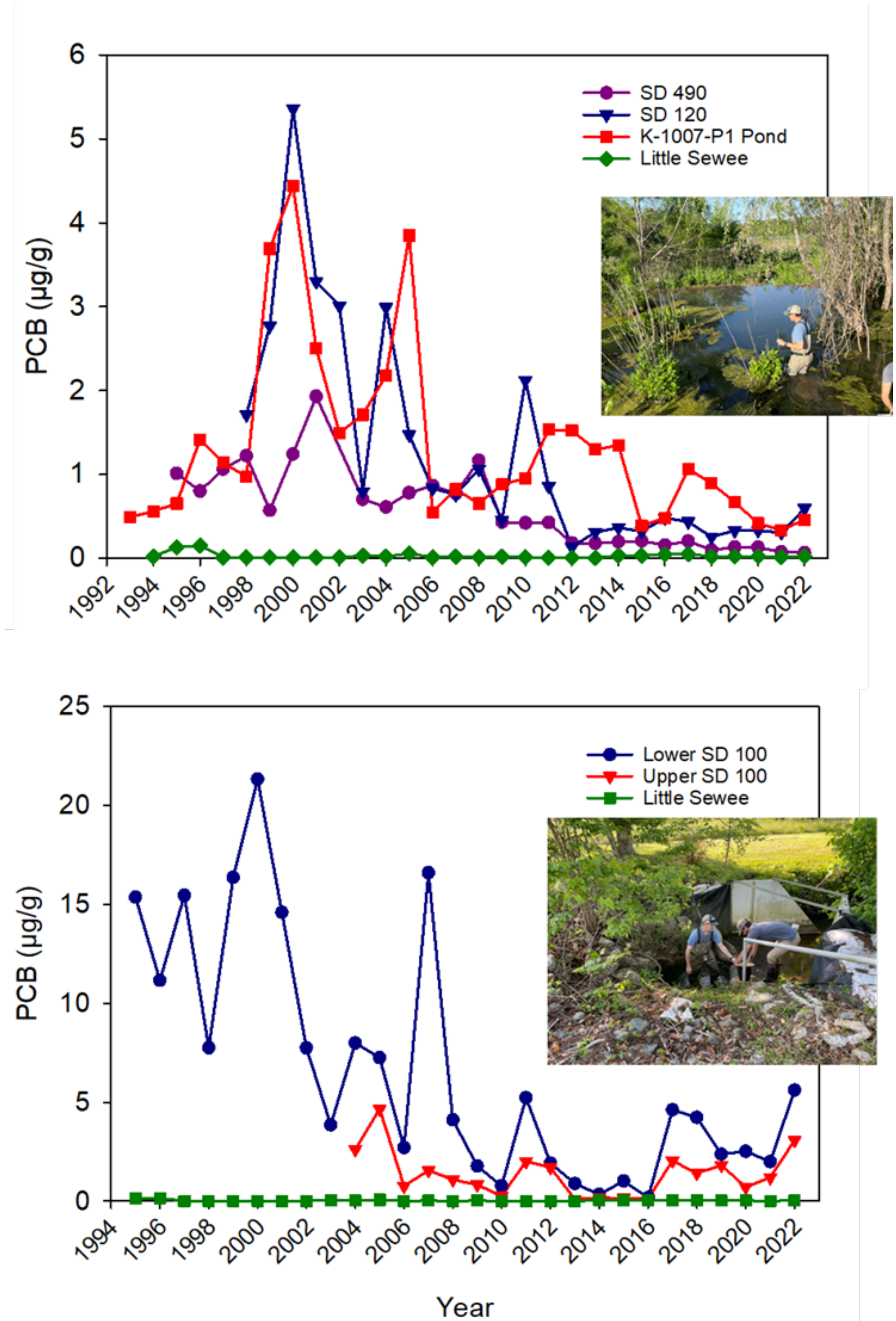


Notes:

1. *Means for PCBs in water and TSS are based on results across all collections made each year.*
2. *Note that mean concentrations of PCBs in water from First Creek were <0.3 ng/L in all years.*

Acronyms: *PCB = polychlorinated biphenyl ITSS = total suspended solids*

Figure 3.30. Mean aqueous total PCB concentrations, total suspended solids, and vegetation cover in the K-1007-P1 Pond, 2007–2022

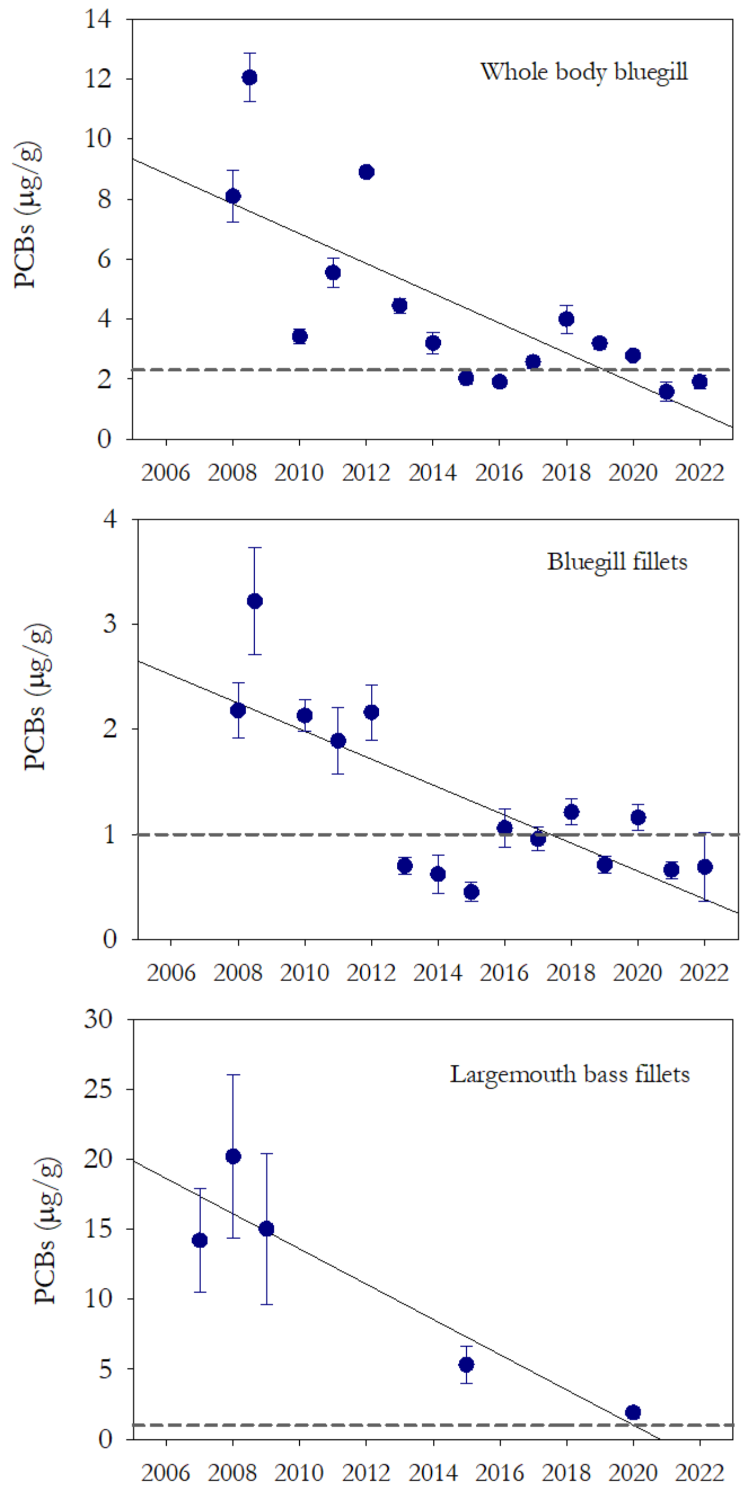


Notes:

1. *N = 2 clam composite samples per site/year.*
2. *Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.*
3. *Photos: Upper graph shows the SD-490 location; lower graph photo shows placement of clam cages in the Upper SD-100 location.*

Acronyms: *PCB = polychlorinated biphenyl SD = storm drain*

Figure 3.31. Mean total PCB concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2022



Notes:

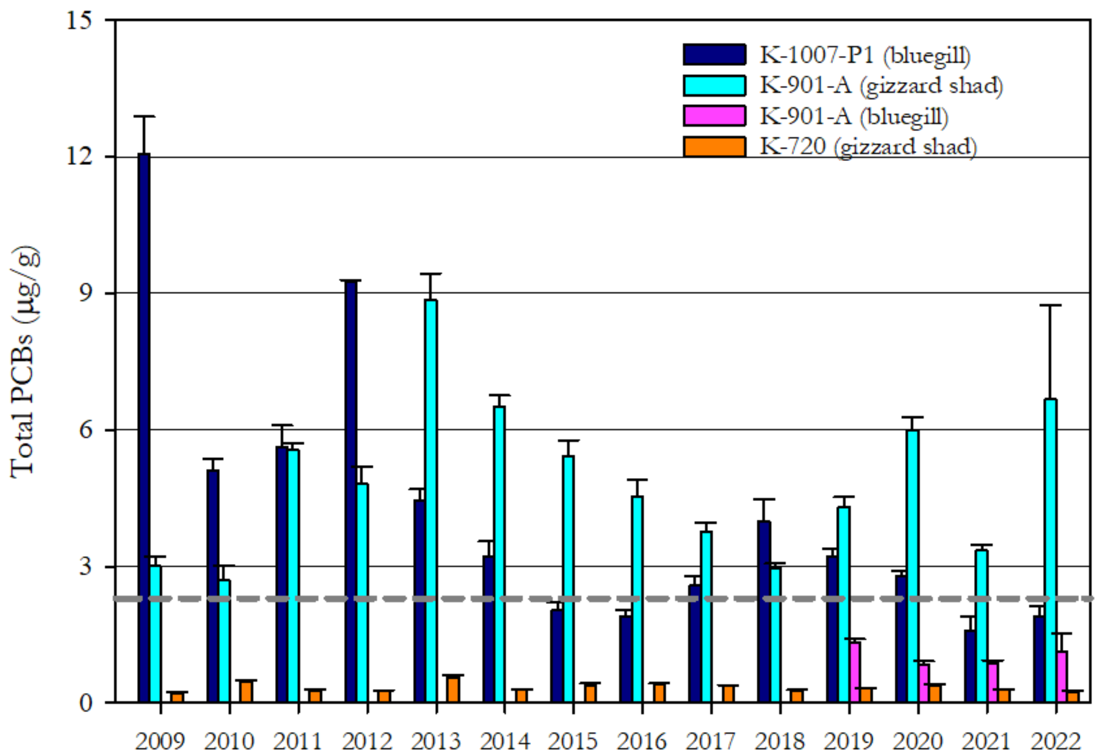
1. *For largemouth bass, N = 6 fish per site/year. For bluegill sunfish, N = 20 for fillets and N = 6 composites of 10 whole body fish.*
2. *The target for fillet (1 µg/g) and whole-body concentrations (2.3 µg/g) is shown with the gray dotted lines.*

Acronym: *PCB = polychlorinated biphenyl*

Figure 3.32. Mean PCB concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2022

Pond increased slightly from 0.66 µg/g in 2021 to 0.69 µg/g in 2022, remaining below the remediation goal for this pond (1 µg/g total PCBs in fillets). Mean concentrations in whole-body bluegill increased from 1.58 µg/g in 2021 to 1.91 µg/g in 2022, also remaining below the remediation target for whole body fish in this pond (2.3 µg/g in whole-body composites). (Figures 3.32 and 3.33; Table 3.8).

The interannual fluctuations in PCB concentrations could be due to water quality changes that have taken place in this pond, e.g., higher TSS, PCB inputs, and fluctuations in vegetation cover (Figures 3.32 and 3.33).



Notes:
1. *Total PCBs are defined as the sum of Aroclors 1248, 1254, and 1260.*
2. *The dotted line signifies the target PCB concentration of 2.3 µg/g in whole body fish.*

Acronym: *PCB = polychlorinated biphenyl*

Figure 3.33. Mean (+1 standard error) total PCB concentrations (µg/g, wet wt) in whole body fish from K1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2022

Table 3.8. Average concentrations of total PCBs in fillets and whole-body composites of fish collected in 2022 near the East Tennessee Technology Park

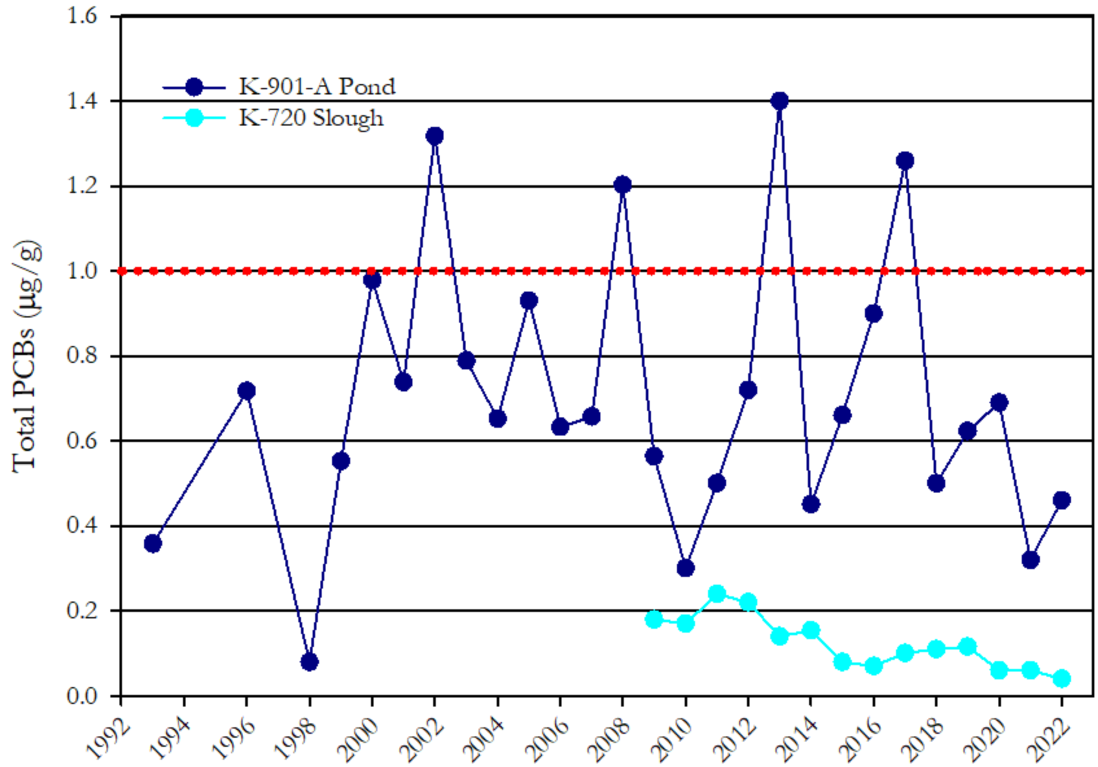
Site	Species	Sample type	Sample size (n)	Total PCBs (mean ± SE)	Range of PCB values	No. > target (PCBs)/n
K-1007-P1 Pond	Bluegill	Fillets	20	0.69 ± 0.33	0.30–1.37	3/20
		Whole-body composites	6	1.91 ± 0.23	1.65–2.30	0/6
K-901-A Pond	Largemouth bass	Fillets	17	0.46 ± 0.26	0.16–1.24	1/17
	Common carp	Fillets	3	1.89 ± 2.31	0.24-5.16	1/3
	Bluegill	Fillets	20	0.42 ± 0.25	0.09–1.00	0/20
		Whole-body composites	6	1.14 ± 0.39	0.64–1.78	0/6
	Gizzard shad	Whole-body composites	6	6.67 ± 2.06	3.78–9.50	6/6
K-720 Slough	Largemouth bass	Fillets	12	0.04 ± 0.02	0.02–0.10	0/12
	Common carp	Fillets	6	0.20 ± 0.10	0.07–0.36	0/6
	Smallmouth buffalo	Fillets	2	0.52 ± 0.30	0.31-0.73	0/2
	Gizzard shad	Whole-body composites	6	0.24 ± 0.03	0.20–0.29	0/6
CRM 11.0	Bluegill	Whole-body composites	6	0.06 ± 0.01	0.05–0.07	0/6
	Gizzard shad	Whole-body composites	6	0.12 ± 0.03	0.09–0.16	0/6
PCM 1.0	Bluegill	Whole-body composites	6	0.12 ± 0.01	0.10–0.13	0/6
	Gizzard shad	Whole-body composites	6	0.34 ± 0.06	0.25–0.46	0/6

Notes:

1. *Average concentrations = μg/g, wet wt.*
2. *Total PCBs = Aroclors 1248, 1254, and 1260.*
3. *Values are mean concentrations (μg/g) ± 1 SE.*
4. *Each whole-body composite sample is composed of 10 individual fish.*
5. *Also shown are the ranges of values observed for PCBs and the number of fish whose fillet PCB concentrations exceeded 1 μg/g out of the total number of fish (or composites) sampled (n). (1 μg/g total PCBs in fish fillets and 2.3 μg/g in whole-body composites*

Acronyms and abbreviations:

CRM = Clinch River mile
PCB = polychlorinated biphenyl
SE = standard error
n = sample size number
No. = number
PCM = Poplar Creek mile



Notes:
1. *Mean PCBs (± 1 SE) in largemouth bass fillets, 1993-2022 (µg/g).*
2. *N = 6 fish per year, when possible.*
3. *The dotted red line shows the advisory level for PCBs in fish fillets (1 µg/g).*

Acronyms:
PCB = polychlorinated biphenyl
SE = standard error

Figure 3.34. Mean total PCB concentrations in largemouth bass from the K-901-A Pond and the K-720 Slough

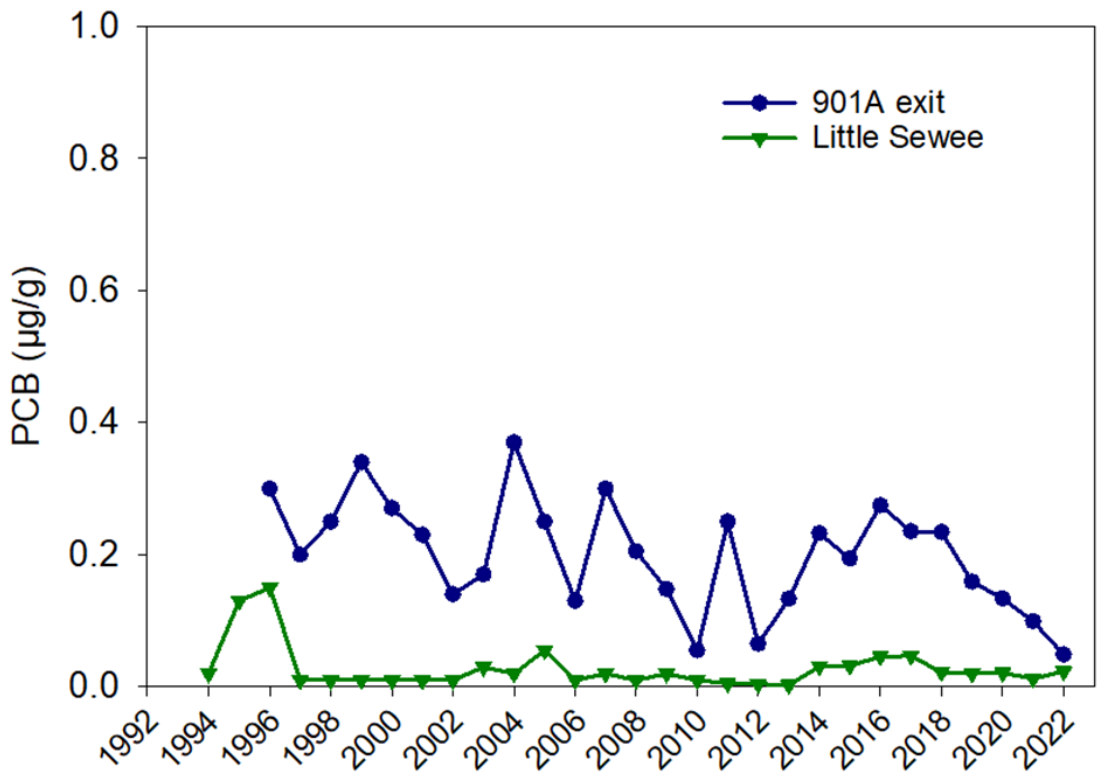
3.7.1.3. K-901-A Pond

The target fish species for analysis of PCBs in the K-901-A Holding Pond were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*).

At the K-901-A Holding Pond, mean PCB concentrations in largemouth bass collected in 2022 (0.46 µg/g) were similar to concentrations seen in 2021 (0.32 µg/g) and were below the target concentration set for the K-1007-P1 Pond of 1 µg/g total PCBs (Figure 3.34). Whole body gizzard shad from the K-901-A Holding Pond, collected as a measure of potential ecological risk to terrestrial wildlife, were substantially higher in concentration (6.65 µg/g) than the fillets of bass and carp, remaining above the target concentration set for the K-1007-P1 Holding Pond for whole body fish (2.3 µg/g) (Figure 3.33). However, mean PCB concentrations in whole-body bluegill (1.14 µg/g) were lower than concentrations in this same species collected from the K-1007-P1 Pond, were below the target concentration for whole-body fish in the K-1007-P1 Pond (2.3 µg/g) (Figure 3.33). PCB concentrations in clams deployed in the K-901-A Pond were similar to those deployed in the K-1007-P1 Pond and were lower in 2022 (0.05 µg/g) than in 2021 (0.10 µg/g; Figure 3.35).

3.7.1.4. K-720 Slough

Routine bioaccumulation monitoring in the K-720 Slough began in 2009 (Figure 3.36). Although the target species for fish fillet monitoring in this slough is largemouth bass, as in the K-901-A Pond it has been difficult to collect a full sample of 20 fish of this species; to complete the collection, common carp also are collected for a total of 20 fish. Figure 3.36 shows the temporal trends in fish fillet concentrations in the slough. In 2022, PCB concentrations in both fish species monitored were below the state advisory limit of 1 µg/g. In all cases PCB levels in fish collected from the K-720 Slough were significantly lower than in the K-901-A Holding Pond for the same species (Table 3.8). PCB concentrations in largemouth bass collected from the K-720 Slough were significantly lower than those in the other monitored ponds, averaging 0.04 µg/g in 2022. Concentrations in carp collected from the slough were higher than concentrations in bass, averaging 0.20 µg/g. Total PCBs in whole body gizzard shad from the K-720 Slough were similar to those seen in recent years and were lower than those seen in whole body fish collected from the other monitored ponds, averaging 0.24 µg/g in 2022.



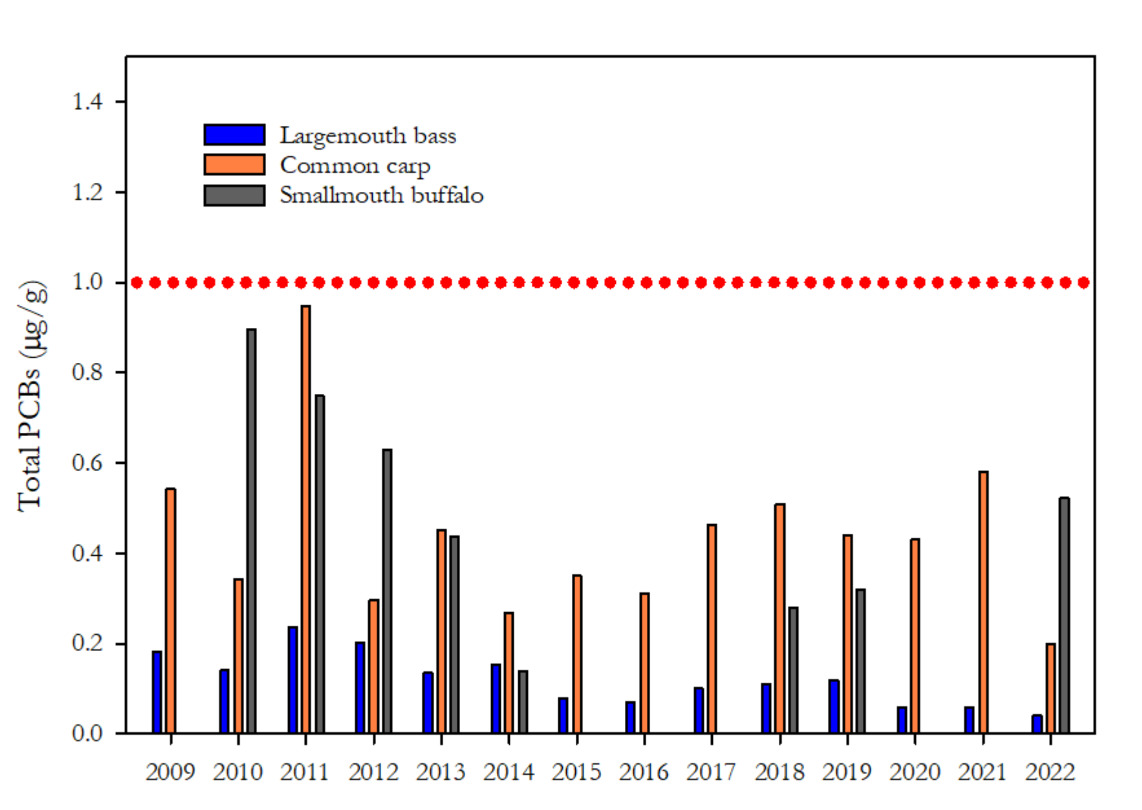
Notes:

1. *Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.*
2. *N = 2 composites of 10 clams each per year.*
3. *Shown in green are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tenn.).*

Acronym:

PCB = polychlorinated biphenyl

Figure 3.35. Mean total PCB (µg/g, wet wt; 1993–2022) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4-week period



Notes:

1. *Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.*
2. *The target sample was 20 largemouth bass, but because these fish are not abundant in the slough, carp and smallmouth buffalo were collected to complete the sample size of 20 fish.*

Acronym:

PCB = polychlorinated biphenyl

Figure 3.36. Mean total PCB (µg/g, wet wt; 2009–2022) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough

3.7.2. Task 2: Instream Benthic Macroinvertebrate Communities

Benthic macroinvertebrate communities in Mitchell Branch are sampled using ORNL and TDEC protocols (Figures 3.37 and 3.38). Evaluation of long-term trends of macroinvertebrate communities in the stream make it possible to document the effectiveness of pollution abatement activities or remediation, efforts as well as to assess the potential consequences of unanticipated events as sitewide remediation continues (e.g., chromium release into Mitchell Branch).

Figure 3.37. Collecting an invertebrate sample using Oak Ridge National Laboratory Biological Monitoring and Abatement Program protocols

Figure 3.38. Sampling for benthic macroinvertebrates with TDEC protocols

3.7.2.1. Benthic Macroinvertebrates

The major objectives of the benthic macroinvertebrate task are: (1) to help assess the ecological condition of Mitchell Branch, and (2) to evaluate changes in stream ecology associated with changes in facilities operations and RAs within the Mitchell Branch watershed. To meet these objectives, the condition of the benthic macroinvertebrate community of Mitchell Branch has been monitored routinely since late 1986. This summary includes results of samples collected each April from 1987 to 2022 following ORNL BMAP quantitative sampling protocols and samples collected annually (August/September) with TDEC semi-quantitative sampling protocols for estimating the Tennessee Macroinvertebrate Biotic Index (TMI) and the Habitat Index (TDEC 2021). For both sets of protocols, four sites were assessed in Mitchell Branch—MIKs 0.4, 0.7, 0.8, and 1.4. MIK 1.4 serves as the primary reference site, but narrative Biotic Index results for TDEC protocols are based on reference conditions established by TDEC from a suite of reference sites in the same ecoregion as Mitchell Branch. Finally, also included in this summary is a comparison between the macroinvertebrate community structure at the four Mitchell Branch sites and five other reference sites on ORR. Most of these reference sites—spanning a range of stream sizes both smaller and larger than Mitchell Branch (based on watershed area)—have been monitored using ORNL protocols since the mid-1980s for other biological monitoring projects on ORR (ORNL BMAP and WRRP/Bear Creek Biological Monitoring Program) (Table 3.9). This summary provides information on how invertebrate community structure at Mitchell Branch sites, including MIK 1.4, compares with the community structure of a range of relatively unaffected reference sites on ORR.

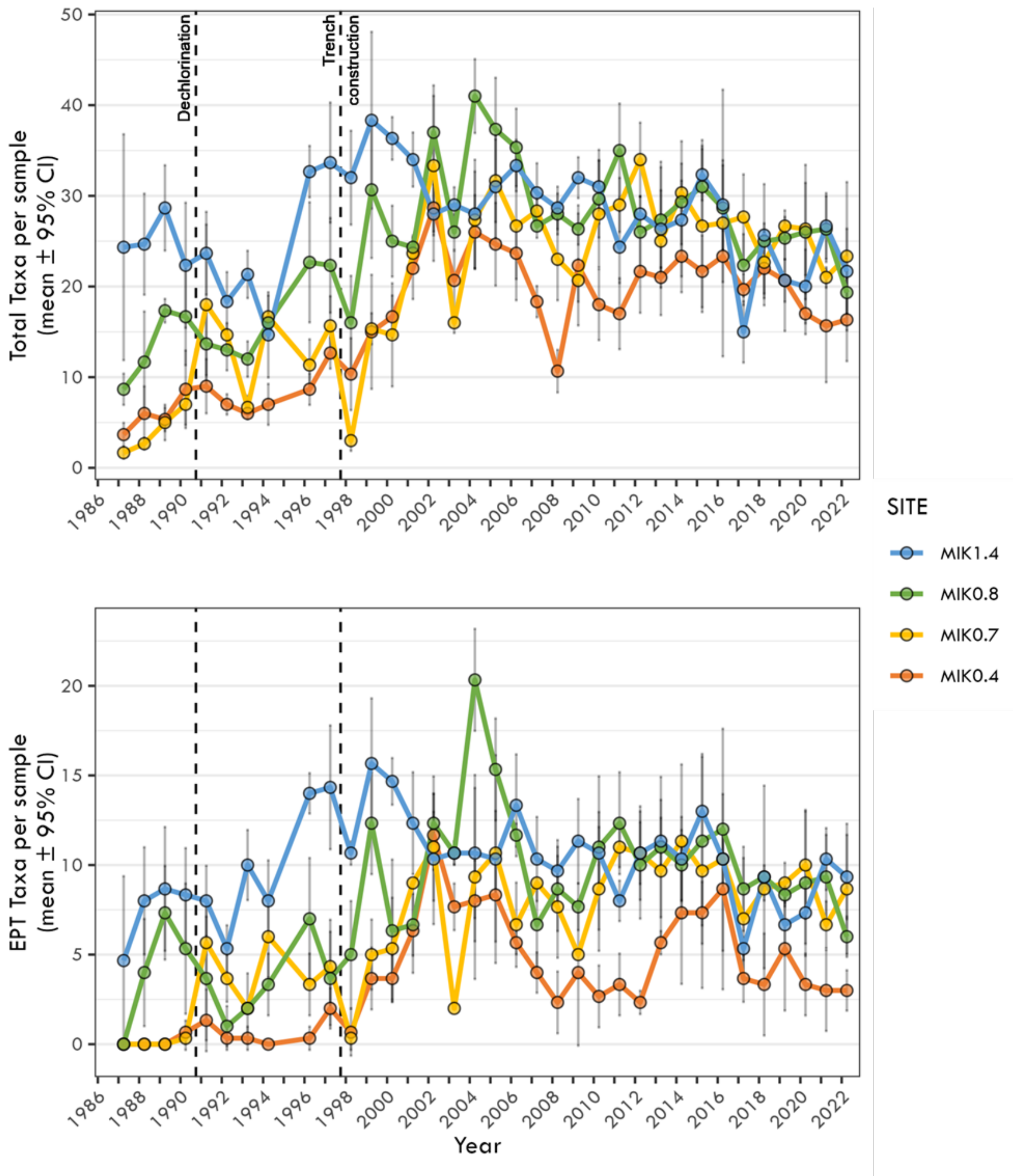
Table 3.9. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation

Site	Location		Watershed area (km^2)	Program
	Latitude (N)	Longitude (W)		
Mitchell Branch				
MIK 0.4	35.93859	84.39040	1.554	ETTP BMAP
MIK 0.7	35.93786	84.38792	1.347	ETTP BMAP
MIK 0.8	35.93786	84.38682	1.269	ETTP BMAP
MIK 1.4 (reference)	35.93790	84.37662	0.311	ETTP BMAP
Other ORR reference sites				
First Creek (FCK 0.8)	35.92670	84.32355	0.596	ORNL BMAP
Fifth Creek (FFK 1.0)	35.93228	84.31746	0.596	ORNL BMAP
Gum Hollow Branch (GHK 2.9)	35.96385	84.31594	0.777	Bear Creek BMP/WRRP
Walker Branch (WBK 1.0)	35.95805	84.27953	1.010	ORNL BMAP
White Oak Creek (WCK 6.8)	35.94106	84.30145	2.072	ORNL BMAP

Acronyms:
BMAP = Biological Monitoring and Abatement Program
BMP = Biological Monitoring Program
ETTP = East Tennessee Technology Park
km^2 = square kilometers
MIK = Mitchell Branch kilometer
N = north
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
W = west
WRRP = Water Resources Restoration Program

3.7.2.2. Mitchell Branch–ORNL and TDEC Protocols

Total taxa richness (i.e., the total number of taxa per sample) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness (i.e., the total number of pollution-intolerant EPT taxa [mayflies, stoneflies, and caddisflies] per sample) measured using ORNL protocols has varied over the measurement period (1987–2021) in all Mitchell Branch sites (Figure 3.39). Both total taxa richness and EPT taxa richness increased in MIKs 0.4, 0.7, and 0.8 from 1987 to the late 1990s, and then reached fairly consistent values, albeit with considerable year to year variation (Figure 3.39). Total taxa richness and EPT taxa richness have been fairly consistent throughout the measurement period in the reference site, MIK 1.4, though values have been lower in four of the past six years (Figure 3.39). In April 2022, total taxa richness and EPT taxa richness declined at MIK 1.4 and MIK 0.8 while both values improved at MIK 0.7. Due to this, total taxa richness was highest at MIK 0.7, while EPT taxa richness was highest at MIK 1.4, while both metrics were lowest at MIK 0.4 (Figure 3.39). The increase in EPT taxonomic richness at MIK 0.7 returned EPT taxa to values similar to those observed prior to 2020, whereas the decrease observed at MIK 0.8 represents a marked departure from the relatively stable values seen over the previous five years (Figure 3.39).



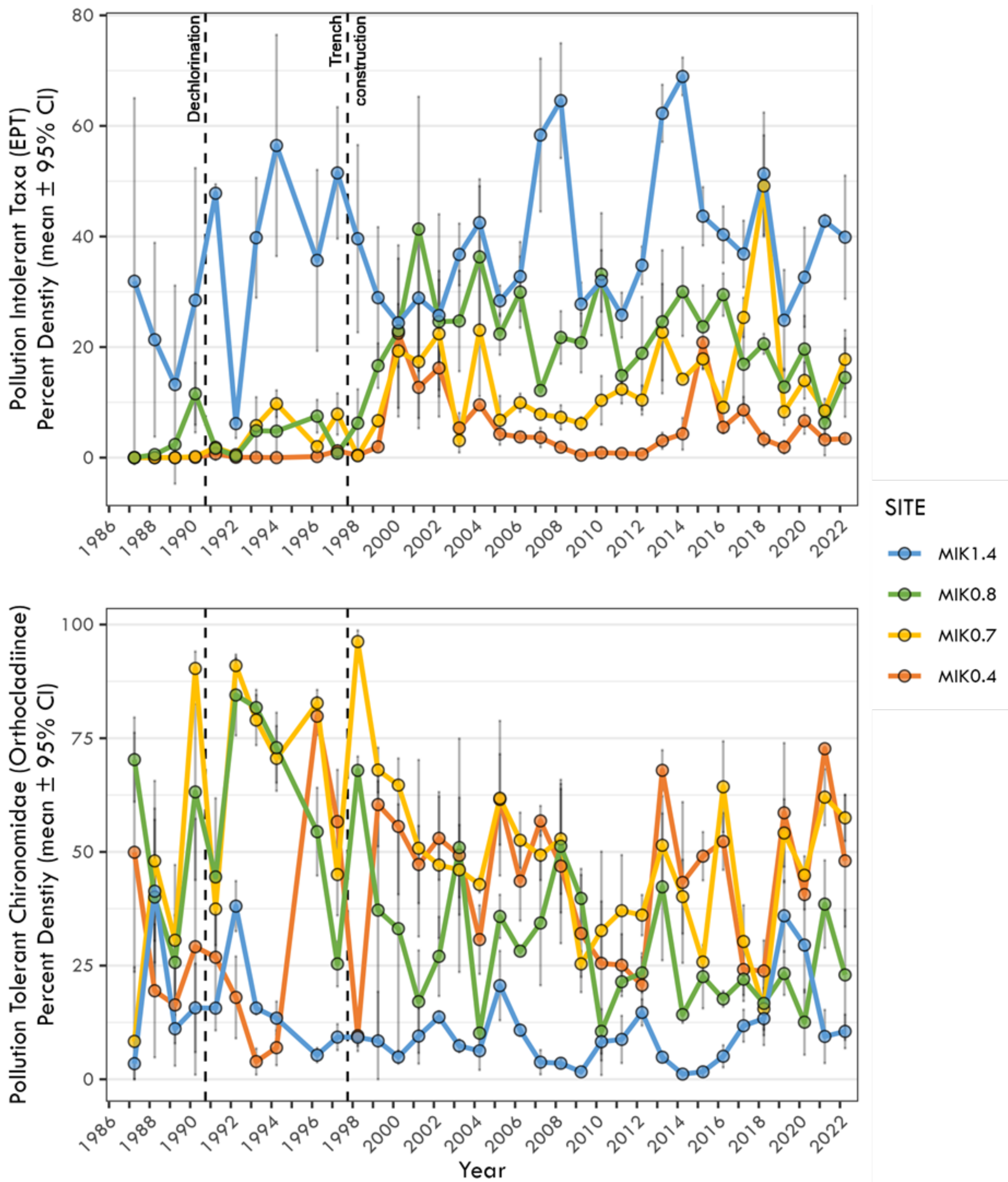
Note: *Samples were not collected in April 1995.*
Acronyms:
EPT = Ephemeroptera, Plecoptera, and Trichoptera *MIK = Mitchell Branch kilometer* *CI = confidence interval*

Figure 3.39. Mean (± 95 percent confidence interval) total taxonomic richness (top) and richness of the pollution-intolerant taxa per sample (bottom) for Mitchell Branch sites, April 1987–2022

The percent density of the pollution-intolerant taxa (higher values are indicative of good condition) was highest at MIK 1.4, the reference site, and lowest at MIK 0.4 in April 2022, which is a pattern that has been observed in most years since monitoring began in 1987 (Figure 3.40). In 2022, as in most years, the percent density of pollution-tolerant taxa (lower values are indicative of good conditions) was lowest at the reference site, MIK 1.4. An exception to this pattern occurred during 2019 and 2020 when the percent density of pollution-tolerant taxa was higher at MIK 1.4 than MIK 0.8 but still lower than at MIK 0.4 and MIK 0.7 (Figure 3.40). In 2022, the percent of pollution-tolerant taxa at MIK 1.4 remained stable after a two-year period (2019 and 2020) that had the highest values seen since monitoring began and were only surpassed in 1988 and 1992 (Figure 3.40). Continued monitoring will determine if those higher values at MIK 1.4 reflect increased interannual variability or a stochastic deviation from long-term patterns.

Based on TDEC protocols (TDEC 2021), scores for the TMI in 2022 rated the invertebrate community at all sites as falling below biocriteria guidelines (Figure 3.41). TMI scores in 2022 declined (MIK 1.4, MIK 0.7), remained stable (MIK 0.4), or increased (MIK 0.8) compared to 2021 scores (Figure 3.41). In 2022, MIK 1.4 scores decreased for EPT taxa richness but remained stable for all other metrics (Table 3.10). MIK 0.8 improved for a percentage of clingers and a percentage of EPT taxa, while remaining stable for all other metrics. MIK 0.7 metrics decreased for a percentage of clingers. Both MIK 0.7 and MIK 0.8 received low scores for all metrics except a percentage of oligochates and chironmids, which was high across all sites in Mitchell Branch. As in 2021, the TMI score for MIK 0.7fell below MIK 0. MIK 0.4 received low scores for total taxa richness, EPT taxa richness, and percentage EPT, but received the highest scores possible for all other invertebrate metrics except the percentage of nutrient-tolerant taxa (Table 3.10). Since sampling using TDEC protocols began in 2008 in Mitchell Branch, TMI scores at have almost always rated the invertebrate community at MIK 1.4 as passing biocriteria guidelines, while MIK 0.4, MIK 0.7, and MIK 0.8 were generally rated as falling below biocriteria guidelines. (Figure 3.41).

Based on TDEC stream habitat protocols, habitat quality was above the ecoregion 67f guideline at all sites within Mitchell Branch (Figure 3.41). Habitat scores increased at MIK 0.4, MIK 0.8, and MIK 1.4 but decreased at MIK 0.7. In general, increases from the previous year were primarily seen in decreased sediment deposition and increased channel flow. Small riparian width, particularly on the left bank, remained an issue at all sites, except MIK 1.4.



Notes:

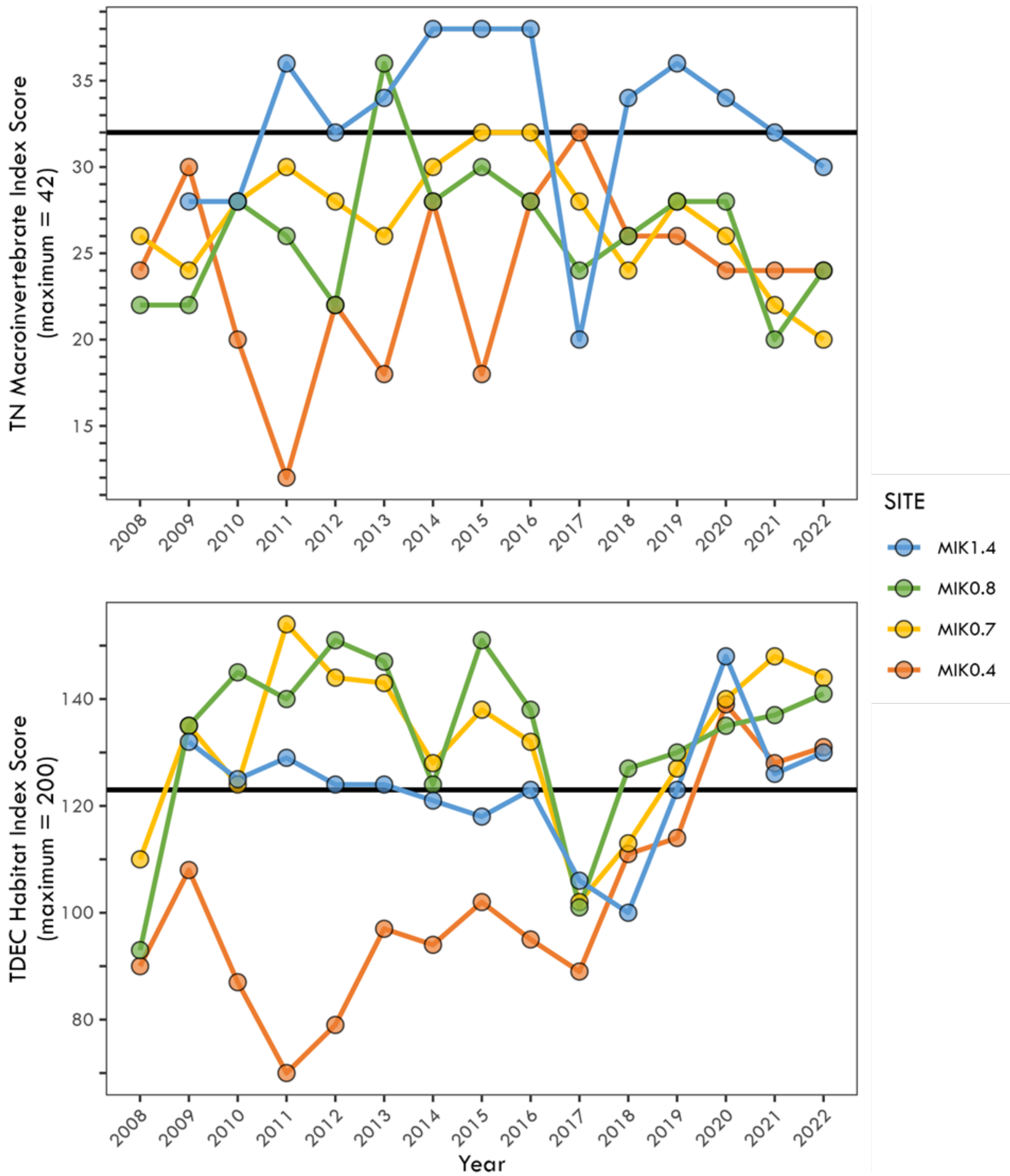
1. *Pollution-intolerant taxa, i.e., stoneflies, mayflies, and caddisflies or Ephemeroptera, Plecoptera, and Trichoptera taxa (top).*
2. *Percentages were based on total densities for each site.*
3. *Samples were not collected in April 1995.*

Acronyms:

MIK = Mitchell Branch kilometer CI = confidence interval

EPT = Ephemeroptera, Plecoptera, and Trichoptera (pollution-intolerant taxa)

Figure 3.40. Mean percent density of pollution-intolerant taxa and of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) at Mitchell Branch sites, April 1987–2022



Notes:

1. *Mitchell Branch site MIK 1.4 was not sampled with TDEC protocols in 2008.*
2. *The horizontal line on each graph shows the rating threshold for each index for ecoregion 67f; TDEC macroinvertebrate index threshold is 32; TDEC habitat index threshold is 123. Values above the thresholds are indicative of passing biocriteria or habitat guidelines.*

Figure 3.41. Temporal trends in the TDEC Macroinvertebrate Index (top) and Stream Habitat Index (bottom) scores for four Mitchell Branch sites, August 2008–2022

Table 3.10. Tennessee Macroinvertebrate Index metric values and scores and index scores for Mitchell Branch, August 16, 2022[a,b,c]

Site	Metric values							Metric scores							TMI[d]
	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	
MIK 0.4	20	2	0.8	11.6	4.6	73.6	43.4	2	0	0	6	6	6	4	24
MIK 0.7	18	4	13.8	3.6	5.5	48.5	57.7	2	2	0	6	4	4	2	20
MIK 0.8	19	5	17	14.4	5.8	66	61.7	2	2	2	6	4	6	2	24
MIK 1.4	26	7	32.2	17.4	4.2	44.3	41.7	4	2	4	6	6	4	4	30

[a] *TMI metric calculations and scoring and index calculations are based on Tennessee Department of Environment and Conservation (TDEC) protocols for ecoregion 67f: TDEC 2021, Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys, TDEC Division of Water Resources, Nashville, Tennessee. Available* ***here****.*

[b] *Taxa rich = Taxa richness; EPT rich = Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies) taxa richness; %EPT = EPT abundance excluding Cheumatopsyche spp.; %OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; %Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water excluding Cheumatopsyche spp; %TN Nuttol. = percent abundance of nutrient-tolerant organisms.*

[c] *MIK = Mitchell Branch kilometer.*

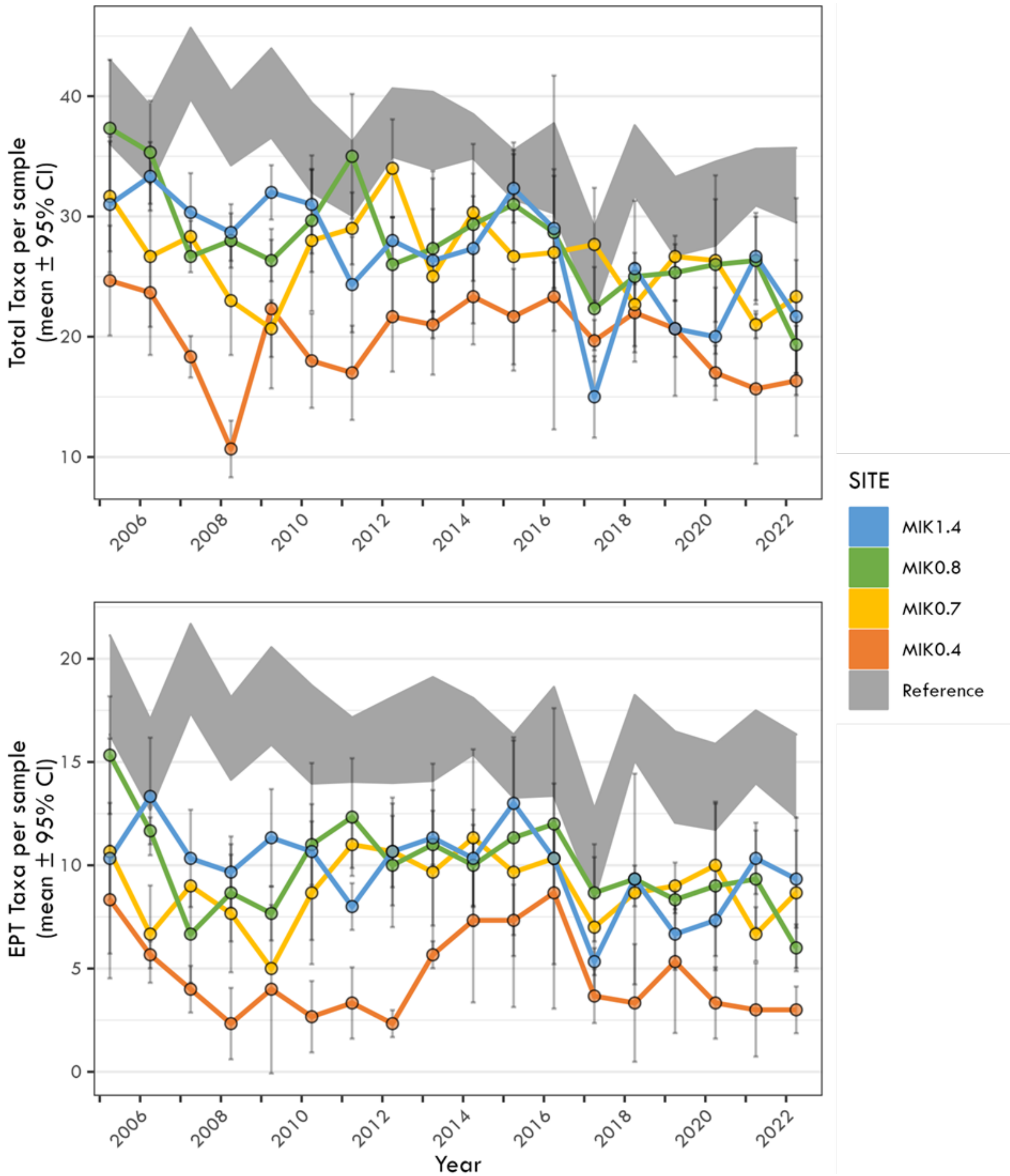
[d] *TMI = Tennessee Macroinvertebrate Index score. TMI is the total index score, and higher index scores indicate higher-quality conditions. A score of ≥ 32 is considered to pass biocriteria guidelines.*

3.7.2.3. Comparison between Mitchell Branch and Other Reference Sites on ORR

In Figure 3.42, the benthic macroinvertebrate communities in Mitchell Branch are compared to ORR reference streams over a 17-year period. Mean values for total taxa richness and taxa richness of pollution-intolerant (EPT) taxa for Mitchell Branch are shown in Figure 3.42, and percent density of the pollution-intolerant and pollution-tolerant taxa are shown in Figure 3.43. Also shown in gray shading in Figures 3.42 and 3.43 is the 95 percent confidence interval for the five reference sites on ORR—First Creek kilometer 0.8, Fifth Creek kilometer 1.0, White Oak Creek kilometer 6.8, Walker Branch kilometer 1.0, and Gum Hollow Branch kilometer 2.9.

In 2022, total taxa richness and taxa richness of pollution-intolerant taxa at Mitchell Branch sites, including MIK 1.4, were less than both the 95 percent confidence interval for the five reference sites (Figure 3.42). This trend was observed since these comparisons began in 2005, with some exceptions (e.g., 2011, 2017). In contrast to richness metrics, the mean percent densities of pollution-intolerant and pollution-tolerant taxa at MIK 1.4 were not often outside of the 95 percent confidence interval for the reference sites (Figure 3.43). The percent density of pollution-tolerant taxa at MIK 1.4 increased slightly in 2022, but fell within the 95 percent confidence interval for reference sites for the first time since 2017 (Figure 3.43). Since 2005, the mean percent density of pollution-intolerant taxa at MIK 0.7 and MIK 0.8 have largely remained below the reference 95 percent confidence interval, while the percent density of pollution-tolerant taxa at these sites were higher than the reference 95 percent confidence interval. MIK 0.4 has remained well outside the 95 percent confidence intervals for reference sites since 2005 (Figure 3.43).

These results from the comparison of Mitchell Branch sites with the reference sites, combined with the long-term results for all Mitchell Branch sites discussed above, suggest that from the standpoint of reference sites, MIK 1.4 falls near the lower distribution of expected reference conditions on ORR. Factors potentially contributing to excursions of invertebrate community metrics outside of the 95 percent confidence interval for other reference sites include the somewhat smaller size of MIK 1.4 compared with the other reference sites (based on watershed area, Table 3.10), which may limit the range of invertebrate species that can colonize and thrive at the site, and habitat characteristics that have typically contributed to the lower-quality habitat at the site, such as low flow and poor substrate quality (seen earlier in Figures 3.40 and 3.41). These results also support the contention that sites downstream of MIK 1.4 continue to exhibit evidence of mild to moderate degradation.

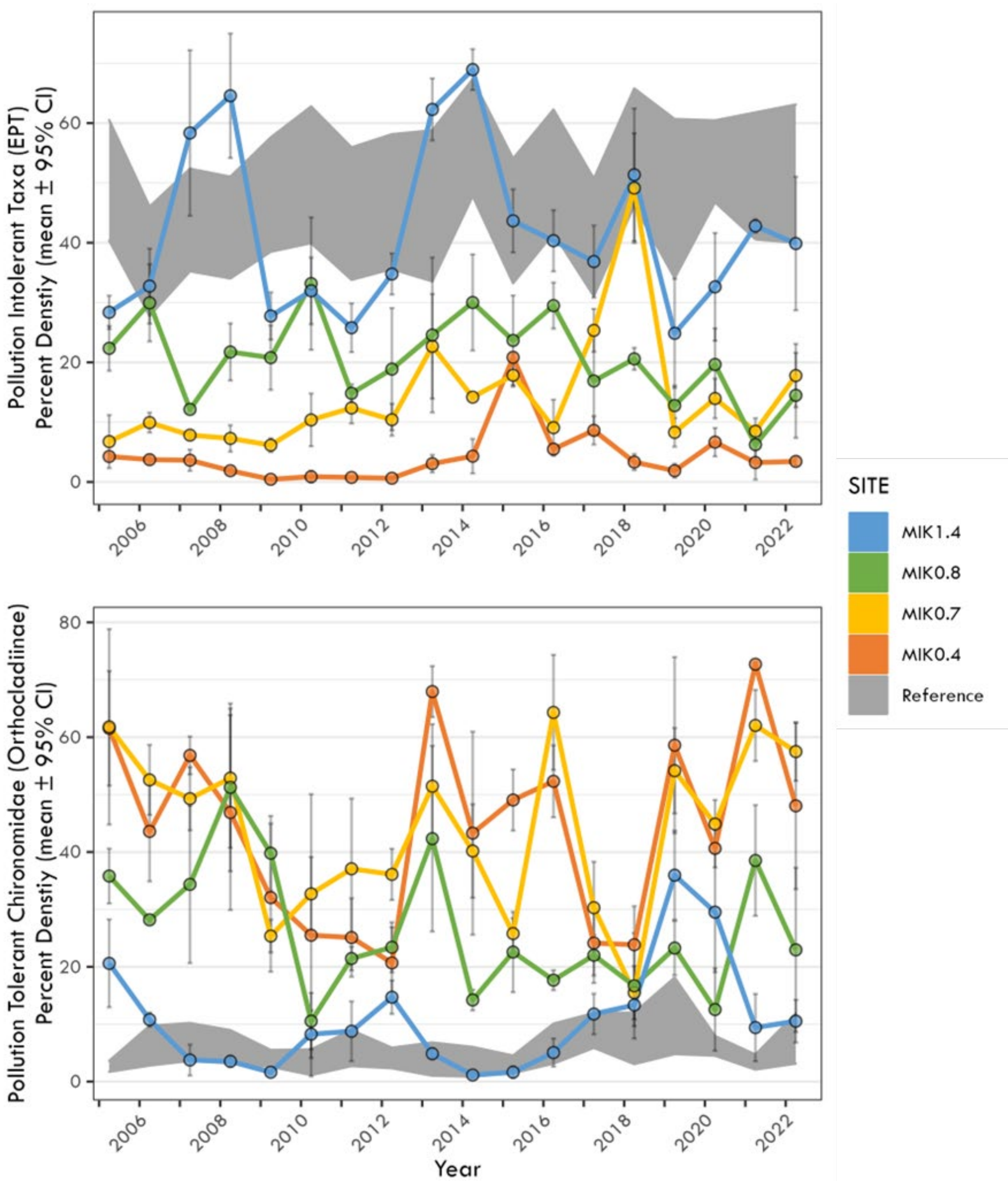


Note: *The gray shading on each graph shows the 95% confidence interval of values at five additional reference stream sites on ORR from 2005 to 2022.*

Acronyms:

CI = confidence interval
EPT = Ephemeroptera, Plecoptera, and Trichoptera
MIK = Mitchell Branch kilometer
MIK 1.4 = reference site
ORR = Oak Ridge Reservation

Figure 3.42. Mean total taxonomic richness (top) and pollution-intolerant taxa per sample (bottom) for the benthic macroinvertebrate community at Mitchell Branch and the 95% confidence interval for ORR reference sites, April 2005–2022



Notes:

1. *Pollution-intolerant taxa, i.e., stoneflies, mayflies, and caddisflies or Ephemeroptera, Plecoptera, and Trichoptera taxa (top).*
2. *Pollution-tolerant Orthocladiinae midge larvae (bottom).*
3. *Percentages were based on total densities for each site.*
4. *The gray shading on each graph shows the 95% confidence interval for values at five additional reference sites on ORR from 2005 to 2022.*

Acronyms:

CI = confidence interval *MIK 1.4 = reference site* *EPT = Ephemeroptera, Plecoptera, and Trichoptera*
ORR = Oak Ridge Reservation *MIK = Mitchell Branch kilometer*

Figure 3.43. Mean percent density of pollution-intolerant taxa (top) and pollution-tolerant Chironomidae (bottom) in Mitchell Branch the 95% confidence interval for ORR reference sites, April 2005–2022

3.7.3. Task 3: Fish Community

Fish population and community studies are used to evaluate the biotic integrity (or general ecological health) of Mitchell Branch. The fish community is sampled quantitatively at two sites in Mitchell Branch, MIK 0.4 (downstream of SD-190) and MIK 0.7 (downstream of SD-170) and at local reference streams each spring.

Mitchell Branch Fish Community

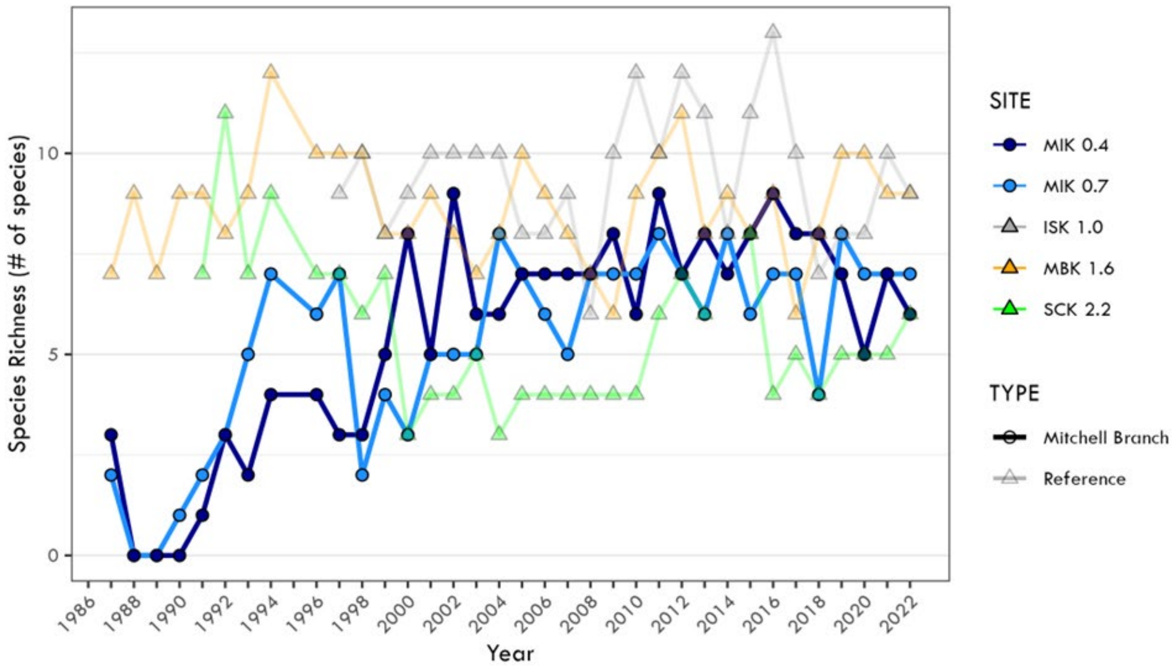
Historically, the fish community in Mitchell Branch was most severely affected in the late 1980s and early 1990s. After some recovery in the mid-1990s, Mitchell Branch was affected negatively again in 1998 in association with a remedial activity that replaced a large section of stream bottom with a liner and interlocking rock substrate (Figure 3.44). In recent years, this reach of stream appears to be developing more natural habitat, including a more robust riparian plant community and some instream riffle/pool sequences as substrate is slowly beginning to throughout the reach (Figure 3.45). This has added to the complexity of the habitat available for fishes to colonize. Since 2000, the fish community has had relatively stable species diversity but rather large variations in fish density and biomass, which are often reflective of unstable, impaired streams. Streams that experience high density and biomass of tolerant

Figure 3.44. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998

Figure 3.45. More recent habitat conditions at Mitchell Branch in 2022

fish species are often indicative of either high nutrient influences on a fish community (i.e., more algal growth means more food at the base of the food chain) or poor instream habitat—and often a combination of both. Of the two sites sampled for fish community, MIK 0.7 has experienced the greatest fluctuations in these community parameters. This is likely due to the modified stream channel and riparian areas and poor instream habitat associated with the remediation work in this reach. Similar conditions are seen in other area streams on ORR, including sections of East Fork Poplar Creek where tolerant species dominate the concrete- and bedrock-lined channel, which supports little riparian protection. In addition, extremely low precipitation amounts, which often occur in the summer, result in very low flows in many area streams. Small first and second order streams without springs or groundwater influence are most severely affected by these conditions. This may partially explain the decreased density and biomass numbers observed in some years and the apparent return of higher values in following years.

At both MIK 0.4 and MIK 0.7, the 2022 sample of fish community parameters indicated continued variation. Species richness (number of species) at the lower site decreased slightly while richness at the upper site remained stable compared to 2021 values (Figure 3.46). Both sites have species



Acronyms:

ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

SCK = Scarboro Creek

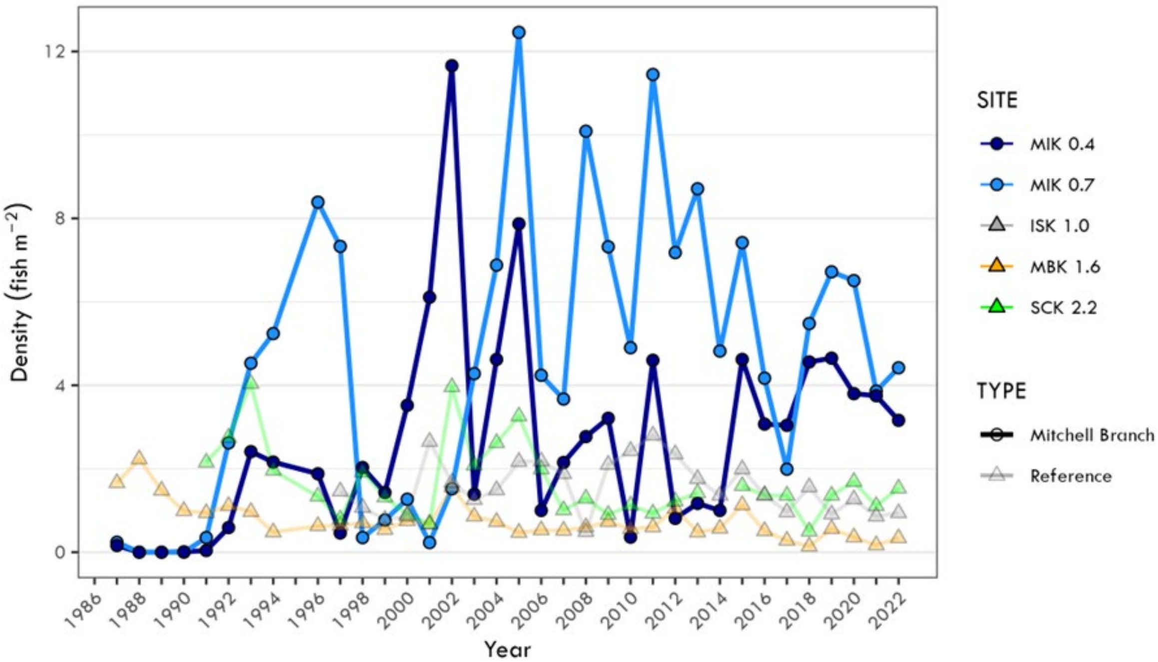
Figure 3.46. Species richness for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2022

richness comparable with similar sized reference streams. Density (number of fish) at both sites still remains well above reference conditions (Figure 3.47). Biomass (weight) also remains elevated at both sites (Figure 3.48). Both the lower Mitchell Branch site and the upper site had reduced diversity and density of sensitive fish species in 2022 compared to reference sites.

Over the last decade, there has been a slight uptick in the occurrence of sensitive fish species at both sampled sites in Mitchell Branch, which can be attributed to the regular presence of fish such as banded sculpin (*Cottus carolinae*) that appear to be a resident species in Mitchell Branch, and also occasional occurrences of other more sensitive fish. In 2022, no new species were observed in the two sites and the resident banded sculpin were very limited. However, new species of darters, suckers, and sunfish continue to show up within Mitchell Branch, and some represent unique sensitive species in this reach of stream.

In general, the Mitchell Branch fish communities at MIK 0.4 and MIK 0.7 continue to lack diverse resident species that are sensitive to stress or that have specialized feeding or reproductive requirements, such as darters or suckers that occur consistently at higher frequencies in the reference streams. Like the benthic communities, fish community monitoring provides an integrated response to *all* of the various water chemistry and habitat influences in a stream. Identifying the major stressor influences on the community (i.e., causal analysis) would require additional investigatory strategies coupled with the monitoring data.

During routine bioaccumulation sampling, several species of fish are collected regularly at MIK 0.2 that are infrequently observed in the Mitchell Branch fish community monitoring activities at the upstream sites. These included four pollution-sensitive species: black redhorse (*Moxostoma duquesnei*), snubnose darter, greenside darter



Acronyms:

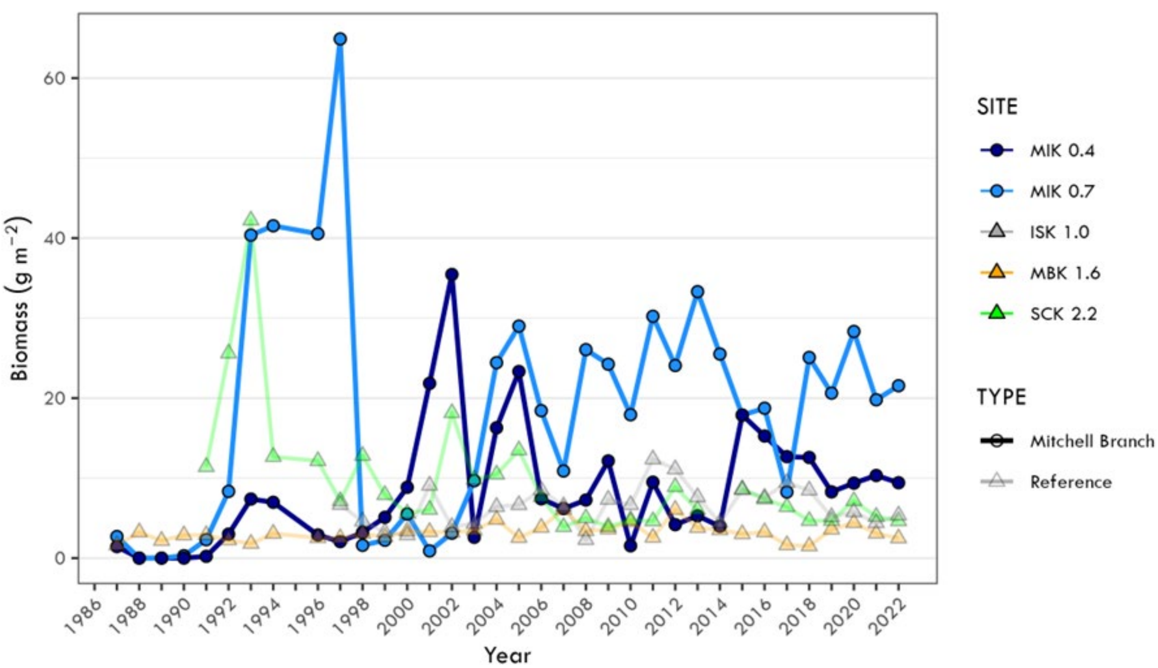
ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

SCK = Scarboro Creek

Figure 3.47. Density for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2022



Acronyms:

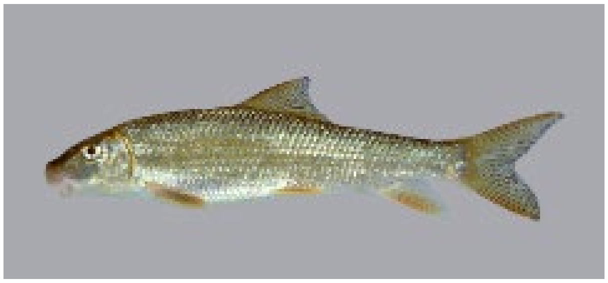
ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

SCK = Scarboro Creek

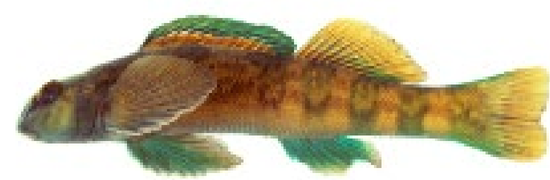
Figure 3.48. Biomass for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2022



Black redhorse *(Moxostoma duquesnei)*

Snubnose darter *(Etheostoma simoterum)*

Northern hogsucker *(Hypentelium nigricans)*



Greenside darter *(Etheostoma blennioides)*

Photos: Chris Bryant

Figure 3.49. Sensitive fish species observed in lower Mitchell Branch

(*Etheostoma blennioides*), and northern hogsucker (*Hypentelium nigricans*) (clockwise, Figure 3.49). Future monitoring will help determine if these species are becoming established farther upstream in Mitchell Branch or are merely seasonal migrants to the stream's lower section, which is easily accessible from the much larger Poplar Creek.

K-1007-P1 Pond Fish Community

The fish communities in the K-1007-P1 Pond are assessed annually. This sampling is conducted to evaluate the effectiveness of remediation efforts implemented in 2009 and is aimed at reducing the PCBs available for transfer out of the pond via natural routes (i.e., trophic transfer). The RAs included capping contaminated sediment with fill dirt, planting native aquatic vegetation to stabilize sediment, and removing potentially contaminated fish from the pond. Fish initially were removed from the pond using a piscicide (Rotenone), and uncontaminated native fish were stocked in the pond with the goal of establishing a sunfish-dominated community. Sunfish have a shorter lifespan than many other species of fish, especially higher trophic level fish, and they have a prey source that is generally varied but consistently lower on the aquatic food chain compared with species such as largemouth bass, thus reducing the likelihood that contaminants would biomagnify within the system.

Despite efforts to remove all unwanted fish from the pond, an unexpected breach in the weir separating the K-1007-P1 Pond from the adjacent Poplar Creek in May 2010 allowed numerous fish to enter the pond during high waters. These unwanted fish constituted several species that were unfavorable to the pond action—including: (1) nonnative species and (2) species with life history traits that undermined the remediation efforts, such as being long-lived and having feeding habits that disturb potentially contaminated sediments. Continued work to remove these unwanted fish has been productive, and only limited numbers of the most long-lived species, such as common carp (*Cyprinus carpio*) and smallmouth buffalo (*Ictiobus bubalus*), are encountered in annual monitoring.

Two additional species that returned to the pond after the weir breach were gizzard shad (*Dorosoma cepedianum*) and largemouth bass

(*Micropterus salmoides*). Gizzard shad feed on phytoplankton and zooplankton in natural environments such as larger reservoirs, but in smaller ponds such as P1, they often turn to feeding on algal growth at the surface of the pond sediment, which can disturb soils and potentially resuspend contaminants in the pond substrate. Largemouth bass tend to be a long-lived species and are a top predator in aquatic environments, making them particularly susceptible to bioaccumulation. They also are a game fish highly prized by many anglers as well as a common table fare. These two species also have been targeted for removal during continued remediation efforts and fish surveys.

Overall, the K-1007-P1 Pond fish community surveys conducted in February 2022 revealed the presence of 12 species of fish. An observation of particular importance from previous surveys is the abundance of sunfish species (bluegill, redear sunfish, and warmouth), which constitute approximately 93 percent of the total fish population (Figure 3.50). Bluegill, the most prevalent of these species, were historically the dominant sunfish species in the pond, and they are the desired bioindicator fish species to have in the remediated pond. Although largemouth bass continue to persist in the pond, their abundance remains relatively low. Despite removal efforts, their presence is likely to continue, given the habitat conditions currently in the pond (i.e., abundant prey sources and open water). Gizzard shad (*Dorosoma cepedianum*) continue to be present in the pond and are suspected of reproducing some years. Although they constituted a much larger portion of the fish population in 2020 than in previous years, they have been almost absent in subsequent sampling. Their abundance has had some minor fluctuations each year but in general has remained relatively low compared with earlier years.

3.8. Environmental Management and Waste Management Activities

Remediation activities were underway across ETTP in 2022. Wastes were generated during these operations and were handled in accordance with the applicable regulations.

3.8.1. Waste Management Activities

Most of the waste generated during FY 2022 cleanup activities in Oak Ridge went to disposal facilities on the Oak Ridge Reservation—namely, the EMWMF and the Oak Ridge Reservation Landfills (ORRL). These facilities are owned by DOE and operated/maintained by UCOR. They have been vital to cleanup progress and success, Enabling OREM to accomplish more cleanup by avoiding costly and unnecessary cross-country shipments.

EMWMF only receives low-level radioactive and hazardous waste meeting specific criteria. The waste is mostly soil and building debris. In FY 2022, EMWMF received 7,172 waste shipments from cleanup projects at ETTP, ORNL, and Y-12, plus 643 clean fill shipments for the enhanced operational cover expansion and constructing access roads and dump ramps. The EMWMF landfill has a design capacity of 2.331 million yd^3 and is now over 82 percent filled.

EMWMF generated 17.28 million gal of wastewater in FY 2022. Approximately 3.30 million gal of leachate (water that enters the leachate collection system) was transported by tanker to the ORNL Liquid and Gaseous Waste Operations for treatment and release. Approximately 13.98 million gal of contact water (water that contacts waste but does not enter the leachate collection system) was released to Bear Creek after laboratory analysis verified it met all regulatory limits and discharge standards.

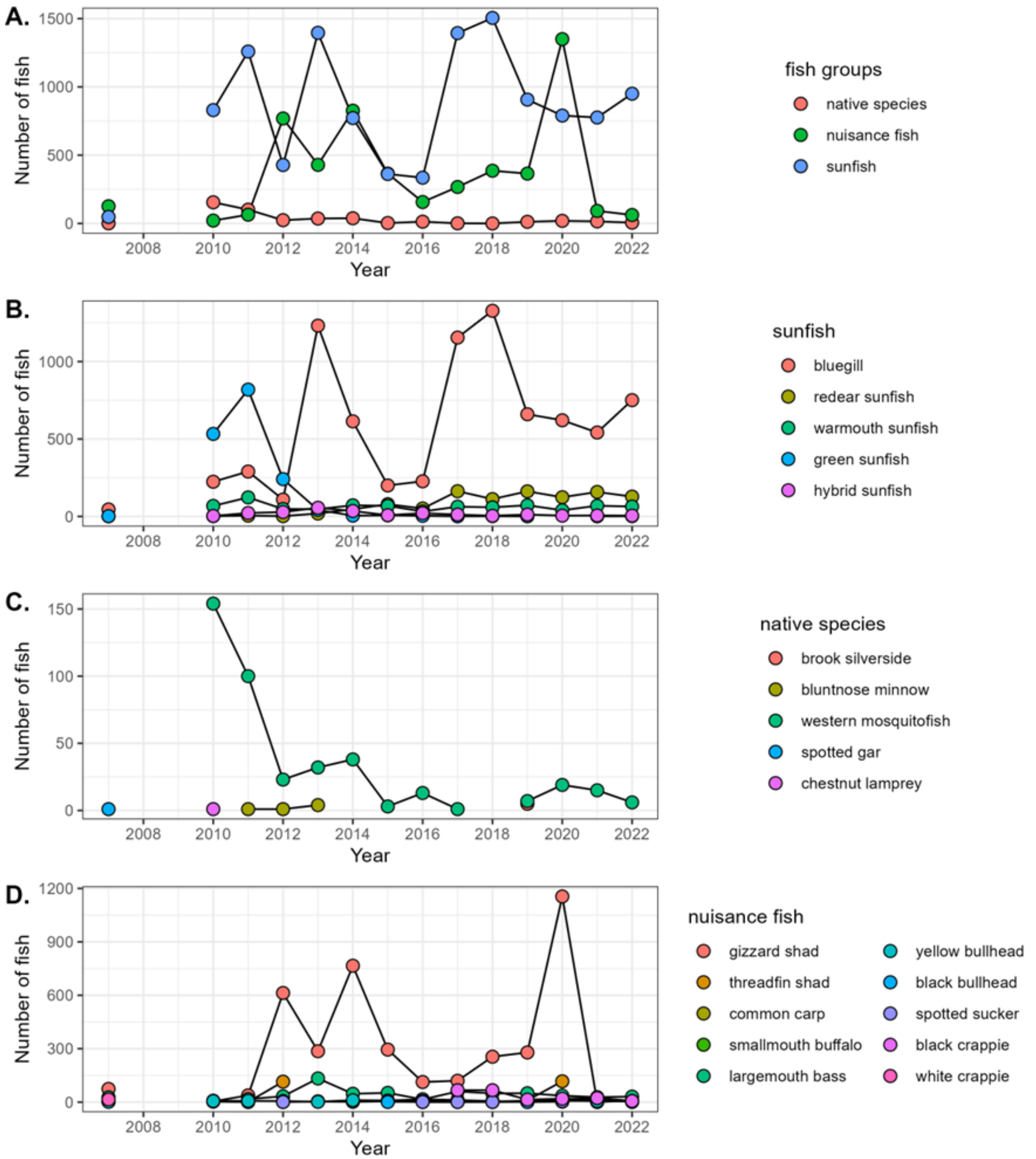


Figure 3.50. Changes in the K-1007-P1 Pond fish community from 2007–2022

ORRL accepts sanitary/industrial waste and construction/demolition debris. In FY 2022, these three active landfills received 11,146 waste shipments, totaling 155,034 yd^3 of waste.

ORRL also manages non-regulated leachate. In FY 2022, ORRL compliantly discharged 4.1 million gal of leachate from the three active landfills to the Y-12 sanitary sewer system.

Work continued with regulatory agencies on seep mitigations for Sanitary Landfill II (a closed landfill) and active Landfill VII. Repairs at Landfill VII included developing and implementing a minor modification approved by the regulators that allowed landfill operations to remove approximately 456,000 gal of leachate trapped inside of Landfill VII for an extended period of time. This water was transferred to the Landfill V leachate facility for discharge.

In FY 2022, ORRL continued improvements for all sediment and erosion controls. These measures included upgrading drainage features, which significantly reduces the amount of sediment released from these landfills. TDEC inspections in FY 2022 noted excellent sediment and erosion controls with no areas of concern or violations. Workers removed approximately 60,000 yd^3 of soil and made major preparations for the Landfill V (Area 5) expansion.

EMWMF will reach capacity before OREM completes its cleanup at Y-12 and ORNL. Planning continued in FY 2022 for another disposal facility, the Environmental Management Disposal Facility (EMDF), to provide the capacity required to complete Oak Ridge's cleanup mission.

The EMDF ROD was signed on September 30, 2022. This major milestone for the project allows OREM to begin site preparation activities and finalize the facility's design. OREM continues to work with EPA and TDEC on follow-on regulatory documents related to the project. Planning for the groundwater field demonstration that will augment the existing site characterization is in progress, including finalizing the demonstration design. Planning for early site preparation activities to reroute roads and provide utilities to the future EMDF site is in progress. FFS for Water Management for the Disposal of CERCLA Waste was approved on September 6, 2022 (DOE 2022a). This approval followed the dispute resolution for radiological discharge limits. The FFS provides an evaluation of landfill wastewater treatment alternatives, and its approval was a prerequisite for the EMDF ROD signature by the Federal Facility Agreement parties.

OREM continued to monitor 31 groundwater wells at the selected site for the disposal facility, measuring and recording water levels and groundwater characteristic data for the entire year.

The Transuranic (TRU) Waste Processing Center (TWPC) continued processing and shipping TRU, mixed low-level waste (MLLW), and low-level waste in FY 2022. In 2022, the TWPC portion of the RCRA Hazardous Waste Permit (TNHW-145) was transferred from North Wind Solutions, LLC to UCOR. The facility has completed processing of 98 percent and shipment of 83 percent of its contact-handled TRU waste and 70 percent of its remote-handled TRU waste.

TWPC's operational focus in FY 2022 was on processing the legacy Nuclear Fuel Services waste (12.4 cubic meters [m^3]) and TRU waste processing by-product wastes (46 m^3). TWPC completed limited processing operations for 1.9 m^3 of MLLW macro-encapsulation. TWPC continued critical actions associated with readiness preparation to commission new waste processing capabilities at TWPC for high activity oxide and wastes requiring new infrastructure, which encompasses over 75 percent of the remaining 39 m^3 of the TRU legacy waste inventory on the Site Treatment Plan for Mixed Wastes on the DOE Oak Ridge Reservation. TWPC continued certification and shipment of 59.3 m^3 of TRU waste to the Waste Isolation Pilot Plant, 58.5 m^3 MLLW to treatment and disposal, and 2.7 m^3 of hazardous waste to treatment and disposal, eliminating 475 containers of the stored inventory.

3.8.2. Environmental Remediation Activities

During 2020, the final major cleanup project was completed. The ultimate goal of the remediation work is to make parcels of land available for a general aviation airport, conservation areas, and private-sector development that can economically benefit the region. Highlights of this effort are given below. For details, please see the *2022 Cleanup Progress—Annual Report to the Oak Ridge Regional Community* (UCOR 2023, OREM-23-7632).

3.8.2.1. Soil Remediation

UCOR's soil remediation efforts at ETTP are helping to prepare the site for future commercial industrial use. The site is divided into two cleanup regions: Zone 1, a 1,400-acre area outside the main plant area, and Zone 2, the 800-acre area that comprises the main plant area. The areas in these zones are divided into EUs that vary in size from 6 to 38 acres. Remediation efforts are designed to protect groundwater, wildlife, and the future workforce. Remediation activities include removal of facilities, excavation of soil, and land use covenants. In FY 2022, OREM excavated and removed soil with radiological contaminants from several small areas in EU-13, an area near Poplar Creek that once housed many of the gaseous diffusion and uranium hexafluoride enrichment support facilities. Workers also removed the K-1131 ash pit and surrounding soils in that area.

Remediation was also underway within EU-21, an area that is located in the middle of the K-25 footprint, which is part of the Manhattan Project National Historical Park. Characterization sampling was performed as part of the overall cleanup of the ETTP site. Based on results of model calculations, workers are set to excavate 108,000 yd^3 of soil to eliminate risks to groundwater.

Excavations to remediate the potential risk to groundwater began in April 2021 and are ongoing. To support the treatment of water that could accumulate within the excavation areas, a treatment system was designed to remove contaminants from the water prior to discharge to the Clinch River.

Other RA accomplishments in FY 2022 include the following:

- Completed soil RA activities within the footprint of the former K-1303, Mercury Distillation Facility; site restoration activities included placing clean fill and hydroseeding the area to stabilize the site
- Completed the concrete slab/associated plenum and soil RA surrounding the former K-1302, Fluorine Storage and Distribution Facility; site restoration activities included placing soil fill with final site stabilization pending
- Completed the concrete slab RA of the former K-1301, Fluorine Production Facility; site restoration activities included placing and compacting gravel across the area's footprint

3.8.2.2. Groundwater Protection

ETTP completed several soil RAs in FY 2022 that help protect groundwater. Workers on these projects removed approximately 20,000 yd^3 of soil and concrete.

The EU-25 RA centered on the slab, foundation, and underlying soil of the former K-1413 Building. Constructed in the 1950s, the building was operated until the early 1980s for a range of chemical waste processing activities. Included with the building were three neutralization pits ranging from 2,500 to 21,000 gal. Extensive contamination in the concrete and soil was removed during the action. Over 13,000 yd^3 of concrete and soil were removed from the site.

The EU-35 RA was conducted on the site of the former K-1407-K Building. This facility contained six 500-gal tanks and a system used for mixing chemical solutions. Four of the tanks were used to convert dry chemicals into solutions; two tanks were used to hold rinse water. Concrete and soil in the footprint of the former building were found to contain methylene chloride and PCE that exceed site groundwater screening levels. Approximately

800 yd^3 of soil and concrete was removed from the area.

The EU-42 area is the site of the former K-1004-J Building, a laboratory that was part of the now-demolished Centrifuge Complex. Remediation was performed on the former slab and soils remaining after demolition. Research conducted in the former facility resulted in discharges to drain lines and neutralization pits that contaminated the concrete and soil in the area with radioactive isotopes. RAs in this EU removed more than 6,200 yd^3 of concrete and soil.

OREM is also working to develop RODs to address groundwater cleanup at the site. RODs document the cleanup approach that will be used. The RODs will be for the K-31/33 Area, Main Plant Area, and Zone 1.

3.8.3. Reindustrialization

OREM continued to see significant momentum in the Reindustrialization Program at ETTP. The former government-owned uranium enrichment complex is being turned into a multiuse industrial park that includes national historic preservation and conservation and greenspace areas. To date, OREM has successfully transferred almost 1,300 acres at ETTP for beneficial reuse and is working to complete transfer of the remaining acreage at the site.

During FY 2022, the Reindustrialization team advanced the regulatory review of seven land transfer packages. This includes areas such as the former Powerhouse area, the Centrifuge area, and the K-1037 and TSCA Incinerator area. OREM and UCOR continued to partner with CROET to identify remaining available property, coordinate schedules, and support new businesses as they set up operations.

FY 2022 saw an increase in economic development with four new companies acquiring land. An estimated 1,500 jobs will be added in the coming years with an investment of nearly $500 million. Their expertise ranges from an advanced nuclear demonstration project to nuclear fuel fabrication facilities and a glass fiber recycling facility. Oak Ridge is quickly becoming an area known for next-generation nuclear and clean energy industries.

The national historical preservation activities continued with the completion of the building design for the K-25 Viewing Platform. This new facility will be adjacent to the K-25 History Center and is positioned to overlook the former K-25 Building footprint.

Conservation/Greenspace

Enhancing the area's natural assets and creating more public recreation opportunities continued to be a major focus at ETTP. The Tennessee Wildlife Resources Agency and OREM collaboration resulted in the signing of an agreement in principle to plan to transfer almost 3,500 acres for greenspace and mixed-use recreational areas.

OREM and UCOR continued to share progress and lessons learned with the community and stakeholders through several meetings, workshops, and a virtual public event held in February 2022. These activities helped describe the remaining scope of work and provided an update on how the site is being transformed into a valuable community asset.

3.9. References

DOE 1992. *Federal Facility Agreement for the Oak Ridge Reservation*. FFA-PM/18-011, DOE/OR-014, January 1, 1992 or latest revision, U.S. Environmental Protection Agency Region IV, U.S. Department of Energy, and Tennessee Department of Environment and Conservation, Oak Ridge, Tennessee. Retrieved April 20, 2023, from https://www.energy.gov/sites/prod/files/em/2001_Agreements/ORR_FFA_1-1-92.pdf.

DOE 1993a. *Radiation Protection of the Public and the Environment,* DOE Order 5400.5, Chg. 2. Approved January 7, 1993. US Department of Energy, Washington, DC.

DOE 1993b. *Record of Decision for the K-1407-B/C Ponds at the Oak Ridge K-25 Site, Oak Ridge, Tennessee*. DOE/OR/02-1125&D3, September 1, 1993, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1995. *Remedial Action Report for the K-1407-B Holding Pond and the K-1407-C Retention Basin*. DOE/OR/01-1371&D1, August 3, 1995, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2011a. *Radiation Protection of the Public and the Environment*. DOE Order 458.1. Approved February 11, 2011. US Department of Energy, Washington, DC.

DOE 2011b. *Departmental Sustainability*. DOE Order 436.1. Approved May 2, 2011. US Department of Energy, Washington, DC.

DOE 2012. *Memorandum of Agreement Among the U.S. Department of Energy Oak Ridge Office of Environmental Management, Department of Energy Federal Preservation Officer, the Tennessee State Historic Preservation Office, the Advisory Council on Historic Preservation, the City of Oak Ridge, Tennessee, and the East Tennessee Preservation Alliance, Pursuant to 36 CFR Part 800.6(B)(2) For Decommissioning And Demolition of the K-25 Site and Interpretation of the East Tennessee Technology Park, on the Oak Ridge Reservation, Roane County, Tennessee*, August 6, 2012, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2018. *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement*. ORR-PCB-FFCA, Revision 6. US Department of Environmental Protection Agency, US Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee. Retrieved April 20, 2023 from: http://ucor.com/wp-content/uploads/2021/07/PCB_FFCA.pdf.

DOE 2020. *Compliance Plan National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee*. DOE/ORO/2196, Rev. 2, May 1, 2020, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

DOE 2021a. *East Tennessee Technology Park Main Plant Groundwater Focused Feasibility Study, Oak Ridge, Tennessee*. DOE/OR/01-2894&D1, June 30, 2021, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2021b. *Derived Concentration Technical Standard*. DOE-STD-1196-2021, July 7, 2021, US Department of Energy, Washington, DC.

DOE 2021c. *Zone 1 Groundwater Plumes Remedial Investigation Work Plan, East Tennessee Technology Park, Oak Ridge Tennessee*. DOE/OR/01-2903&D1, September 20, 2021, US Department of Energy, Oak Ridge Office of Environmental Management, Tennessee.

DOE 2021d. *Remedial Investigation/Feasibility Study Report for the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee*. DOE/OR/01-2893&D1/R1, November 1, 2021, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2022a. *Focused Feasibility Study for Water Management for the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee*, DOE/OR/01-2664&D4, June 2022, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2022b. *Proposed Plan for an Interim Record of Decision for Groundwater in Main Plant Area at East Tennessee Technology Park, Oak Ridge, Tennessee*, DOE/OR/01-2921&D1, March 2022, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2022c. *Proposed Plan for the Record of Decision for Groundwater in the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee*, DOE/OR/01-2922&D1, September 14, 2022, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2022d. *2021 Oak Ridge Reservation Annual Site Environmental Report*. DOE-SC-OSO/RM-2022-01, September 2022, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOI 2015. *Interior and Energy Departments Formally Establish the Manhattan Project National Historical Park.* Retrieved July 6, 2023, from https://www.doi.gov/pressreleases/interior-and-energy-departments-formally-establish-manhattan-project-national.

EO 13514. *Federal Leadership in Environmental, Energy, and Economic Performance*, October 8, 2009, Federal Register, Vol. 74(194).

EO 13693. *Planning for Federal Sustainability in the Next Decade*, March 25, 2015, Federal Register, Vol. 80(57).

EO 13834. *Efficient Federal Operations*, May 22, 2018, Federal Register, Vol. 83 (99).

EO 14008. Justice40 Initiative. EO 14008. Justice40 Initiative, *Tackling the Climate Crisis at Home and Abroad*, January 27, 2021, Federal Register, Vol. 86 (19).

EO 14057. EO 14057. *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, December 8, 2021, Federal Register, Vol. 86 (236).

EPA 1975. *National Primary Drinking Water Regulations*. December 24, 1975, 40 CFR Part 141, Subparts B and G. US Environmental Protection Agency, Washington, DC.

EPA 1978. *Terminology and Index*, "Categorical exclusion." November 29, 1978, 40 CFR Part 1508.4. US Environmental Protection Agency, Washington, DC.

EPA 1979. *Polychlorinated Biphenyls (PCBS) Manufacturing, Processing, Distribution in Commerce, And Use Prohibitions*. May 31, 1979, 40 CFR Part 761. US Environmental Protection Agency, Washington, DC.

EPA 1984. *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos," April 5, 1984, 40 CFR Part 61, Subpart M. US Environmental Protection Agency, Washington, DC.

EPA 1989. *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities.* 40 CFR Part 61.93(b)(1)(iii), Emission monitoring and test procedures; appendix B, Method 114, EPA 1989; updated Sept 9, 2002. US Environmental Protection Agency, Washington, DC.

EPA 1990. *National Emission Standards for Hazardous Air Pollutants*, Subpart M—National Emission Standard for Asbestos, Standard for demolition and renovation, Notification requirements. November 20, 1990, 40 CFR Part 61.145(b). US Environmental Protection Agency, Washington, DC.

EPA 1993. *Protection of Stratospheric Ozone*, Subpart F—Recycling and Emissions Reduction. May 14, 1993, 40 CFR Part 82, US Environmental Protection Agency, Washington, DC.

EPA 1994. *Chemical Accident Prevention Provisions*. January 31, 1994, 40 CFR Part 68. US Environmental Protection Agency, Washington, DC.

EPA 2009. *Mandatory Greenhouse Gas Reporting*. October 30, 2009, 40 CFR Part 98. US Environmental Protection Agency, Washington, DC.

ISO 2004. *Environmental management systems—Requirements with guidance for use*. ISO 14001:2004. November, International Organization for Standardization, Geneva, Switzerland.

K-25 Virtual Museum 2015. UCOR LLC, US Department of Energy, Oak Ridge, Tennessee. Retrieved April 19, 2023, from http://k-25virtualmuseum.org/.

Souza et al. 2001. Souza, Peter A., Glyn D. DuVall, and Melisa J. Hart, *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*. DOE/ORO/2085, US Department of Energy, Washington, DC.

TDEC 2017a. *Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys*, August 2018, DWR-PAS-P-01-QSSOP-081117, TDEC Division of Water Pollution Control, Nashville, Tennessee. Retrieved on April 20, 2023, at https://www.tn.gov/content/dam/tn/environment/water/documents/DWR-PAS-P-01-Quality_System_SOP_for_Macroinvertebrate_Stream_Surveys-081117.pdf.

TDEC 2017b. Construction and Operating Permits, Permits-by-Rule. TDEC Rule 1200-03-09-.07, August 2017 revised. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

TDEC 2018. *Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*. TDEC Rule 1200-03-11-.08, September 2018 revised (1996). Tennessee Department of Environment & Conservation, Nashville, Tennessee.

UCOR 2018. *Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge, Tennessee*. UCOR-4257/R2, September, URS | CH2M Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2020a. *Disposition of Personal Property.* PROC-PR-2032, Rev. 10, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2020b. *Radioactive Contamination Control and Monitoring.* PROC-RP-4516, Rev. 14, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2020c. *Environmental Management and Protection*. POL-UCOR-007, Rev. 7, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2022a. *Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee.* UCOR-4127/R10, February, UCOR LLC, Oak Ridge, Tennessee. (Available for public release by request.)

UCOR-2022b. *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee*, UCOR-4028/R13, July, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Available for public release.)

UCOR 2023. *2022 Cleanup Progress—Annual Report to the Oak Ridge Regional Community*. OREM-23-7632, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. Retrieved April 19, 2023, from https://www.energy.gov/sites/default/files/202301/Cleanup%20Progress%202022_FINAL.pdf.

Y-12 is a one-of-a-kind manufacturing complex that plays an important role in United States national security. Through Life Extension Program activities, Y-12 produces refurbished, replaced, and upgraded weapons components to modernize the enduring stockpile.

4

The Y-12 National Security Complex

Y-12, a premier manufacturing facility managed and operated by Consolidated Nuclear Security, LLC (CNS) for the National Nuclear Security Administration (NNSA), plays a vital role in the DOE Nuclear Security Enterprise. Drawing on more than 75 years of manufacturing excellence, Y-12 helps ensure a safe and reliable United States nuclear weapons deterrent.

Y-12's primary mission includes processing, retrieving, and storing nuclear materials; dismantling nuclear weapons; providing fuels for use in the nation's naval reactors; and performing work for other government and private sector entities.

Today's environment requires Y-12 to have a new level of flexibility and versatility; therefore, while continuing its key role, Y-12 has evolved to become the resource that the nation looks to for support in protecting America's future by developing innovative solutions in manufacturing technologies, prototyping, safeguards and security, technical computing, and environmental stewardship.

4.1. Description of Site and Operations

4.1.1. Mission

Charged with maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile, Y-12 is a one-of-a-kind manufacturing facility that has a core mission to ensure a safe, secure, and reliable nuclear deterrent. Every weapon in the nuclear stockpile has components manufactured, maintained, or ultimately dismantled by Y-12. Through Life Extension Program activities, Y-12 produces refurbished, replaced, and/or upgraded weapons components to modernize the enduring stockpile. As the nation reduces the size of its arsenal, Y-12 has a central role in decommissioning weapons systems and providing weapons material for nonexplosive, peaceful uses.

Y-12 secures and stores highly enriched uranium, and makes uranium available for non-weapon uses (e.g., in research reactors that produce cancer-fighting medical isotopes and for other research reactor purposes). Y-12 also processes highly enriched uranium from weapons removed from the nuclear weapons stockpile for use by the Naval Reactors Program to fuel nuclear-powered submarines and aircraft carriers.

Located within the city limits of Oak Ridge, Tennessee, the Y-12 site covers more than 3,024 acres including 810 acres in the Bear Creek Valley, stretching 4.0 km (2.5 mi) in length down the valley and nearly 2.4 km (1.5 mi) in width across it. Additional NNSA-related facilities are located off-site from Y-12 and include the Central Training Facility, Alternate Emergency Operations Center, Oak Ridge Enhanced Training & Technology Center (ORETTC), Uranium Processing Facility (UPF) project laydown storage and offices, Y-12 Material Acquisition and Control Facilities, John M. Googin Technology Development Center, Test and Demonstration Facility, Commerce Park Office Complex, and Union Valley Sample Preparation Facility.

4.1.2. Modernization

Y-12 directly supports four of the five NNSA Centers of Excellence, including uranium, lithium, weapons assembly and disassembly, and safe and secure storage of strategic materials. The Y-12 strategic vision is driven by the overarching objectives that, by 2040, Y-12 will be capable of reliably fabricating any component, building any weapon, and qualifying any system on any day, as well as executing a digital transformation strategy that enables smart, real-time, data-driven operations. Today, Y-12 is not well suited to deliver this type of responsive capability. Following the end of the Cold War, operations were scaled back, and many once-reliable processes have since atrophied.

The ability to deliver a nuclear weapon without reusing components from legacy weapons and relying heavily on aging infrastructure does not exist. Additionally, Y-12 faces a unique need to reestablish capabilities and two material streams—binary and special materials—associated with the Y-12 mission. A key component to reestablishing these capabilities is accelerated planning and execution of site infrastructure improvements, including the following:

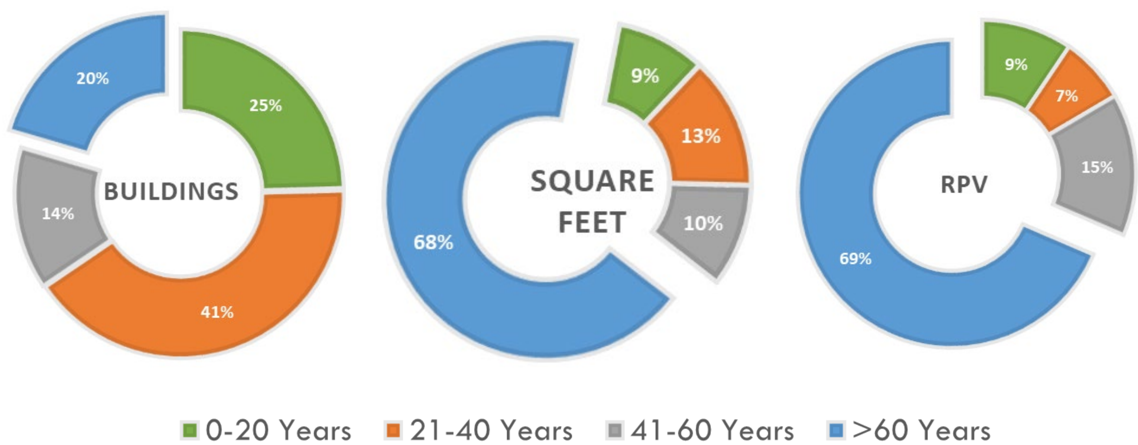
- New production facilities
- New capability and operational support facilities
- Capability bridging until new facilities are in place

Planning for the future site is designed to ensure that Y-12 will continue to provide the infrastructure needed to support the primary capabilities and materials missions with new facilities and associated technologies. In addition to new and revitalized facilities, the security posture will be strengthened by a reduced protected area footprint and revitalized security infrastructure and systems. The envisioned future Y-12 site includes the following elements:

- Major supply chains, including uranium (enriched uranium [EU], depleted uranium [DU]), and low enriched uranium) and lithium, are reestablished and/or transformed.
- The UPF, Lithium Processing Facility (LPF), Enriched Uranium Manufacturing Center, Assembly and Disassembly Center, and Depleted Uranium Manufacturing Capability are constructed.
- The security posture is sustained and improved through recapitalized and transformed footprint and security systems.
- The Mercury Treatment Facility and Environmental Management Disposal Facility are constructed, enabling approximately 2.8 million gross square feet of excess facility demolition and legacy environmental threats are remediated.
- Active participation in the Manhattan Project National Historic Park, which accommodates public tours for Y-12 historic facilities.

More than 50 percent of the Y-12 footprint is over 60 years old, as shown in Figure 4.1. To address this situation, Y-12 has been consolidating operations, modernizing facilities and infrastructure, and reducing the legacy footprint. These actions are consistent with and supportive of NNSA enterprise transformation planning. Through continued infrastructure projects, new construction, and the disposition of excess facilities, Y-12 will continue to strive toward becoming a more responsive, sustainable enterprise.

Replacement and revitalization are key elements to modernizing Y-12. A significant number of facilities are at or beyond design life. Currently, construction activities include the UPF, Fire Station, West End Protected Area Reduction (WEPAR) project, and soon the LPF.



***Acronym:** RPV = replacement plant value*

Figure 4.1. Age of facilities at Y-12, 2022

4.1.3. Production Operations

Y-12's core manufacturing and processing operations are housed in decades-old buildings near or past the end of their expected life spans. An integral part of Y-12's transformation, the UPF is being constructed as one of two main facilities at Y-12 in which EU will be stored and processed in a more centralized area.

The major production capabilities and associated facilities at Y-12 include the following:

- **EU:** Buildings 9212, 9215, and UPF (2027)
- **DU:** Buildings 9215, 9201-05N, 9201-05W, 9996, and 9998
- **Lithium:** Buildings 9204-02 and 9202
- **General manufacturing and fabrication:** Building 9201-01
- **Assembly and disassembly:** Building 9204-02E
- **Special materials:** Buildings 9225-03 (2025) and 9990-03 (2028)
- **Storage:** Buildings 9720-82, 9720-05, 9720-26, 9720-32, 9720-33, 9720-59, and 9811-01

The following major construction activities comprise the long-range vision for replacing key production operations from aging, oversized facilities:

- Building 9212 functions are to be replaced by the UPF in 2027, with some Building 9212 processes relocated to Buildings 9215 and 9204-2E.
- Building 9215 EU functions are to be replaced by the EU Manufacturing Center by 2050.
- Building 9204-02E functions are to be replaced by the Assembly and Disassembly Center by 2055.
- Building 9204-02 lithium functions are to be replaced by the LPF by 2031.
- DU and fabricating and manufacturing functions from the Building 9215 Complex, Building 9201-05N, Building 9201-05W, and Building 9201-01 are to be replaced by a phased approach line item construction, with the first phase—the Agile Rad Case and Component Capability—by 2035.

4.1.4. Support Facilities

Operations support infrastructure plays an integral role in ensuring Y-12 mission-critical work is completed. The primary missions of operations support infrastructure are to protect vital national security assets and people and enable site missions. These organizations and facilities provide the resources and infrastructure that support mission-critical production operations. Operations support facilities include the following categories:

- Security
- Emergency Services
- Development
- Analytical Chemistry
- General Storage and Warehousing
- Cybersecurity and Information Technology
- Global Security and Strategic Partnerships
- Waste Management
- Sustainability and Stewardship
- Oak Ridge Enhanced Technology and Training Center

The following major construction activities comprise the long-range vision for replacing key operations support facilities:

- Occupy the newly constructed Emergency Operations Center and Fire Station by 2023.
- Implement the WEPAR project and a new Entry Control Facility by 2025.
- Relocate some development functions from Buildings 9202 and 9203. Initially, the off-site 103 Palladium Way facility will be occupied in 2025 and then followed by phased line item construction, with the first phase—the Applied Technologies Laboratory—by 2035.
- Implement the Security Infrastructure Revitalization Program to replace the legacy Perimeter Intrusion Detection and Assessment System and secondary systems.
- Explore new construction for replacement facilities to support Analytical Chemistry operations, including phased line item construction, with the first phase—the Analytical Chemistry Laboratory—in 2037.
- Construct the Simulated Nuclear and Radiological Activities Facility at the new Oak Ridge Enhanced Technology and Training Center Strategic Partnership Program training campus.
- Construct a new Maintenance Complex through phased line item construction, with the first phase to replace the 78-year-old Building 9201-03 and other aging maintenance facilities.
- Construct a new Waste Management Complex to replace the aging West End Treatment Facilities.
- Implement a digital transformation and cybersecurity strategy.

- Refurbish existing facilities to accommodate a protected area security facility and construct a new Security Complex to accommodate growing requirements.

4.1.5. Excess Facility Disposition

Currently, 58 excess facilities at Y-12 and another 60 facilities are projected to be excessed within the next 10 years. The major excess process-contaminated facilities, including Building 9201-05, Building 9204-04, and Building 9206, will be transitioned to the DOE Office of Environmental Management (EM) for disposition. The smaller, process-contaminated, ancillary facilities associated with Buildings 9201-05, 9204-04, and 9206; Building 9212-associated facilities; and the Building 9401-03 (Steam Plant) Complex facilities are planned to be dispositioned by NNSA.

Process-contaminated facilities contain radiological and/or chemical contamination resulting from mission operations during the Manhattan Project or Cold War eras. Excess process-contaminated facilities are expected to be sufficiently managed until facility conditions meet criteria for transition to EM. Excess non-process-contaminated facilities are generally expected to be demolished by NNSA; however, some excess non-process-contaminated facilities may be demolished by EM depending on their complexity and/or proximity to process-contaminated facilities.

The Mercury Treatment Facility and the Environmental Management Disposal Facility will be constructed before any mercury-contaminated facilities can be demolished. Surveillance and maintenance activities, along with utility reroutes, unneeded material cleanout, and fluid and oil disposition, continue while the Mercury Treatment Facility and Environmental Management Disposal Facility are being constructed.

4.2. Environmental Management System

DOE Order 436.1, *Departmental Sustainability* (DOE 2011d), requires that federal facilities use a certified or conforming Environmental Management System (EMS) as a management framework to implement programs to meet sustainability goals and support the fulfillment of environmental compliance obligations. The DOE Order also requires that EMSs, covering all site activities, are certified to or conform to the International Organization for Standardization's (ISO) 14001, *Environmental Management Systems—Requirements with Guidance for Use* (ISO 2015).

In September 2021, the Y 12 EMS was declared to be in conformance with ISO 14001:2015. The audit team from the University of Tennessee Center for Industrial Services noted in the audit report that the Y-12 management and operating contract still requires the site to conform to the 2004 version of the ISO 14001 standard. The team audited the site to the revised 2015 version of the standard in anticipation that the requirement will change with the next Y-12 contract. The EMS applies to site activities and operations managed by CNS as described in Section 4.1. By design, the "plan-do-check-act" approach of the ISO 14001 standard improves environmental performance, which supports Y 12's overall mission effectiveness.

The Y-12 EMS has two areas of focus—environmental compliance and environmental sustainability. Environmental compliance consists of regulatory compliance and monitoring programs that implement federal, state, and local requirements, agreements, and permits. Environmental sustainability promotes and integrates initiatives such as energy and natural resource conservation, air pollutant emission minimization, waste minimization, and the use of sustainable products and services.

4.2.1. Integrating with Integrated Safety Management System

Y-12's Integrated Safety Management System (ISMS) is the basis for planning and implementing environment, safety, and health (ES&H) programs and systems that provide the necessary structure for any work activity that could affect the public, a worker, or the environment. At Y-12, the elements of the ISO 14001 EMS are incorporated in ISMS to achieve environmental compliance, pollution prevention, waste minimization, resource conservation, and sustainability. Both ISMS and EMS are based on an internationally recognized cycle of continual improvement, commonly known as the "plan-do-check-act cycle," as depicted in Figure 4.2, which shows the relationship between ISMS and the integrated EMS.

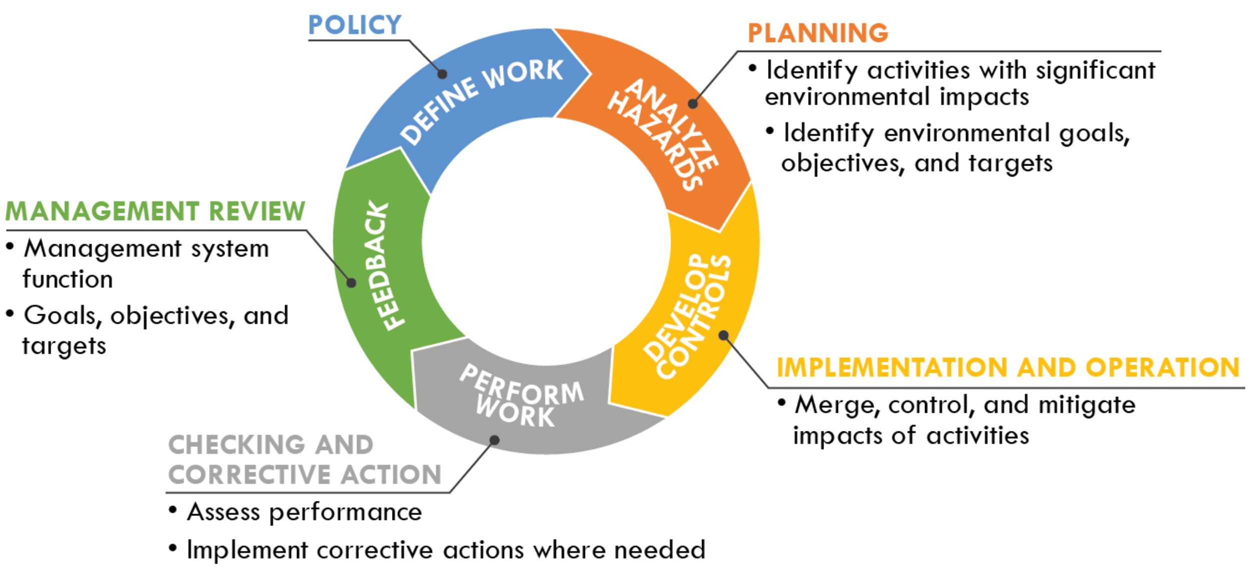


Figure 4.2. The Environmental Management System "plan-do-check-act" cycle of continual improvement

4.2.2. Policy

Y-12's environmental policy and commitment to providing sound environmental stewardship practices through the implementation of an EMS have been defined, are endorsed by top management, and have been made available to the public via company-sponsored forums and public documents. Y-12's ES&H policy is provided in Figure 4.3.

In addition to Y-12's ES&H policy, CNS has issued an environmental policy that is a significant component of the corporate ISMS and contributes to sustaining its imperatives of safe and secure operations. The Y-12 ES&H policy and the CNS environmental policy are communicated to and are incorporated into mandatory training for every employee and subcontractor. The policies are available for viewing on both Y-12's external and internal websites. Y-12 personnel are made aware of the commitments stated in the policies and how the commitments relate to Y-12 work activities. Communication of Y-12's environmental policy and other EMS training and awareness activities foster a greater understanding of environmental issues at all levels of the organization and empowers employees to contribute to improving Y-12's environmental footprint.

4.2.3. Planning

The following sections describe planning activities conducted as part of the Y-12 EMS.

4.2.3.1. Y-12 Environmental Aspects

Environmental aspects may be thought of as potential environmental hazards associated with a facility operation, maintenance job, or work activity. The environmental aspects and their impacts (i.e., potential risks to and effects on the environment) are evaluated to ensure that the significant aspects of Y-12 activities that are identified continue to reflect stakeholder concerns and changes in regulatory requirements. The EMS ensures that environmental aspects are systematically identified, monitored, and controlled to mitigate or eliminate potential impacts to the environment.

The analysis identified the following as significant environmental aspects in 2022:

- Storm water (runoff from roofs and outdoor storage areas)
- Surface water (process water and dike emissions to creek)
- Wastewater (sanitary sewer and process water treated and disposed)
- Radiological waste
- Excess facilities and unneeded materials and chemicals
- Aging infrastructure and equipment
- Legacy contamination and disturbance

Y-12 Environment, Safety, and Health Policy Statement

As we work to achieve the Y-12 mission and our vision of a modernized Y-12 Complex, we will do so by ensuring the safety and health of every worker, the public, and the environment. Every employee, contractor, and visitor is expected to take personal responsibility for their actions.

- Environmental Policy Statement: We protect the environment, prevent pollution, comply with applicable requirements, and continually improve our environment.
- Safety and Health Policy Statement: The safety and health of our workers and the protection of public health and safety are paramount in all that we do. We maintain a safe work place, and plan and conduct our work to ensure hazard prevention and control methods are in place and effective.

In support of these policies, we are committed to:

- Integrating environment, safety, and health into our business process.
- Continuously improving our process and systems.
- Directly, openly, and truthfully communicating this policy and our ES&H performance.
- Striving to minimize the impact of our operations on the environment in a safe, compliant, and cost-effective manner using sustainable practices.
- Incorporating sustainable design principles into the design and construction of facility upgrades, new facilities, and infrastructure, considering life-cycle costs and savings.
- Incorporating the use of engineering controls to reduce or eliminate hazards whenever possible into the design and construction of facility upgrades, new facilities, and infrastructure.
- Striving to provide a clean and efficient workplace free of occupational injuries and illnesses (Target Zero).
- Fostering and maintaining a work environment of mutual respect and teamwork that encourages free and operating expression of ES&H concerns.

Acronym:
ES&H = environment, safety, and health

Figure 4.3. Y-12's environment, safety, and health policy

4.2.3.2. Legal and Other Requirements

To implement the compliance commitments of the ES&H policy and to meet legal requirements, systems are in place to review changes in federal, state, or local environmental regulations and to communicate those changes to affected staff. The environmental compliance status is documented each year in this report (see Section 4.3).

4.2.3.3. Objectives, Targets, and Environmental Action Plans

CNS responds to change and pursues sustainability initiatives at Y-12 by establishing and maintaining environmental objectives, targets (goals), and action plans. Goals and commitments are established annually and consider Y-12's significant environmental aspects. They are consistent with Y-12's mission, budget guidance, ES&H work scope, and DOE sustainability goals. Targets and action plans are established for broad objectives to pursue improvement in environmental performance in five areas: clean air; energy efficiency; hazardous materials; stewardship of land and water resources; and waste reduction, recycling, and buying green. Highlights of the 2022 environmental targets achieved at Y-12 are presented in Section 4.2.6.1.

4.2.3.4. Programs

NNSA has developed and funded several important programs to integrate environmental stewardship into all facets of Y-12 missions. The programs also address the requirements in DOE orders for protecting various environmental media, reducing pollution, conserving resources, and helping to promote compliance with all applicable environmental regulatory requirements and permits.

Environmental Compliance

Y-12's Environmental Compliance Department provides environmental technical support services and oversees Y-12 line organizations to ensure that site operations are conducted in a manner that is protective of workers, the public, and the environment; in compliance with applicable standards, DOE orders, environmental laws, and regulations; and consistent with CNS environmental policy and Y-12 site procedures. The department serves as Y-12's interpretive authority for environmental compliance requirements and as the primary point of contact between Y-12 and external environmental compliance regulatory agencies such as the City of Oak Ridge, the Tennessee Department of Environment and Conservation (TDEC), and the EPA. Environmental Compliance staff members administer compliance programs aligned with the major environmental legislation that affects Y-12 activities. Compliance status and results of monitoring and measurements conducted for these compliance programs are presented in this document.

The organization also maintains and ensures implementation of the Y-12 EMS and spearheads initiatives to address environmental concerns, to continually improve environmental performance, and to exceed compliance requirements.

Waste Management

The Y-12 Waste Management Program supports the full life cycle of all waste streams within the site. While ensuring compliance with federal and state regulations, DOE orders, Waste Acceptance Criteria, and Y-12 procedures and policies, the program provides services for day-to-day solid and liquid waste operations, including collection and transport, storage, on-site treatment operations, and shipment to off-site treatment and disposal. The program also provides technical support to Y-12 Operations for waste planning, characterizing, packaging, tracking, reporting, and managing waste treatment and disposal subcontracts.

Sustainability and Stewardship

The Sustainability and Stewardship Program has two major missions. The first is to establish and maintain programs and services to support sustainable material management operations. These sustainable operations include pollution prevention and recycling programs, excess materials programs, the PrYde Program, generator services programs, sanitary waste and landfill coordination, and Destruction and Recycle Facility operations. Y-12 has implemented continuous improvement activities, such as an Items Available for Reuse section on the site Property Accountability Tracking System website and a central telephone number (574-JUNK) to provide employees with easy access to information and assistance related to the proper methods for disposing of excess materials.

The second mission is stewardship practices—the programs that manage legacy issues and assist in preventing development of new problematic issues. Stewardship programs include Clean Sweep, Unneeded Materials and Chemicals, and Targeted Excess Materials.

The Clean Sweep Program provides turnkey services to material generators, including segregation, staging, and pickup of materials for excess, recycle, and disposal. "Sustain" areas have been established across the site to improve housekeeping through efficient material disposition. Customers place unneeded items into the transition portion of each Sustain area, and Clean Sweep Program personnel take care of the rest.

Unneeded materials at Y-12 are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be used at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale; recycle; or, as a last resort, disposal as waste.

Combining these programs under a single umbrella improves overall compliance with Executive Orders, DOE orders, federal and state regulations, and NNSA expectations, as well as eliminates duplication of efforts, while providing an overall improved appearance at Y-12.

Additionally, implementing these programs supports EMS objectives and targets to disposition unneeded materials and chemicals; continually improves recycle programs by adding new recycle streams as applicable; improves sustainable acquisition (i.e., promotes the purchase of products made with recycled content and bio-based products); meets sustainable design requirements; and adheres to pollution prevention reporting requirements.

Energy Management

The Y-12 Energy Management Program incorporates energy efficient technologies across the site and positions Y-12 to meet NNSA energy requirement needs and reduction requirements as set forth by DOE. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, is involved with energy savings and performance contracts, and promotes employee awareness of energy conservation programs and opportunities.

4.2.4. Implementing and Operating

The following sections describe activities conducted as part of the Y-12 EMS to establish, implement, and maintain good environmental practices and procedures.

4.2.4.1. Roles, Responsibility, and Authority

Safe, secure, efficient, and environmentally responsible operation of Y-12 requires the commitment of all personnel. All personnel share the responsibility for day-to-day accomplishment of work and the environmentally responsible operation of Y-12.

Environmental and Waste Management technical support personnel assist line organizations with identifying and carrying out their environmental responsibilities. Additionally, the Environmental Officer Program facilitates communication of environmental regulatory requirements and promotes EMS as a tool to drive continual environmental improvement at Y-12. Environmental officers coordinate their organizations' efforts to maintain environmental regulatory compliance and promote other proactive improvement activities.

4.2.4.2. Community and Community Involvement

Y-12 is committed to keeping the community informed on operations, environmental concerns, safety, and emergency preparedness. The Community Relations Council, composed of more than 20 members from a cross section of the community, including environmental advocates, neighborhood residents, Y-12 retirees, and business and government leaders, facilitates communication between Y-12 and the community. The council provides feedback to Y-12 regarding its operations and ways to enhance community and public communications.

Local charities receive donations from funds raised by Y-12 employee aluminum beverage can recycling efforts. Since the program began in 1994, more than $94,600 raised by the collection of aluminum beverage cans has been donated to various local charities.

Y-12 continues to promote sustainable behaviors for environmental improvements at the site and within the community. A United Way Coat and Toiletries Drive is conducted annually to provide coats and other needed items for the Volunteer Ministry Center for the Homeless. These activities reflect Y-12 employees' commitment to reduce landfill waste and to support community outreach.

4.2.4.3. Environmental Justice

CNS endorses and implements the core value of environmental justice through charitable and educational outreach to disadvantaged communities that are located in the counties that surround the Y-12 site. These counties include Anderson, Blount, Knox, Morgan, Roane, Hamblen, and Loudon.

In 2022, the CNS Y-12 Community Investment Fund awarded grants totaling $100,000 to 30 nonprofits across East Tennessee. The fund is managed by the East Tennessee Foundation and directed by a committee that includes Y-12 employees.

CNS is also a major supporter of United Way of Anderson County and the United Way of Greater Knoxville, with corporate and employee contributions totaling hundreds of thousands of dollars.

CNS continued its efforts to build relationships with K-12 teachers, community colleges, and technical schools. CNS provided volunteers for classroom outreach and community service projects and also provided leaders who served on local committees, nonprofit boards, and area business and professional organizations. CNS continued to fund educational scholarships to residents of the Scarboro community, located in Oak Ridge. Introduce a Girl to Engineering drew attention from hundreds of young girls toward an engineering career with in-person events early in 2022.

Additional organizations that CNS supports through charitable and educational outreach include the following:

- Aid to Distressed Families of Appalachian Counties
- American Museum of Science and Energy
- Angel Tree
- Big Brothers Big Sisters
- Casting for Recovery
- Children's Museum of Oak Ridge
- Cold War Patriots
- Covenant Health
- East Tennessee Children's Hospital
- Emory Valley Center
- Free Medical Clinic
- Helen Ross McNabb Center
- Junior Achievement
- Oak Ridge Breakfast Rotary Club Foundation
- Leukemia & Lymphoma Society
- March of Dimes
- McNabb Center

- Methodist Medical Center of Oak Ridge
- Pull for Our Veterans
- Secret City Festival

4.2.4.4. Emergency Preparedness and Response

Local, state, and federal emergency response organizations are fully involved in Y-12's emergency drill and exercise program. The annual drill and exercise schedule is coordinated with all organizations to ensure maximum possible participation. At a minimum, the Tennessee Emergency Management Agency (TEMA) Operations Office and the DOE Headquarters Watch Office participate in all Y-12 emergency response exercises.

The exercises, performance drills, and training drills conducted at Y-12 during FY 2022 focused on topics such as responding to an active assailant, radiological fire and release, chemical release, and a response to a criticality event. Building evacuation and accountability drills were also conducted.

4.2.5. Checking

The following sections describe activities conducted as part of the Y-12 EMS to review, assess, and monitor operations to maintain environmentally safe and compliant practices and continually improve environmental performance.

4.2.5.1. Monitoring and Measuring

Y-12 maintains procedures to monitor overall environmental performance and to monitor and measure key characteristics of its operations and activities that can have a significant environmental impact. Environmental effluent and surveillance monitoring programs are well established, and results of 2022 program activities are described throughout this chapter. Progress in achieving environmental goals is reported as a monthly metric on PerformanceTrack, the senior management web portal that consolidates and maintains Y-12 site-level performance. Progress is reviewed in periodic meetings with senior management and the NNSA Production Office (NPO).

4.2.5.2. Environmental Management System Assessments

To periodically verify that EMS is operating as intended, assessments are conducted as part of the Y-12 internal assessment program. The assessments are designed to ensure that nonconformities with ISO 14001 are identified and addressed.

The Environmental Assessment Program conducts several types of assessments, each type serving a distinct but complementary purpose. Assessments range from informal observations of specific activities to rigorous audits of site-level programs.

To self-declare conformance to ISO 14001 in accordance with instructions issued by the Federal Environmental Executive and to adhere to DOE Order 436.1A, *Departmental Sustainability* (DOE 2023a), requirements, EMS must be audited at least every 3 years by a qualified party outside of the control or scope of EMS. To fulfill this requirement, a four-person audit team from The University of Tennessee Center for Industrial Services evaluated Y-12's EMS during September 2021. The Y-12 EMS was found to fully conform, and no issues were identified. The next external verification audit is scheduled for summer 2024.

4.2.6. Performance

This section discusses EMS objectives, targets, other plans, initiatives, and successes that work together to accomplish DOE goals, reduce environmental impacts and risks, and improve effectiveness in overall mission. Y-12 uses DOE reporting systems, including the following, to report performance:

- The Federal Automotive Statistical Tool, which collects fleet inventory and fuel use.
- The DOE Sustainability Dashboard, which collects data on metering requirements, water use, renewable energy generation and purchases, greenhouse gas (GHG) generation,

and sustainable buildings. Pollution prevention waste reduction and recycling data, sustainable acquisition product purchases, electronic stewardship, and best practices data are also collected in this dashboard system.

Y-12 was given an EMS scorecard rating for FY 2022 of "green," indicating full and effective implementation of EMS requirements after submitting its DOE 2022 EMS compliance report via the DOE EMS Site Information Database.

4.2.6.1. Environmental Management System Objectives and Targets

At the end of 2022, Y-12 had achieved six of 11 targets that had been established; the remaining targets were carried into future years. Highlights include the following, with additional details and successes presented in other sections of this report:

- **Clean air:** Y-12 completed a project to seal the Stack 11 basin and identified improved mission operations and improvements to air emissions.
- **Energy efficiency:** Y-12 completed a project to upgrade power lines to 13.8-kV service on Second and Third Street., as well as projects to upgrade cooling towers and heating, ventilation, and air conditioning systems in two areas.
- **Hazardous materials:** A project to disposition and ship legacy mixed waste according to the site treatment plan continued, and 50 items were shipped in FY 2022 to meet plan milestones. Unneeded materials and equipment were dispositioned from Building 9998 and two tanker trailers in FY 2022. Y-12 improved waste characterization processes and implemented real-time radiography to improve control and management of low-level radioactive waste.
- **Land, water, and natural resources:** Y-12 completed upgrading sanitary sewer networks in two areas as part of a project to protect the sanitary sewer lines from infill and infiltration. Y-12 also completed assessments on 34 aboveground inactive tanks and dikes in FY 2022.

4.2.6.2. Sustainability and Stewardship

Numerous efforts, including increased use of environmentally friendly products and processes and reductions in waste and emissions, have reduced Y-12's impact on the environment. During the past few years, these efforts have been recognized by NNSA, the community, and other stakeholders. Pollution prevention efforts at Y-12 have not only benefited the environment but have also resulted in cost efficiencies (Figure 4.4).

In FY 2022, Y-12 implemented 107 pollution prevention initiatives (Figure 4.5), with a reduction of more than 11.3 million lb of waste and projected cost efficiencies of more than $2.5 million. The completed projects include the activities described below.

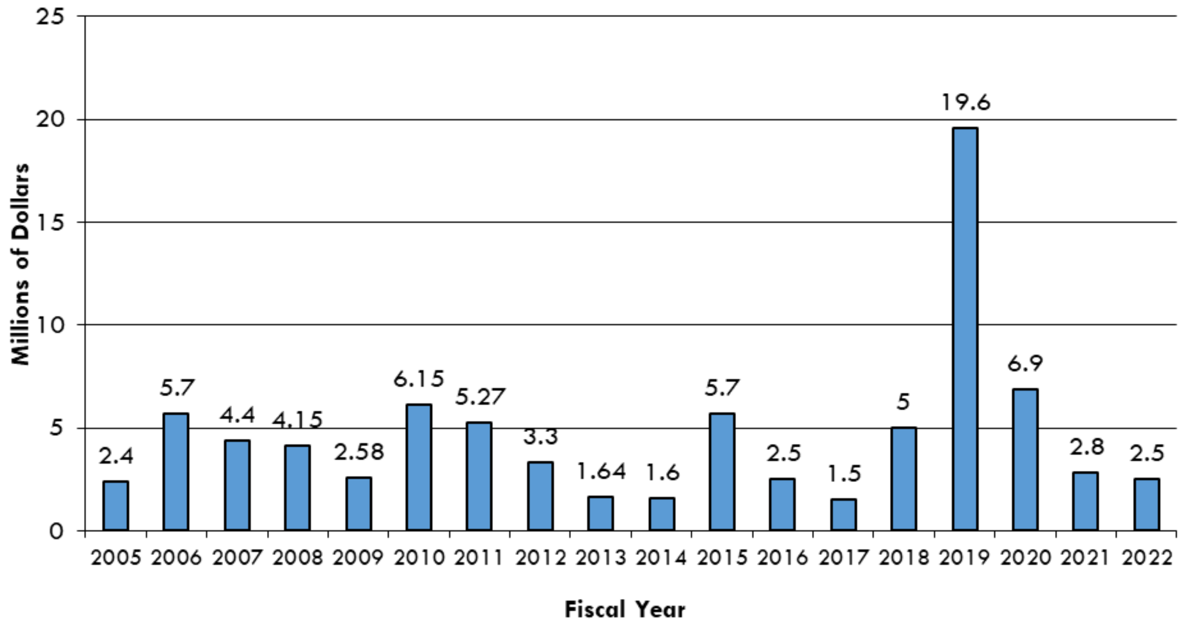


Figure 4.4. Cost efficiencies from Y-12 pollution prevention activities, 2005–2022

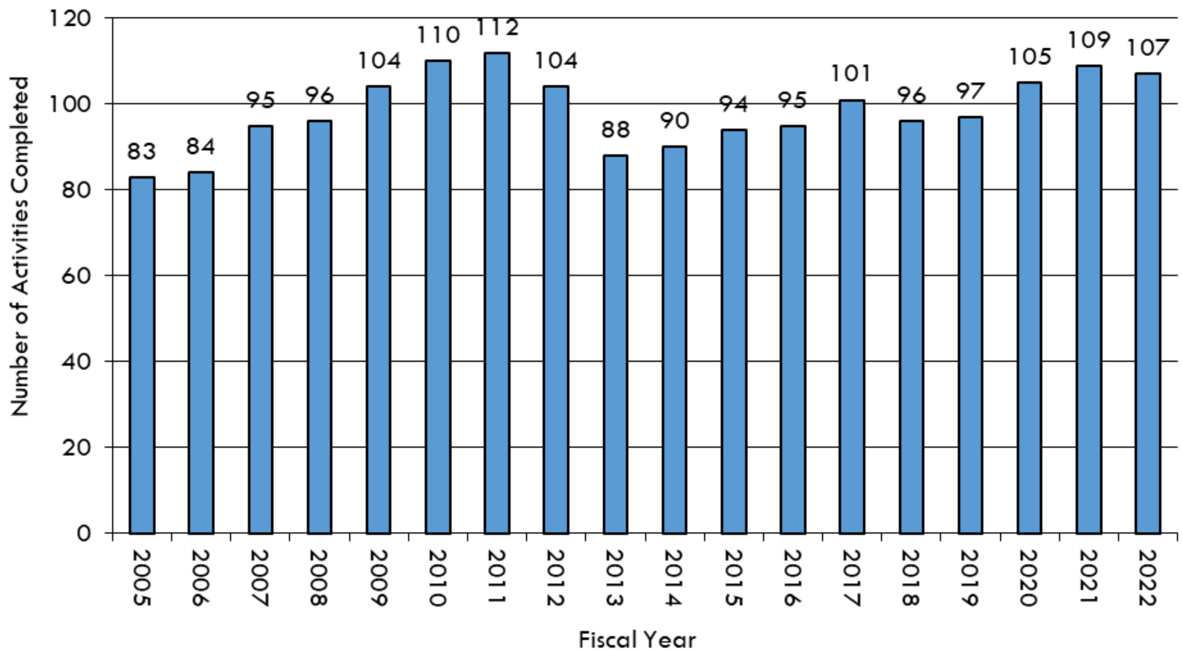


Figure 4.5. Y-12 pollution prevention initiatives, 2005–2022

Pollution Prevention and Source Reduction

Across Y-12, sustainable initiatives have been embraced to reduce the impact of pollution on the environment and to increase operational efficiency. Many of Y-12's sustainable initiatives have pollution prevention benefits or targets eliminating the source of pollution, including the 2022 activities highlighted in this section.

Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled content materials, are procured for use across Y-12. In 2022, Y-12 procured recycled content materials valued at more than $6.28 million for use at the site.

Solid Waste Reduction

Y-12 strives to minimize the generation of solid waste with a focus on waste diversion through source reduction, reuse and recycling. In 2022, Y-12 diverted 55.8 percent of municipal and 7.5 percent of construction and demolition waste from landfill disposal through reuse and recycle. Y-12 diverted more than 3.6 million lb of municipal materials from landfill disposal through source reduction, reuse, and recycling in FY 2022. More than 4.7 million lb of construction and demolition materials were diverted from landfill disposal.

Hazardous Chemical Minimization

Generator Services Group provides material disposition management services for generators at Y-12, which includes technical support to assist generators with determining whether the materials can be recycled, excessed, or reused rather than determining all materials received must be declared as a waste. Generator Services Group can be used by any organization or generator at Y-12. During FY 2022, Generator Services Group personnel reused, or disseminated to other Y-12 organizations for reuse, more than 5,600 lb of various excess materials and chemicals. In FY 2022, Legacy Facilities produced more than 1,545 gallons of hypochlorous acid, a safe, environmentally friendly, sustainable, and effective disinfectant on-site. Site-produced hypochlorous acid has reduced the amount of commercial disinfectants purchased to support COVID-19 prevention and response measures. Refillable containers are used to reduce the associated packaging waste materials from disinfectants.

Recycling

Y-12 has a well-established recycling program. The site continues to identify new material streams and expand the types of materials that can be recycled by finding new markets and outlets for the materials. As shown in Figure 4.6, more than 4.8 million lb of materials were diverted from landfills and into viable recycle processes during 2022. Currently, recycled materials range from office-related materials to operations-related materials, such as scrap metal, tires, and batteries. Y-12 adds at least one new recycle stream to the Recycle Program each year to continue to increase the waste diversion rate. The Recycle Program was expanded in FY 2022 to include hard hats to broaden waste diversion efforts.

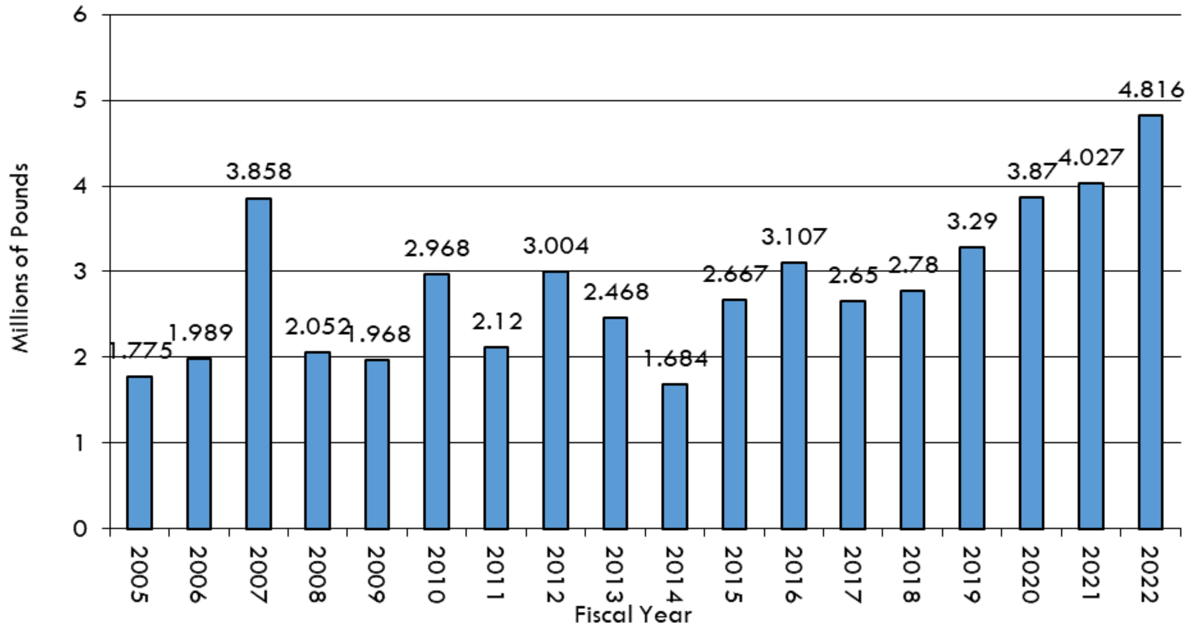
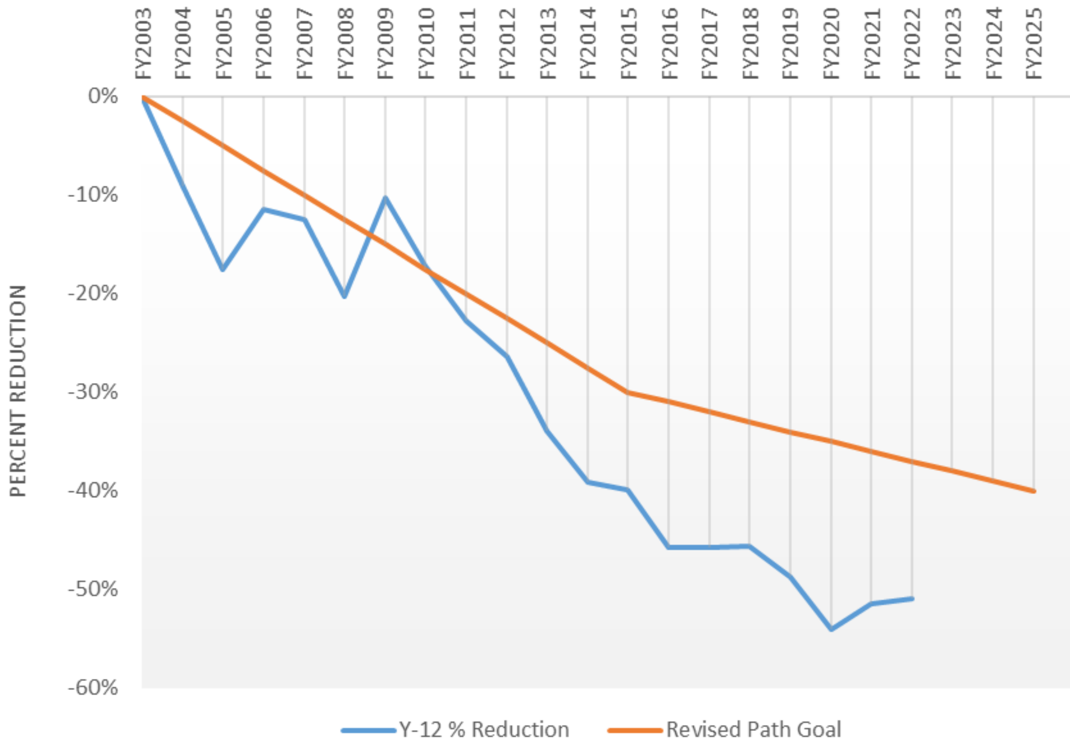


Figure 4.6. Y-12 recycling results, 2005–2022

4.2.6.3. Energy Management

Energy management activities are performed within the Energy Sustainability organization. Energy usage and intensity, Energy Independence and Security Act of 2007 (EISA) benchmarking and evaluations, facility metering/monitoring in accordance with the Energy Act of 2020, and non-fleet vehicles and equipment are components of energy-management reporting activities.

Y-12 exceeded the goal of meeting a 30 percent energy intensity (Btu per gross square foot) reduction in goal-subject buildings by FY 2015 from a FY 2003 baseline and 1 percent year-to-year reduction thereafter. During FY 2022 energy intensity was 205,343 Btu/gsf, which is a full 1.1 percent above the prior year (203,085 Btu/gsf). The upward trend in the site energy intensity figures is largely attributed to the height of the pandemic occurring during FY 2020 and then having a larger portion of the plant population returning to the site, thus increasing infrastructure use. Energy intensity reductions since FY 2018 will be further analyzed, and it is anticipated that FY 2020 and FY 2021 will be determined to be an anomaly. Compared to the FY 2003 baseline year, Y-12 has seen an energy intensity reduction of 50.93 percent as of FY 2022. Energy intensity through 2022 is shown in Figure 4.7.



Acronym: *FY = fiscal year*

Figure 4.7. Y-12 energy intensity versus baseline goal

4.2.6.4. Sustainable Goals and Performance

DOE is required to meet sustainability goals mandated by statute and related Executive Orders, including goals for GHG emissions, energy and water use, fleet optimization, green buildings, and renewable energy. In 2022, the DOE Sustainability Performance Office used its web-based Sustainability Dashboard to collect and consolidate sustainability data from all DOE sites. The Sustainability Dashboard focuses on specific sustainability goals established by the office, and site sustainability plans are completed within the dashboard. These goals, along with the current Y-12 performance ratings, are listed in Table 4.1.

Table 4.1. Fiscal year 2022 sustainability goals and performance

DOE Goal	Current Status
Energy Management	
Reduce energy use intensity (Btu per gross square foot) in goal-subject buildings.	Goal Met: Y-12 exceeded the reduction in energy intensity for goal-subject facilities by 25% by FY 2025 relative to FY 2015 baseline.
EISA Section 432 continuous (4-year cycle) energy and water evaluations.	Goal Met: Y-12 conducts EISA evaluations on a continuous 4-year cycle.
Meter individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	Goal Not Met: Y-12 meters all utilities; however, not all appropriate buildings are currently metered.
Water Management	
Reduce potable water use intensity (Gal per gross square foot).	Goal Met: Y-12 exceeded the goal of reduction in water intensity by 36% by FY 2025 relative to FY 2007.
Reduce non-potable freshwater consumption (gal) for industrial, landscaping, and agricultural.	Goal Not Applicable. Y-12 does not use industrial, landscaping, and agricultural water.
Waste Management	
Reduce nonhazardous solid waste sent to treatment and disposal facilities.	Goal Met: 55.8% (1,626.9 metric tons/2,913.1 metric tons) of nonhazardous waste diverted from the landfill.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities.	Goal Not Met: 7.5% (2,164.9 metric tons/28,888 metric tons) of C/D materials were diverted from the landfill in FY 2022.
Fleet Management	
Reduce petroleum consumption.	Goal Not Met: Y-12 did not meet the interim target of 20% reduction in fleet petroleum consumption. There was a 9% increase from the FY 2005 baseline.
Increase alternative fuel consumption.	Goal Not Applicable: Y-12 does not have access to alternative fuels.
Acquire alternative fuel and electric vehicles.	Goal Met: Y-12 replaced 11 fleet vehicles with zero emission vehicles during FY 2022 and installed electric vehicle charging stations on-site.
Clean & Renewable Energy	
Increase consumption of clean and renewable electric energy.	Goal Met: Y-12 has exceeded the interim target and retains 15% renewable energy as a percentage of overall facility electric and thermal energy use.
Increase consumption of clean and renewable non-electric thermal energy.	Goal Not Met: Y-12 had a 1% decrease in natural gas use for FY 2022.
Sustainable Buildings	
Increase the number of owned buildings that are compliant with the Guiding Principles for Sustainable Buildings.	Goal Met: Two buildings were certified as High Performance Sustainable Buildings in FY 2022.

Table 4.1. Fiscal year 2022 sustainability goals and performance (continued)

DOE Goal	Current Status
Acquisition & Procurement	
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate.	Goal Met: All eligible contracts after Oct. 1, 2013, contain the sustainable acquisition requirements. The CNS Sustainable Acquisition Program plans to work with Contracts and Procurement to review the current $150,000 contract threshold sustainable acquisition requirements to be included in subcontract languages so that future appropriate contracts will have the requirements to purchase sustainably.
Efficiency & Conservation Measure Investments	
Implement life cycle cost-effective efficiency and conservation measures with appropriated funds and/or performance contracts.	Goal Met: Y-12 has supported performance contracts issued by NNSA. These contracts have been instrumental in achieving energy, water, building modernization, and infrastructure goals at Y-12.
Electronic Stewardship & Data Centers	
Electronics stewardship from acquisition, operations, to end of life.	Goal Met: Y-12 met the goal of purchasing 95% of eligible electronics as Electronic Product Environmental Assessment Tool registered products. Y-12 also power manages all mission-critical electronics and has increased the automatic duplexing to 92.9%. Y-12's electronics recycling vendor maintained R2 certification; therefore, all FY 2022 shipments were made to a R2 certified recycler. Electronics that were not recycled were electronics that could not be radiologically cleared for release. Therefore, 100% of eligible electronics were recycled to a R2 certified recycler or were donated for reuse.
Increase energy and water efficiency in high performance computing and data centers.	Goal Not Met: Y-12 data centers are not fully metered and estimates the current power usage effectiveness to be 2.4. However, as the site moves to modernized data centers, the overall energy and water efficiencies will continue to increase.
Adaptation & Resilience	
Implement climate adaptation and resilience measures.	Goal Met: Y-12 has issued a severe event emergency response plan that addresses severe natural phenomena events, extended loss of power events, and events that result in the loss of mutual aid. Additionally, the site submitted a vulnerability assessment and resilience plan, along with identified resilience solutions, that included increasing on-site renewable energy generation; solar powered equipment; new facilities; roof repairs and replacement; chiller upgrades; and heating, ventilation, and air conditioning system repairs and replacements.

Table 4.1. Fiscal year 2022 sustainability goals and performance (continued)

Multiple Categories	
Reduce Scope 1 and 2 greenhouse gas emissions.	Goal Met: Site Scope 1 and 2 emissions were reduced by 72.9% from the FY 2008 baseline, nearly doubling the interim target. Most of this can be attributed to the improvements to infrastructure through energy savings performance contract projects.
Reduce Scope 3 greenhouse gas emissions.	Goal Not Met: Site Scope 3 emissions increased by 2.4% from FY 2021 (43,142.8 $MtCO_2e$) to FY 2022 (42,106.3 $MtCO_2e$). Overall Scope 3 emissions have increased by 32% since the FY 2008 baseline (31,894.5 $MtCO_2e$). The decrease in Scope 3 emissions in FY 2022 is primarily due to ongoing telework activities.

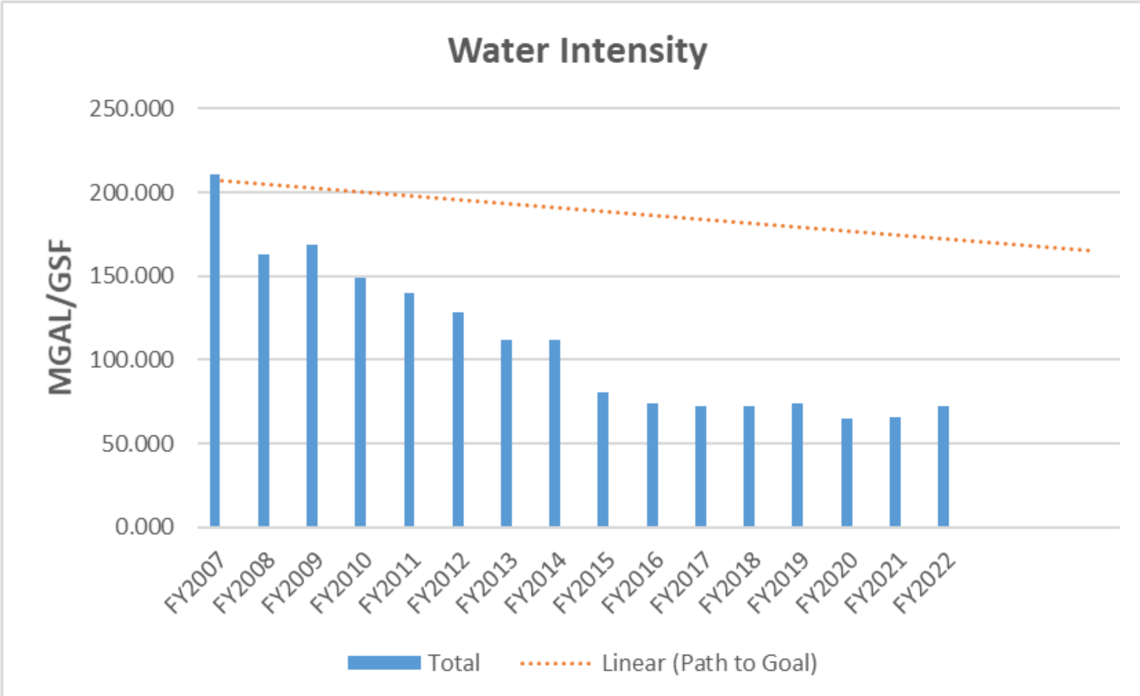
Acronyms:
CNS = Consolidated Nuclear Security
EISA = Energy Independence and Security Act
FY = fiscal year
NNSA = National Nuclear Security Administration

4.2.6.5. Water Management

The current DOE water intensity goal is a 20 percent reduction from a FY 2007 baseline by FY 2015 and year-to-year reductions of 0.5 percent thereafter. In FY 2022, Y-12's water intensity rating was 72.070 gallons per square foot, which is a 9.36 percent decrease from the previous year and a 65.81 percent reduction from the 2007 baseline. In FY 2021, Y-12's water intensity rating was 65.323 gallons per square foot which is a 0.5 percent increase from the previous year and a 69.01 percent reduction from the 2007 baseline. This increase can be attributed to the unforeseen effects that COVID-19 had on the workforce and operations at Y-12 but also to the gradual return of the workforce to the site. The Y-12 telework policy ended most teleworking opportunities earlier this year, bringing back most personnel to the site. Comparing water intensity of FY 2022 to pre-COVID impacts in FY 2019, the reduction is 2.44 percent, which is more indicative of the expected trend for water usage for Y-12. An overview of water intensity performance is shown in Figure 4.8.

Actions that have contributed to the overall reduction in potable water use include:

- Steam trap repairs and improvements
- Condensate return installations, repairs, and reroutes
- Replacement of once-through air handling units
- Low-flow fixture installation
- Chiller replacements
- Cooling tower replacements
- Steam replacements to natural gas when possible



Acronyms:
FY = fiscal year
GSF = gross square feet
Mgal = millions of gallons

Figure 4.8. Water intensity graph from baseline 2007 through FY 2022

Internal EISA audits are conducted on covered facilities on a 4-year rotating schedule. Additionally, in FY 2016, the Pacific Northwest National Lab conducted a water assessment of the Y-12 site through the Federal Energy Management Program. These assessments have identified a number of water conservation projects that could be implemented should funding be allocated. These projects include domestic plumbing retrofits, kitchen equipment upgrades, process system upgrades, cooling tower upgrades, and steam plant upgrades. Continued reductions in water usage will be incorporated into ongoing facility repairs and renovations as funding becomes available. These efforts include:

- Upgrading toilets and urinals to low-flow, hands-free units
- Installing flow restrictors on faucets and shower heads
- Repairing condenser loop connections so all condenser water is returned to the cooling towers
- Replacing existing once-through water-cooled air conditioning system with air-cooled equivalents
- Installing advanced potable water meters

4.2.6.6. Fleet Management

There are 643 vehicles in Y-12 fleet inventory, including 135 Agency-owned units, 496 leased from General Services Administration (GSA), and 12 commercially leased special purpose vehicles. The inventory consists of sedans; light-duty trucks, vans, and sport utility vehicles; medium-duty trucks, vans, and sport utility vehicles; and heavy-duty trucks such as road tractors, dump trucks, box trucks, flatbeds, wreckers, and service trucks.

During FY 2022, Y-12 exchanged 28 older GSA-leased vehicles with new units. The new GSA replacements were all ordered with alternative fuel or zero emission capabilities when available, and these new vehicles have better fuel consumption and GHG emission figures than the older vehicles that were replaced. Vehicle availability (replacements as well as additions) was a struggle during FY 2022 because less than 19 percent of the GSA vehicle replacement order was actually filled. Normally, the vast majority of those replacement orders that are placed with GSA in the December timeframe will be delivered by the end of the fiscal year in September, but manufacturer shortages had a major impact in the vehicles that actually were delivered.

The Y-12 taxi service was increased again in FY 2022 with an additional 15-passenger van, making transportation more accessible for the more than 6,500 employees. This service also helps reduce the number of overall vehicles needed, fuel consumption, and GHG emissions. The taxi service is an important asset to the overall transportation needs of the Y-12 workforce.

The Y-12 vehicle fleet achieved a 97.3 percent vehicle utilization rate for FY 2022 compared to 98.7 percent in FY 2021. Of those 17 vehicles that failed utilization, 10 achieved 80 percent or greater utilization scores. Vehicle reassignments were made multiple times throughout the year to help meet those utilization goals.

FY 2022 fuel consumption at Y-12 (diesel and gasoline) decreased by 14 percent compared with FY 2021, while miles traveled for those same vehicles was down by 16.9 percent compared to the previous year.

Y-12 continues to use a mobile fuel tanker to dispense gasoline and diesel for vehicles at the site because there is still not a new fuel station, although plans are in place to once again to build one just southwest of the existing Y-12 garage at the east end of the plant. Y-12 does not use alternative fuel (E85) because it is not available in the area, and an Epact 701 waiver (5 miles or 15 minutes away) for FY 2022 was granted to Y-12 as a result of this situation.

4.2.6.7. Electronic Stewardship

Y-12 has implemented various electronic stewardship activities, including virtualizing servers, creating virtual desktop infrastructure, procuring energy efficient computing equipment, reusing and recycling computing equipment, replacing aging computing equipment with more energy efficient equipment, and reconfiguring data centers to achieve more energy efficient operations. All of the desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2022 were registered Electronic Product Environmental Assessment Tool products. Y-12's standard desktop configuration specifies the procurement of Electronic Product Environmental Assessment Tool registered and Energy Star-qualified products.

4.2.6.8. Greenhouse Gases

Compared to the FY 2008 baseline, Y-12 Scope 1 and Scope 2 GHG emissions have been reduced. Emission reductions can be attributed primarily to decreased Scope 1 (on-site fuel burning) emissions from more efficient steam generation and decreased Scope 2 (purchased electricity) emissions from energy efficiency projects.

Purchased electricity is by far the biggest contributor to Y-12's GHG footprint. Energy reduction efforts include major initiatives involving production facilities and utility infrastructure completed through energy savings performance contract projects.

4.2.6.9. Storm Water Management and the Energy Independence and Security Act of 2007

The EISA of 2007, Section 438, requires federal agencies to reduce storm water runoff from development and redevelopment projects to protect water resources. Y-12 complies with these requirements by using a variety of storm water management practices, often referred to as green infrastructure or low impact development practices. During the last few years, several green infrastructure initiatives have been implemented to reduce the size and number of impervious surfaces through the use of sustainable vegetative practices and porous pavements. During 2022, the projects building the new Emergency Operation Center and Fire Station contributed to the overall prevention of storm water runoff by installing bioretention infiltration areas on the project sites.

4.3. Compliance Status

During 2022, Y-12 operations were conducted to comply with contractual and regulatory environmental requirements. Table 4.2 presents a summary of environmental audits conducted at Y-12 in 2022. The following discussions summarize the major environmental programs and activities carried out at Y-12 and provide an overview of the compliance status for the year.

4.3.1. Environmental Permits

Table 4.3 lists environmental permits in force at Y-12 during 2022. More detailed information can be found in the following sections.

Table 4.2. Summary of external regulatory audits and reviews, 2022

Date	Reviewer	Subject
February 15	TDEC	Quarterly ORR Landfill inspection ILF-V and CDL-VII
February 23	TDEC	Annual RCRA Hazardous Waste Compliance Inspection (ORR Landfill)
February 23-24	TDEC	Annual RCRA Hazardous Waste Compliance Inspection
March 11	TDEC	Quarterly ORR Landfill inspection
March 16	City of Oak Ridge	Industrial and Commercial User Wastewater Discharge Permit Inspection
March 23	TDEC	Annual Air Quality Inspection
March 24	TDEC	Quarterly ORR Landfill inspection ILF-IV
May 5	TDEC	Quarterly ORR Landfill inspection ILF-IV, ILF-V and CDL-VII and first Semi-annual inspection of Post Closure ILF-II
August 2	City of Oak Ridge	Industrial and Commercial User Wastewater Discharge Permit Inspection
August 4	TDEC	Minor Permit Modification approval ILF-V, Area 5 Buildout Design
August 9	TDEC	Quarterly ORR Landfill inspection ILF-V and CDL-VII
August 24	TDEC	Quarterly ORR Landfill inspection of ILF-IV and second Semi-annual Inspection of Closed ILF-II
August 31	TDEC	Minor Permit Modification approval CDL-VII, Seep Repairs
November 22	TDEC	Quarterly ORR Landfill inspection of ILF-V and CDL-VII
December 1	TDEC	Quarterly ORR Landfill inspection of ILF-IV

Acronyms:
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

Table 4.3. Y-12 environmental permits, CY 2022

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit	571832	12/01/17	11/30/22[a]	DOE	DOE	CNS
CWA	Industrial and Commercial User Wastewater Discharge (Sanitary Sewer) Permit	1-91	07/20/21	03/31/26	DOE	DOE	CNS
CWA	NPDES Permit	TN0002968	08/05/22	09/30/27[b]	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 (41.7 ha/103 acres)	TNR 134022	10/27/11	09/30/26	DOE	CNS	CNS
CWA	UPF NPDES General Permit for Construction Storm Water	TNR135568	08/06/18	09/30/26	DOE	BNI	BNI
CWA	Central Training Facility Berm Reinvestment Project NPDES Construction General Permit	TNR 135924	10/01/19	09/30/26	DOE	DOE	CNS
CWA	UCOR ILF-II General Storm Water Permit Y-12 (8.2 acres)	TNR 136478	08/03/21	Upon Notice of Termination	DOE	UCOR	UCOR
CWA	Y-12 Outfall 014 Repair Aquatic Resource Alteration Permit	NR1903.116	06/21/19	04/05/25	DOE	DOE	CNS
CWA	Central Training Facility Berm Aquatic Resource Alteration Permit	NR1903.096	05/15/19	04/05/25	DOE	DOE	CNS
CWA	Security Infrastructure Revitalization Program NPDES General Construction Permit	TNR 136604	11/30/21	Upon Notice of Termination	DOE	DOE	CNS
CWA	No Discharge Portal 20 Pump and Haul Permit	SOP-170-14	06/24/22	06/30/27	DOE	DOE	CNS
CWA	No Discharge Portal 23 Pump and Haul Permit	SOP-170-15	06/20/22	07/30/27	DOE	DOE	CNS
CWA	No Discharge Portal 19 Pump and Haul Permit	SOP-13031	06/26/18	06/30/23	DOE	DOE	CNS
CWA	No Discharge Environmental Management Waste Management Facility Pump and Haul Permit	SOP-01043	09/01/22	08/31/27	DOE	UCOR	UCOR
CWA	Simulated Nuclear and Radiological Activities Facility Aquatic Resource Alteration Permit	NR2003.249	01/14/21	Upon Notice of Termination	DOE	DOE	CNS
CWA	Simulated Nuclear and Radiological Activities Facility NPDES General Construction Permit	TNR136307	04/26/21	09/30/26	DOE	DOE	CNS
CWA	Y-12 Operations Center NPDES General Construction Permit	TNR136305	01/14/21	09/30/26	DOE	DOE	CNS
CWA	Y-12 Fire Station NPDES General Construction Permit	TNR136350	03/14/21	09/30/26	DOE	DOE	CNS

Table 4.3. Y-12 environmental permits, CY 2022 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CWA	West End Protected Area Reduction NPDES General Construction Permit	TNR136382	04/26/21	09/30/26	DOE	DOE	CNS
CWA	Monitoring Station 8 and Outfalls 051 and 099 Access Improvements Aquatic Resource Alteration Permit	NR2103.288	11/08/21	04/07/25	DOE	DOE	CNS
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/05/22	01/31/24	DOE	DOE	CNS
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	09/15/15	09/15/25	DOE	DOE, NNSA, and all ORR co-operators of hazardous waste permits	UCOR
RCRA	Hazardous Waste Container Storage Units	TNHW-184	03/05/21	03/05/31	DOE	DOE/CNS	CNS/LATS co-operator
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-127	10/06/05	10/06/15[c]	DOE	DOE/CNS	CNS co-operator
Solid Waste	Industrial Landfill IV (operating, Class II)	IDL-01-000-0075	Permitted in 1988—most recent modification approved 06/20/19	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill V (operating, Class II)	IDL-01-000-0083	Permitted in 1993—most recent modification approved 08/04/22	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill (overfilled, Class IV subject to CERCLA Record of Decision)	DML-01-000-0012	Initial permit 01/15/86	N/A	DOE	DOE/UCOR	UCOR

Table 4.3. Y-12 environmental permits, CY 2022 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
Solid Waste	Construction and Demolition Landfill VI (post-closure care and maintenance)	DML-01-000-0036	Permit terminated by TDEC 03/15/07	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VII (operating, Class IV)	DML-01-000-0045	Permitted in 1993—most recent modification approved 08/31/22	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Centralized Industrial Landfill II (post-closure care and maintenance)	IDL-01-000-0189	Most recent modification approved 05/08/92	N/A	DOE	DOE/UCOR	UCOR
SDWA	Underground Injection Control Class V Injection Well Permit	Permit by Rule, TDEC Rule 0400-45-06 AND-00041	N/A	N/A	DOE	DOE	CNS

[a] *The Title V air permit renewal is still in the review process by TDEC.*
[b] *Some aspects of the current NPDES permit are currently under appeal by NNSA.*
[c] *Continue to operate in compliance pending TDEC action on renewal and reissuance.*

Acronyms:
BNI = Bechtel National Inc.
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security, LLC
CWA = Clean Water Act
DOE = US Department of Energy
LATS = LATA-Atkins Technical Services, LLC
N/A = not applicable
NNSA = National Nuclear Security Administration
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
SDWA = Safe Drinking Water Act
TDEC = Tennessee Department of Environment and Conservation
UCOR = URS|CH2M Oak Ridge LLC (prior to May 2022) or United Cleanup Oak Ridge (after May 2022)
UPF = Uranium Processing Facility
Y-12 = Y-12 National Security Complex

4.3.2. National Environmental Policy Act

As federal agencies, DOE and NNSA comply with National Environmental Policy Act (NEPA) requirements (procedural provisions, 40 *Code of Federal Regulations* [CFR] Parts 1500 through 1508), as outlined in DOE's NEPA Implementing Procedures (10 CFR 1021). NEPA requires that all federal actions go through a review process that identifies any environmental or public consequences associated with that action. NEPA does not require that certain decisions be made or activities be rejected—it just makes sure that everything reasonably possible (related to environmental law and public protection) has been considered in the decision-making process. This evaluation process helps Y-12 and NNSA stay in compliance with many federal and state laws, regulations, and permits. Many of the NEPA documents for Y-12 can be found on the Y-12 publicly accessible website at www.y12.doe.gov.

The broadest and most complex NEPA document for Y-12 is the *Final Site-Wide Environmental Impact Statement (EIS) for the Y-12 National Security Complex* (DOE 2011a). This document takes into account the myriad activities planned for Y-12 in the foreseeable future. As changes in plans are identified or additional information becomes available, the sitewide document is updated with various supplement analyses. Following the 2011 sitewide EIS, supplement analyses were issued in 2016, 2018, and 2020 (NNSA 2016, NNSA 2018, NNSA 2020a). NNSA plans to pursue a contract for a new Supplement Analysis in 2023.

In addition to an EIS or supplement analysis, there are NEPA environmental assessments, which are prepared for larger projects that may not have been covered in the EIS or supplement analysis. In 2015, an environmental assessment and Finding of No Significant Impact (FONSI) were issued for the Y-12 Emergency Operations Center (NNSA 2015a, NNSA 2015b). In 2020, an environmental assessment and FONSI were issued for the Oak Ridge Enhanced Technology and Training Center (NNSA 2020b, NNSA 2020c). In 2021, the LPF and off-site Y-12 Development Organization facility were each addressed with an environmental assessment and FONSI (NNSA 2021a, 2021b, 2021c, 2021d). Planning for three environmental assessments (EAs) began in 2021 and 2022. These three projects are (1) Special Materials Manufacturing, (2) Depleted Uranium Program bridging or modernization, and (3) the transfer of a property parcel to the Oak Ridge Utility District. Once these EAs are completed, NNSA will determine whether to issue a FONSI or prepare an EIS.

The lowest level of NEPA documentation is a Categorical Exclusion (CX). These documents are used for smaller projects that have fewer environmental impacts and less cost than the types of activities covered by an EIS or environmental assessment. During CY 2021, 48 CX reviews/approvals were issued, with 12 of those being federal CX documents approved by the NNSA NEPA Compliance Officer (NCO). CY 2022 had 60 CX reviews/approvals with six of those being federal CX documents requiring approval by the NCO. Some of these CX documents were for new projects, and others may be revisions to older project documents based on new information or small changes in project scope.

Eight umbrella CXs were also approved by the NNSA NCO during 2022. Together, these documents provide an environmental review on differing categories of standard work activities that are common at Y-12 while also being considered low risk or low impact where environmental compliance is concerned. Any CX issued under these umbrella documents still receives a full review by subject matter experts and oversight by NPO—they just do not require NNSA to approve each project individually. The eight umbrella CX areas are: (1) routine maintenance; (2) deinventory, deactivation, decommissioning, and limited predemolition; (3) support buildings, modifications, and equipment installations; (4) analytical laboratory and research and development activities; (5) site characterization and environmental monitoring; (6) waste management, waste minimization, energy conservation, sustainability, and pollution prevention; (7) personnel safety enhancements and safety equipment improvements; and

(8) routine administrative actions, emergency preparedness training exercises, drills, and simulations.

The following types of documents are available at Y-12's public NEPA website (https://www.y12.doe.gov/about/environment-safety-and-health/national-environmental-policy-act-0): EIS, supplement analyses, environmental assessments, umbrella CXs, and federal CXs. Table 4.4 lists the six federal CX documents developed during 2022.

Table 4.4. National Nuclear Security Administration-approved Categorical Exclusions for 2022

Date issued	Title
03/08/2022	CRADA NFE-22-00001, Collaboration for Manufacturing Solutions and Material Applications
07/05/2022	UAS and Counter UAS, Testing and Evaluation, External Department of Energy Sites
09/19/2022	NEPA 4201.25, UPF, Security Portal 10 Demolition
09/27/2022	NEPA 4834, rev 4, West End Protected Area Reduction Project
10/18/2022	NEPA 5028, Use of Unmanned Aircraft Systems at Y-12 National Security Complex, DOE Oak Ridge Reservation, and other NNSA and DOE-owned or leased properties
12/06/2022	NEPA 5041 South Ridge Facility Dispositions

Acronyms:
NEPA = National Environmental Policy Act
UAS = unmanned aerial systems
UPF = Uranium Processing Facility

4.3.3. National Historic Preservation Act

In accordance with the National Historic Preservation Act of 1966, NNSA is committed to identifying, preserving, enhancing, and protecting its cultural resources. The prescribed evaluation process ensures that the proper level of environmental review is performed before an irreversible commitment of resources is made. Compliance activities in 2022 at Y-12 included completing Section 106 reviews of ongoing and new projects, working to develop an updated cultural resource survey of the site, and collecting and storing historic artifacts.

In 2022, 30 proposed projects were evaluated to determine whether any historic properties eligible for inclusion in the National Register of Historic Places would be adversely impacted. The proposed Integrated Facilities Disposition Project, which is planned to demolish Buildings 9201-05 and 9204-04, was determined to have adverse effects on historic properties eligible for listing in the National Register of Historic Places. In accordance with the *Programmatic Agreement Among the Department of Energy, Oak Ridge Operations Office, the National Nuclear Security Administration, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation Concerning the Management of Historical and Cultural Properties at the Y-12 National Security Complex* (DOE 2003), required Section 106 recordation, interpretation, and documentation information has been prepared and submitted to the State Historic Preservation Office for concurrence to demolish these two major process facilities. The state requested that Y-12 resubmit this information after completion of the Y-12 Cultural Resource Survey, which is currently in progress.

Y/TS-1893, *National Historic Preservation Act Historic Preservation Plan for the Y-12 National Security Complex* (BWXT 2003), stipulates that the plan be reviewed every 5 years to maintain its effectiveness as a guiding document for the National Historic Preservation Act Program at Y-12. In its last review, it was determined that this document and the programmatic agreement needed to be updated to accurately reflect the changes at Y-12 since the documents were completed in 2003. To this end, Y-12 is to update a cultural resource survey, which will evaluate all facilities currently located on the Y-12 site and constructed through 1992 to determine their eligibility for the National Register of Historic Places and inclusion within the redrawn boundaries of the Y-12 Historic District. This cultural resource survey is being developed in consultation with the State Historic Preservation Office and will inform the strategies for the updated preservation plan and programmatic agreement.

Y-12 continues to grow its collection of artifacts as employees donate items when vacating offices and buildings. In 2022, Y-12 added approximately 35 books to its library, which is located adjacent to the Y-12 History Center at the New Hope Center.

4.3.4. Clean Air Compliance Status

Permits issued by the state of Tennessee are the primary means used to impose clean air requirements that are applicable to Y-12. New projects are governed by construction permits and modifications to the Title V operating air permit, and eventually the requirements are incorporated into the sitewide Title V operating permit. Y-12 is currently governed by Title V Major Source Operating Permit 571832.

The permit requires recordkeeping and annual and semiannual reports. More than 2,000 data points are obtained and reported each year. All reporting requirements were met during 2022, and there were no exceedances during the reporting period. A surveillance in December 2022 identified that the 2021 annual preventive maintenance (oil and filter change) for one emergency engine was not completed as required. The preventive maintenance was performed in December 2022.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at Y-12 to satisfy requirements in DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011b), as a best management practice and/or to provide evidence of sufficient programmatic control of certain emissions. Ambient air monitoring conducted specifically for Y-12 (i.e., mercury monitoring) is supplemented by additional monitoring conducted for ORR and by both on- and off-site monitoring conducted by TDEC.

Section 4.4 provides detailed information on 2022 activities conducted at Y-12 in support of the Clean Air Act.

4.3.5. Clean Water Act Compliance Status

During 2022, Y-12 continued its excellent record for compliance with the National Pollutant Discharge Elimination System (NPDES) water discharge permit limits. Data obtained as part of the NPDES program are provided in a monthly report to TDEC. The percentage of compliance with permit discharge limits for 2022 was 100 percent.

Approximately 3,400 data points were obtained from sampling required by the NPDES permit. Y-12's new NPDES permit was issued on August 5, 2022, and became effective on October 1, 2022. The new permit is currently under appeal in part and settlement negotiations are ongoing.

4.3.6. Safe Drinking Water Act Compliance Status

The City of Oak Ridge supplies potable water to Y-12 and meets all federal, state, and local standards for drinking water. The water treatment plant, located north of Y-12, is operated by the City of Oak Ridge. Y-12 potable water distribution is operated by a state-certified distribution system operator. The distribution system is regulated by TDEC as a public water system, with public water distribution system identification number 0001068.

Tennessee's *Public Water Systems,* Chapter 0400-45-01 (TDEC 2019a), sets limits for biological contaminants, chemical activities, and chemical contaminants. Sampling for total coliform, chlorine residuals, lead, copper, and disinfectant byproducts is conducted by Y-12's Environmental Compliance organization, with oversight by a state-certified operator.

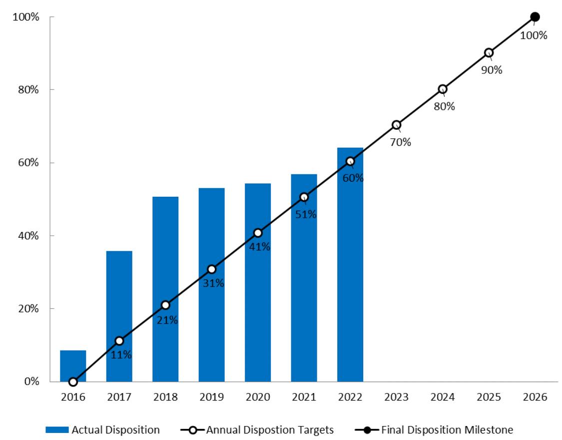
Y-12's potable water distribution system was last reviewed by TDEC in 2021 and received a sanitary survey score of 100 out of a possible 100 points and, thus, retained its approved status as a public water system in good standing with TDEC. All total coliform samples collected during 2021 were analyzed by the state of Tennessee laboratory, and all results were negative. Analytical results for disinfectant byproducts (total trihalomethanes and haloacetic acids) for Y-12's water distribution system were within allowable TDEC and Safe Drinking Water Act limits for the yearly average. Y-12's potable water system is currently sampled triennially for lead and copper. The system sampling was last completed in 2020. These results were below TDEC and Safe Drinking Water Act limits and met established requirements.

4.3.7. Resource Conservation and Recovery Act Compliance Status

The Resource Conservation and Recovery Act (RCRA) regulates hazardous wastes that, if mismanaged, could present risks to human health or the environment. The regulations are designed to ensure that hazardous wastes are managed from the point of generation to final disposal. In Tennessee, EPA delegates the RCRA program to TDEC, but EPA retains an oversight role. Y-12 is considered a large quantity generator because it may generate more than 1,000 kg of hazardous waste in a month and because it has RCRA permits to store hazardous wastes for up to 1 year before shipping off-site to licensed treatment and disposal facilities. Y-12 also has a number of satellite accumulation areas and 90-day waste storage areas.

Mixed wastes are materials that are both hazardous (under RCRA guidelines) and radioactive. The Federal Facility Compliance Act requires that DOE work with local regulators to develop a site treatment plan to manage mixed waste. The plan has two purposes: to identify available treatment technologies and disposal facilities (federal or commercial) that can manage mixed waste produced at federal facilities and to develop a schedule for treating and disposing of the waste streams that cannot be treated and disposed of in strict compliance with RCRA time limits.

The *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation* (TDEC 2022a) is updated annually and submitted to TDEC for review. The current plan documents the mixed waste inventory and describes efforts undertaken to seek new commercial treatment and disposal outlets for various waste streams. NNSA has developed a disposition schedule for the mixed waste in storage and will continue to maintain and update the plan, as a reporting mechanism, as progress is made. Y-12 has developed disposition milestones to address its remaining inventory of legacy mixed waste. Disposition milestones for the final inventory are FYs 2016 through 2026, as shown in Figure 4.9. In FY 2022, Y-12 staff dispositioned 64 percent of the legacy mixed waste inventory listed in the ORR site treatment plan.



Note: *As part of the Oak Ridge Reservation Site Treatment Plan.*

Figure 4.9. Path to eliminate Y-12's legacy mixed waste inventory by fiscal year (2016–2022)

The quantity of hazardous and mixed wastes generated by Y-12 in 2022 increased compared to the previous year, as shown in Figure 4.10. Y-12 is a state-permitted treatment, storage, and disposal facility. Under its permits, Y-12 received 3,611 kg of hazardous and mixed waste from off-site in 2022.

In addition, 557,529 kg of hazardous and mixed waste was shipped to DOE-owned and commercial treatment, storage, and disposal facilities. More than 10 million (10.993890 million kg for updating the graph) kg of hazardous and mixed wastewater was treated at on-site wastewater treatment facilities.

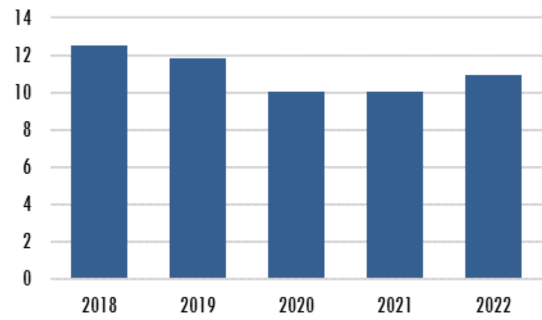


Figure 4.10. Y-12 hazardous waste generation, 2018–2022

4.3.7.1. Resource Conservation and Recovery Act Underground Storage Tanks

TDEC regulates active petroleum underground storage tanks (USTs). Existing UST systems that remain in service must comply with performance requirements described in TDEC underground storage tank regulations (TN 0400 18 01).

The last two petroleum USTs at the East End Fuel Station were closed and removed in August 2012. No petroleum USTs remain at Y-12.

4.3.7.2. Resource Conservation and Recovery Act Subtitle D Solid Waste

ORR landfills operated by DOE EM are located within the Y-12 boundary. The facilities include two Class II operating industrial solid waste disposal landfills and one operating Class IV construction demolition landfill. The facilities are permitted by TDEC and accept solid waste from DOE operations on ORR. In addition, one Class IV facility (Spoil Area 1) is overfilled by 8,945 m^3 and has been the subject of a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation and feasibility study. A CERCLA Record of Decision for Spoil Area 1 was signed in 1997 (DOE 1997b). One Class II facility (Landfill II) has been closed and is subject to post-closure care and maintenance. Associated TDEC permit numbers are noted in Table 4.3. Additional information about the operation of these landfills is provided in Section 4.8.2.

4.3.8. Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination

The intent of the ORR Federal Facility Agreement (DOE 2022a) is to coordinate the corrective action processes of RCRA required under the ORR Corrective Action TNHW-164, which was renewed for a 10-year period from September 15, 2015, through September 15, 2025. As required in TNHW-164, the annual update of solid waste management units and areas of concern was submitted to TDEC in January 2023 as an update of the previous CY 2022 activities.

4.3.9. Toxic Substances Control Act Compliance Status

Storage, handling, and use of polychlorinated biphenyls (PCBs) are regulated under the Toxic Substances Control Act (TSCA). Capacitors manufactured before 1970 believed to be oil-filled are handled as though they contain PCBs, even when that cannot be verified from manufacturer records. Certain equipment containing PCBs and PCB waste containers must be inventoried and labeled. The inventory is updated by July 1 of each year and was last submitted on June 23, 2022.

Given the widespread historical uses of PCBs at Y-12 and fissionable material requirements that must be met, EPA and DOE negotiated an agreement to assist ORR facilities in becoming compliant with TSCA regulations. This agreement, the ORR PCB Federal Facility Compliance Agreement, which became effective in 1996, provides a forum within which to address PCB compliance issues that are unique to these facilities. Y-12 operations involving TSCA-regulated materials were conducted in accordance with TSCA regulations and the agreement.

4.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act requires that facilities report inventories (i.e., Tier II Report sent to state and local emergency responders) and releases (i.e., toxic release inventory report submitted to state and federal environmental agencies) of certain chemicals that exceed specified thresholds. Y-12 submitted reports for reporting year 2022 in accordance with requirements under Sections 303, 311, 312, and 313 of the Act.

Y-12 had no unplanned release of a hazardous substance that required notification of the regulatory agencies (see Section 4.3.11 for more information). Five new substances were over threshold during 2022. Inventories, locations, and associated hazards of over-threshold hazardous and extremely hazardous chemicals were submitted to TEMA and local emergency responders in the annual Tier II Report required by Section 312. Data submittal was through the E-Plan web-based reporting system, as requested by TEMA. Some local emergency responders accepted data through the E-Plan system, but others require that electronic copies of the Tier II Reports be submitted via email. Y-12 reported 47 chemicals that were over Section 312 inventory thresholds in 2022.

Y-12 operations are evaluated annually to determine the applicability for submittal of a toxic release inventory report to TEMA and EPA in accordance with Emergency Planning and Community Right-to-Know Act Section 313 requirements. The amounts of certain chemicals manufactured, processed, or otherwise used are calculated to identify those that exceed reporting thresholds. After threshold determinations are made, releases and off-site transfers are calculated for each chemical that exceeds a threshold. Submittal of the data to TEMA and EPA is made through the Toxics Release Inventory-Made Easy (abbreviated as TRI-ME) web-based reporting system operated by EPA. Total 2022 reportable toxic releases to air, water, and land and waste transferred off-site for treatment, disposal, and recycling were 451,373 lb. Table 4.5 lists the reported chemicals for Y-12 for 2021 and 2022 and summarizes releases and off-site waste transfers for those chemicals.

Table 4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for Y-12, 2021–2022

Chemical	Year	Quantity[a] (lb)[b]
Chromium	2021	7,601
	2022	47,135
Cobalt	2021	Not reported
	2022	6,790
Copper	2021	331,722
	2022	14,669
Lead compounds	2021	169,300
	2022	238,655
Manganese	2021	57,735
	2022	32,070
Mercury	2021	Not reported
	2022	Not reported
Methanol	2021	44,583
	2022	51,169
Nickel	2021	5,774
	2022	60,885

[a] *Represents total releases to air, land, and water and includes off-site transfers. Also includes quantities released to the environment as a result of remedial actions, catastrophic events, or onetime events not associated with production processes.*

[b] *1 lb = 0.4536 kg.*

4.3.11. Spill Prevention, Control, and Countermeasures

Clean Water Act, Section 311, regulates the discharge of oils or petroleum products to waters of the United States and requires spill prevention, control, and countermeasure plans be developed and implemented to minimize the potential for oil discharges. The major requirements for plans are contained in 40 Part 112. These regulations require that these plans be reviewed, evaluated, and amended at least once every 5 years, or earlier if significant changes occur. The rule includes requirements for oil spill prevention, preparedness, and response to prevent oil discharges to navigable waters and adjoining shorelines. The rule requires specific facilities to prepare, amend, and implement spill prevention, control, and countermeasure plans.

The *Spill Prevention, Control, and Countermeasure Plan for the U.S. Department of Energy Y-12 National Security Complex* (CNS 2022c) was revised in October 2022 to update general Y-12 changing site infrastructure. This plan presents the requirements to be implemented by Y-12 to prevent spills of oil and the countermeasures to be invoked should a spill occur. In general, the first response of an individual discovering a spill is to call the Y-12 Plant Shift Superintendent. Spill response materials and equipment are stored near tanks, drum storage areas, and other strategic areas of Y-12 to facilitate spill response. All Y-12 personnel and subcontractors are required to have initial spill and emergency response training before they can work on the site.

4.3.12. Unplanned Releases

Y-12 has procedures for notifying off-site authorities of categorized events at Y-12. Off-site notifications are required for specified events according to federal statutes, DOE orders, and the Tennessee Oversight Agreement. As an example, certain observable oil sheens on East Fork Poplar Creek (EFPC) must be reported to the EPA National Response Center in addition to other reporting requirements. Spills of CERCLA reportable quantity limits must be reported to the EPA National Response Center, DOE, TEMA, and the Anderson County Local Emergency Planning Committee.

In addition, Y-12's Occurrence Reporting Program provides timely notification to the DOE community of Y-12 events and site conditions that could adversely affect public or worker health and safety, the environment, national security, DOE safeguards and security interests, DOE facilities functions, or DOE's reputation.

Y-12 occurrences are categorized and reported through the Occurrence Reporting and Processing System, which provides NNSA and the DOE community with a readily accessible database of information about occurrences at DOE facilities, causes of those occurrences, and corrective actions to prevent recurrence of the events. DOE analyzes aggregate occurrence information for generic implications and operational improvements.

During 2022, there were no reportable releases to the environment, including no reportable radiological air emission releases for Y-12.

4.3.13. Audits and Oversight

In 2022, Y-12 was inspected by federal, state, or local regulators on four occasions. Table 4.2 summarizes the results.

As part of the City of Oak Ridge's pretreatment program, city personnel collect samples from the Y-12 monitoring station to conduct compliance monitoring, as required by the pretreatment regulations. City personnel also conduct compliance inspections twice yearly. No issues were identified in 2022.

Personnel from the TDEC Division of Solid Waste Management conducted an unannounced RCRA hazardous waste compliance inspection of Y-12 on February 23, 2022. The inspections covered waste storage areas and records reviews. Eight issues were identified, including roof leak repairs that were not documented, one container exceeded 90 days in a storage area, inadequate aisle space in one area, one facility did not conduct daily inspections when hazardous waste activities occurred for a period of time, and two instances each of containers inadequately labeled for hazards and improperly closed. Immediate corrective actions were taken where possible. The issues and their causes are being reviewed to prevent recurrence.

Personnel from the TDEC Division of Air Pollution Control conducted an air quality inspection on March 23, 2022. The inspection covered 12 air emission sources, including some emergency generators, and inspections of the facilities. Title V air permit records were also reviewed. No issues were identified.

In July 2019, as the result of a self-identified issue, shipments to the Nevada National Security Site were suspended due to incomplete characterization of weapon material/weapon-related material (WM/WRM). This suspension included the entire Waste Certification Program, affecting both WM/WRM and waste shipments.

Investigations, a series of improvement activities, and layers of self-critical audits were conducted. Additional actions to enhance the Waste Certification Program and prepare for resuming shipments were completed in FY 2021. Reinstatement of the Waste Certification Program occurred in March 2021 for waste shipments. The first shipment of waste occurred in April 2021.

Process mapping sessions for the new WM/WRM disposition program were conducted, and job analyses for roles involved in the WM/WRM disposition process were completed and issued. Procedures and manuals were updated, and Y17-014, *Characterization of Weapon Material and Weapon-Related Material*, was created. Engineering components training was developed and implemented to address identified gaps, and need-to-know issues with Sandia National Laboratories were resolved.

The suspension of the WM/WRM portion of the Waste Certification Program was lifted in October 2022.

In June 2022, real-time radiography unit 4 became operational. The unit has the capability to analyze unclassified radiologically-contaminated waste boxes and drums. Data gathered from real-time radiography images are used to verify that no non-conforming items are packaged within containers destined for Nevada.

Progress will continue on additional waste profiles, analyzing drums and boxes through real-time radiography and shipping newly generated and backlogged containers for disposition.

4.3.14. Radiological Release of Property

Releasing property from Y-12 is conducted in accordance with approved procedures that comply with DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011b). Property consists of real property (i.e., land and structures) and personal property (i.e., property of any type except real property). At Y-12, there are three paths for releasing property to the public based on the potential for radiological contamination:

- Survey and release property potentially contaminated on the surface (Section 4.3.14.1).
- Evaluate materials with a potential to be contaminated in volume (Section 4.3.14.2).
- Evaluate using process knowledge (surface and volumetric) (Section 4.3.14.3).

Table 4.6 summarizes some examples of the property released in 2022 and their amounts. During FY 2022, Y-12 recycled more than 4.8 million lb of materials off-site for reuse, including computers, electronic office equipment, used oil, scrap metal, tires, batteries, lamps, and pallets.

The paths discussed in Sections 4.3.14.1 and 4.3.14.2 use pre-approved authorized limits as outlined in DOE Order 458.1. These limits use screening levels from American National Standards Institute/Health Physics Society (ANSI/HPS) N13.12-2013, *Surface and Volume Radioactive Standards for Clearance* (ANSI 2013). The basis of these standards is to limit the dose to any member of the public to a maximum of 1.0 mrem (0.01 mSv) per year total effective dose from clearing materials from regulatory control. These authorized limits are applicable to the release of personal property only (including recycled material). No real property was released from Y-12 in 2022.

Table 4.6. Summary of materials released in 2022

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle:	82,982 lb
– Computers	
– Monitors	
– Printers	
– Mainframes	
Recycling examples:	
– Used oils	6,785 gal
– Used tires	18,240 lb
– Scrap metal	2,934,076 lb
– Lead acid batteries	65,368 lb
Public and negotiated sales:	
– Brass	5,501 lb
– Miscellaneous furniture	1,716 lb
– Vehicles and miscellaneous equipment/materials	178,280 lb
External transfers	N/A

Note: *External transfers include vehicles, miscellaneous equipment, and materials transferred to various federal, state, and local agencies for reuse during FY 2022. Y-12 transferred property with an acquisition value of approximately $138,565; however, the weight of the transferred items in pounds was unable to be quantified.*

4.3.14.1. Property Potentially Contaminated on the Surface

Property that is potentially contaminated on the surface is completely surveyed, unless it can be released based on process knowledge or through a survey plan that provides survey instructions, along with technical justification (process knowledge) for the plan, based on the *Multi-Agency Radiation Survey and Site Investigation Manual* (NRC 2000) and the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (NRC 2009). Table 4.7 lists the surface contamination limits used at Y-12 to determine whether materials and equipment (M&E) are suitable for release to the public.

Y-12 uses an administrative limit for average and maximum activity of 240 dpm/100 cm^2 for radionuclides in Group 3 and 2,400 dpm/100 cm^2 for radionuclides in Group 4 (see Table 4.7). Y-12 also uses an administrative limit for removable activity of 240 dpm/100 cm^2 for radionuclides in Group 3 (see Table 4.7). The use of the more-restrictive administrative limits ensures that M&E do not enter into commerce exceeding the definition of contamination for high-toxicity alpha emitters and for beta and gamma emitters, respectively, found in 49 CFR 173, "Shippers—General Requirements for Shipments and Packaging."

4.3.14.2. Property Potentially Contaminated in Volume (Volumetric Contamination)

Materials, such as activated materials, smelted-contaminated metals, liquids, and powders, are subject to volumetric contamination (i.e., radioactivity per unit volume or per unit mass) and are treated separately from surface-contaminated objects. Materials that may be subject to volumetric contamination are evaluated for release by one of the following three methods:

- **Unopened, sealed containers:** Material is still in an original commercial manufacturer's sealed, unopened container. A seal can be a visible manufacturer's seal (e.g., lock tabs, heat shrink) or a manufacturer's seal that cannot be seen (e.g., unbroken fluorescent bulbs, sealed capacitors), as long as the container remains unopened once received from the manufacturer.
- **Process knowledge:** If contamination being able to enter a system is unlikely, then process knowledge is documented and used as the basis for release. Often, this is accompanied by confirmatory surveys.
- **Analytical:** The material is sampled, and analytical results are evaluated against the preapproved authorized limits in DOE Order 458.1. If preapproved authorized limits have not been approved, then analytical results are evaluated against measurement method critical levels or background levels from materials that have not been impacted by Y-12 activities. If results meet defined criteria, then they are documented, and the material is released.

Table 4.7. DOE Order 458.1 preapproved authorized limits for surface contamination[a,b]

Radionuclide[c]	Average[d,e]	Maximum[d,e]	Removable[f]
Group 1: Transuranics, ^{125}I, ^{129}I, ^{227}Ac, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	100	300	20
Group 2: Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	1,000	3,000	200
Group 3: U-Natural, ^{235}U, ^{238}U, associated decay products, alpha emitters	5,000	15,000	1,000
Group 4: Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission), except ^{90}Sr and others noted above[g]	5,000	15,000	1,000
Tritium (applicable to surface and subsurface)[h]	N/A	N/A	10,000

[a] The values in this table (except for tritium) apply to radioactive material deposited on but not incorporated into the interior or matrix of the property. No generic concentration guidelines have been approved for release of material that has been contaminated in depth, such as activated material or smelted-contaminated metals (e.g., radioactivity per unit volume or per unit mass). Authorized limits for residual radioactive material in volume must be approved separately.

[b] As used in this table, disintegrations per minute means the rate of emission by radioactive material, as determined by counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[d] Measurements of average contamination should not be averaged over an area of more than 1 m^2. Where scanning surveys are not sufficient to detect levels in the table, static counting must be used to measure surface activity. Representative sampling (static counts on the areas) may be used to demonstrate by analyses the static counting data. The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[f] The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination of objects on surfaces of less than 100 cm^2 is determined, the activity per unit area should be based on the actual area, and the entire surface should be wiped. Wiping techniques to measure removable contamination levels are unnecessary if direct scan surveys indicate the total residual surface contamination levels are within the limits for removable contamination.

[g] This category of radionuclides includes mixed fission products, including ^{90}Sr that is present in them. It does not apply to ^{90}Sr that has been separated from other fission products or mixtures where ^{90}Sr has been enriched.

[h] Measurement should be conducted by a standard smear measurement but using a damp swipe or material that will readily absorb tritium, such as polystyrene foam. Property recently exposed or decontaminated should have measurements (smears) at regular time intervals to prevent a buildup of contamination over time. Because tritium typically penetrates material it contacts, the surface guidelines in Group 4 do not apply to tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure nonremovable fractions and residual tritium in mass will not cause exposures that exceed DOE dose limits and constraints.

Acronyms:
DOE = US Department of Energy *N/A = not applicable*

Y-12 was granted approval to use the DOE Order 458.1 preapproved authorized limits for volumetric contamination on July 20, 2021, which is documented in NPO letter COR-NP0-60 ESH-7.20.2021-919599, “Approval to Use Pre-Approved Authorized Limits for the Release and Clearance of Volumetric Radioactivity of Personal Property” (NNSA 2021e). Table 4.8 lists these volumetric contamination limits for various groups of radionuclides. When multiple radionuclides exist in a single sample, a sum of fractions is used to verify that material meets the specified limits.

4.3.14.3. Process Knowledge

Process knowledge is used to release property from Y-12 without monitoring or analytical data and to implement a graded approach (less than 100 percent monitoring) for monitoring of some M&E (Classes II and III, NRC 2009). A conservative approach (nearly 100 percent monitoring) is used to release older M&E for which a complete and accurate history is difficult to compile and verify (Class I, NRC 2009). The process knowledge evaluation processes are outlined in Y-12 procedures.

The following are examples of M&E released without monitoring based on process knowledge; however, this does not preclude conducting verification monitoring before sale:

- All M&E from rad-free zones
- Pallets generated from noncontaminated areas
- Pallets that are returned to shipping during the same delivery trip
- Lamps from noncontaminated areas
- Drinking water filters
- M&E approved for release by radiological engineering technical review
- Portable restrooms used in noncontaminated areas
- Documents, mail, diskettes, compact disks, and other office media
- Personal M&E
- Paper, plastic products, water bottles, aluminum beverage cans, and toner cartridges
- Office trash, housekeeping materials, and associated waste
- Breakroom, cafeteria, and medical wastes
- Medical and bioassay samples generated in noncontaminated areas
- Subcontractor, vendor, and privately owned vehicles, tools, and equipment used in noncontaminated areas
- M&E that are administratively released
- M&E that were delivered to stores in error and that have not been distributed to other Y-12 locations
- New computer equipment distributed from the Central Computing Facility
- Subcontractor, vendor, and privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities
- New cardboard
- Consumer glass containers

Table 4.8. DOE Order 458.1 preapproved authorized limits for volumetric contamination[a]

Radionuclide groups[b]	SI units, volume (Bq/g)[d,e]	Conventional units, volume (pCi/g)[d,e]
Group 0: Special Case: $^{129}I^{c}$	0.01	0.3
Group 1: High-energy gamma, radium, thorium, transuranics, and mobile beta-gamma emitters: ^{22}Na, ^{46}Sc, ^{54}Mn, ^{56}Co, ^{60}Co, ^{65}Zn, ^{94}Nb, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{182}Ta, ^{207}Bi, ^{210}Po, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{229}Th, ^{230}Th, ^{232}Th, ^{232}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{244}Pu, ^{241}Am, ^{243}Am, ^{245}Cm, ^{246}Cm, ^{247}Cm, ^{248}Cm, ^{249}Cf, ^{251}Cf, ^{254}Es, and associated decay chains[d], and others[b]	0.1	3
Group 2: Uranium and selected beta-gamma emitters: ^{14}C, ^{36}Cl, ^{59}Fe, ^{57}Co, ^{58}Co, ^{75}Se, ^{85}Sr, ^{90}Sr, ^{95}Zr, ^{99}Tc, ^{105}Ag, ^{109}Cd, ^{113}Sn, ^{124}Sb, ^{123m}Te, ^{139}Ce, ^{140}Ba, ^{155}Eu, ^{160}Tb, ^{181}Hf, ^{185}Os, ^{190}Ir, ^{192}Ir, ^{204}Tl, ^{206}Bi, ^{233}U, ^{234}U, ^{235}U, ^{238}U, natural uranium[e], ^{237}Np, ^{236}Pu, ^{243}Cm, ^{244}Cm, ^{248}Cf, ^{250}Cf, ^{252}Cf, ^{254}Cf, and associated decay chains[d], and others[b]	1	30
Group 3: General beta-gamma emitters: ^{7}Be,^{74}As, ^{93m}Nb, ^{93}Mo, ^{93}Zr, ^{97}Tc, ^{103}Ru, ^{114m}In, ^{125}Sn, ^{127m}Te, ^{129m}Te, ^{131}I, ^{131}Ba, ^{144}Ce, ^{153}Gd, ^{181}W, ^{203}Hg, ^{202}Tl, ^{225}Ra, ^{230}Pa, ^{233}Pa, ^{236}U, ^{241}Pu, ^{242}Cm, and others	10	300
Group 4: Low-energy beta-gamma emitters: ^{3}H, ^{35}S, ^{45}Ca, ^{51}Cr, ^{53}Mn, ^{59}Ni, ^{63}Ni, ^{86}Rb, ^{91}Y, ^{97m}Tc, ^{115m}Cd, ^{115m}In, ^{125}I, ^{135}Cs, ^{141}Ce, ^{147}Nd, ^{170}Tm, ^{191}Os, ^{237}Pu, ^{249}Bk, ^{253}Cf, and others[b]	100	3,000
Group 5: Low-energy beta emitters: ^{55}Fe, ^{73}As, ^{89}Sr, ^{125m}Te, ^{147}Pm, ^{151}Sm, ^{171}Tm, ^{185}W, and others[b]	1,000	30,000

[a] The screening levels for clearance have been rounded to one significant figure and are assigned for volume radioactivity.

[b] To determine the specific group for radionuclides not shown, a comparison will be performed of the screening factors, by exposure scenario, listed in Tables B.1, C.1, and D.1 of NCRP Report No. 123 (NCRP 1996), for the radionuclides in question and the radionuclides in the general groups above and a determination of the proper group made, as described in ANSI/HPS N13.12-2013, Annex A (ANSI 2013).

[c] Because of potential groundwater concerns, the volume radioactivity values for 129I when disposal to landfills or direct disposal to soil is anticipated is assigned to Group 0.

[d] For decay chains, the screening levels represent the total activity (i.e., the activity of the parent plus the activity of all progeny) present.

[e] The natural uranium screening levels for clearance shall be lowered from Group 2 to Group 1 if decay-chain progeny are present (e.g., uranium ore versus process or separated uranium in the form of yellowcake). The natural uranium activity equals the activity from uranium isotopes (48.9% from 238U, plus 48.9% from 234U, plus 2.2% from 235U). This approach is consistent with summing radionuclide fractions discussed in ANSI/HPS N13.12-2013, Section 4.4.

[f] Each individual limit applies to the particular radionuclides, but must be summarized, and the sum of fractions must be <1.

Acronym:

DOE = US Department of Energy

4.4. Air Quality Program

Sections of Y-12's Title V Permit 571832 contain requirements that are generally applicable to most industrial sites. Examples include requirements associated with control of asbestos, stratospheric ozone-depleting chemicals, and fugitive emissions, and general administration of the permit. The Title V permit also contains specific requirements directly applicable to individual sources of air emissions at Y-12. Major requirements in that section include the Radiological National Emission Standards for Hazardous Air Pollutants (NESHAP) (40 CFR 61) and numerous ones associated with emissions of criteria pollutants and other, nonradiological hazardous air pollutants. In addition, a number of sources that are exempt from permitting requirements under state rules but subject to listing on the Title V permit application are documented, and information about them is available upon request from the Y-12 Clean Air Program.

4.4.1. Construction and Operating Permits

The following Title V permitting actions were submitted and approved in 2022:

- Initial notification report for Emergency Operations Center new stationary emergency reciprocating internal combustion engine/generator to the Title V operating air permit.
- Y-12 Major Source (Title V) Operating Air Permit renewal application was submitted to TDEC in June 2022.
- Insignificant activity exemption was completed for the existing and new electropolishing operations located in Building 9204-02E.
- Operational flexibility request to replace an old, existing nitric acid rinse system with a new nitric acid rinse system in Foundry Operations at Building 9998.
- Notification of change to CNS Responsible Official for Y-12 Major Source (Title V) Operating Air Permit 571832 to designate Diane McDaniel as the new responsible official for Y-12.
- Notification of change of Federal Responsible Office for Y-12 Major Source (Title V) Operating Air Permit 571832 to designate Glenn C. Smolens as the new responsible official for Y-12.

Demonstrating compliance with air permits conditions is a significant effort at Y-12. Key elements of maintaining compliance are maintenance and operation of control devices, monitoring, recordkeeping, and reporting.

High-efficiency particulate air filters and scrubbers are control devices used at Y-12. High-efficiency particulate air filters are found throughout the site, and in-place testing of high-efficiency particulate air filters to verify the integrity of the filters is routinely performed. Scrubbers are operated and maintained in accordance with source-specific procedures. Monitoring tasks consist of continuous stack sampling, onetime stack sampling, and operation of control devices. Examples of continuous stack sampling are the radiological stack monitoring systems on numerous sources throughout Y-12.

The Y-12 sitewide permit requires annual and semiannual reports, including the following:

- Annual ORR Radiological NESHAP Report, which includes specific information regarding Y-12 radiological emissions.
- Annual Title V Compliance Certification Report, which indicates compliance status with all conditions of the permit.
- Title V Semiannual Report, which covers a 6-month period for some specific emission sources and consists of monitoring and recordkeeping requirements for the sources.
- Boiler Maximum Available Control Technology Report for the Y-12 Steam Plant, which requires the boilers to be tuned up on an annual basis.

Table 4.9. Actual versus allowable air emissions from the Y-12 Steam Plant, 2022

Emissions (tons/yr)[a]			
Pollutant	**Actual**	**Allowable**	**Percentage of allowable**
Particulate	2.80	41.0	6.8
Sulfur dioxide	0.22	39.0	0.6
Nitrogen oxides[b]	11.79	81.0	14.5
VOCs[b]	2.72	9.4	28.9
Carbon monoxide[b]	30.95	139.0	22.3

Note: *The emissions are based on fuel usage data for January through December 2022. The VOC emissions include VOC hazard air pollutant emissions.*

[a] *1 ton = 907.2 kg.*

[b] *When no applicable standard or enforceable permit condition exists for a pollutant, the allowable emissions are based on the maximum actual emissions calculation, as defined in Tennessee Department of Environment and Conservation Rule 1200-3-26-.02(2)(d)3 (maximum design capacity for 8,760 h/yr). Both actual and allowable emissions were calculated based on the latest US Environmental Protection Agency compilation of air pollutant emission factors (EPA 1995, 1998).*

Acronyms:

VOC = volatile organic compound
Y-12 = Y-12 National Security Complex

Table 4.9 lists the actual emissions versus allowable emissions for the Y-12 Steam Plant.

4.4.1.1. Generally Applicable Permit Requirements

Y-12, like many industrial sites, has a number of generally applicable requirements, such as those pertaining to managing and controlling asbestos, ozone-depleting substances, and fugitive particulate emissions.

Asbestos Control

Y-12 also has a number of general requirements applicable to removing and disposing of asbestos-containing materials, including monitoring, notifying TDEC of demolitions and renovations, and prescribed work practices for abating and disposing of asbestos materials. There was no reportable release of asbestos in 2022. There were two notifications of asbestos demolitions and renovations. Asbestos, ozone-depleting substances, and fugitive particulate emissions are notable examples.

Stratospheric Ozone Protection and Hydrofluorocarbon Phasedown

As required by the Clean Air Act Title VI Amendments of 1990, and in accordance with 40 CFR 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances during maintenance activities performed on refrigeration equipment. During 2017, EPA enacted major revisions to the stratospheric ozone rules, including regulating non-ozone-depleting substance substitutes as part of 40 CFR 82, Subpart F. These revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. There were no appliances at Y-12 that leaked refrigerant in 2022 triggering this reporting. On October 1, 2021, EPA began implementing the hydrofluorocarbon phasedown requirements of the American Innovation and Manufacturing Act of 2020, which seeks to reduce hydrofluorocarbon consumption and production to 15 percent of a 2011–2013 baseline by 2036 (EPA 2022). Sitewide use of hydrofluorocarbons is being evaluated to understand future effects of Act phasedowns.

Fugitive Particulate Emissions

As modernization reduction efforts increase at Y-12, good work practices and controls are needed to minimize fugitive dust emissions from construction and demolition activities. Y-12 personnel use a mature project planning process to review, recommend, and implement appropriate work practices and controls to minimize fugitive dust emissions. Precautions used to prevent particulate matter from becoming airborne include the following:

- Where possible, using water or chemicals to control dust when demolishing existing buildings or structures, performing construction operations, grading roads, or clearing land.
- Applying asphalt, water, or suitable chemicals on dirt roads, material stockpiles, and other surfaces that can create airborne dusts.
- Installing and using hoods, fans, and fabric filters to enclose and vent dusty materials.

4.4.1.2. National Emission Standards for Hazardous Air Pollutants for Radionuclides

The release of radiological contaminants, primarily uranium, into the atmosphere at Y-12 occurs almost exclusively as a result of plant production, maintenance, and waste management activities. The major radionuclide emissions contributing to the dose from Y-12 are ^{234}U, ^{235}U, ^{236}U, and ^{238}U, which are emitted as particulates (Figure 4.11). The particle size and solubility class of the emissions are based on review of the operations and processes served by the exhaust systems to determine the quantity of uranium handled in the operation or process, the physical form of the uranium, and the nature of the operation or process. The following four categories of processes or operations are considered when calculating the total uranium emissions:

- Those that exhaust through monitored stacks.
- Unmonitored processes for which calculations are performed according to Appendix D of 40 CFR 61.
- Processes or operations exhausting through laboratory hoods, also involving 40 CFR 61, Appendix D, calculations.
- Emissions from room ventilation exhausts (calculated using radiological control monitoring data from the work area).

Continuous sampling systems are used to monitor emissions from a number of process exhaust stacks at Y-12. In addition, a probe cleaning program is in place, and the results from the cleaning at each source are incorporated into the respective emission point source terms. In 2022, 24 process exhaust stacks were continuously monitored, 23 of which were major sources; the remaining stack was a minor source, and its contribution to Y-12's air emissions was conservatively accounted for using Appendix D calculations. The sampling systems on the stacks have been approved by EPA Region 4.

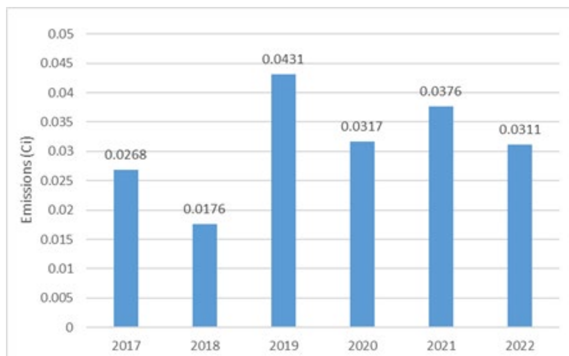


Figure 4.11. Total curies of uranium discharged from Y-12 to the atmosphere, 2017–2022

During 2022, unmonitored uranium emissions at Y-12 occurred from 41 points associated with on-site unmonitored processes and laboratories. Emission estimates for the processes and laboratory stacks were made using inventory data with emission factors provided in 40 CFR 61, Appendix D. The Y-12 source term includes an estimate of these emissions.

Y-12's Analytical Chemistry Organization operates out of two main laboratories. One is located in Building 9995, and the other is located in a leased facility on Union Valley Road, about 0.3 mi east of Y-12 and is not within the ORR boundary. In 2022, there were no radionuclide emission points (or sources) in the off-site laboratory facility.

Additionally, estimates from room ventilation systems are considered using radiological control data on airborne radioactivity concentrations in the work areas. Where applicable, exhausts from any area where the monthly concentration average exceeds 10 percent of the derived air concentration, as defined in *Compliance Plan, National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE 2020a), are included in the annual source term. Annual average concentrations and design ventilation rates are used to arrive at the annual emission estimate for those areas. Two emission points from room ventilation exhausts were identified in 2022, where emissions exceeded 10 percent of the derived air concentration. Both of these emission points fed to monitored stacks, and any radionuclide emissions were accounted for as noted for monitored emission points; therefore, they are not included in the total overall source term for Y-12.

Y-12 Title V (Major Source) operating permits contain a sitewide, streamlined alternate emission limit for EU and DU process emission units. A limit of 907 kg/yr- of particulate was set for the sources for the purposes of paying fees. The compliance method requires the annual actual mass emission particulate emissions to be generated using the same monitoring methods required for radiological NESHAP compliance. An estimated 0.0311 Ci (34.0 kg) of uranium was released into the atmosphere in 2022 as a result of Y-12 process and operational activities.

The calculated radiation dose to the maximally exposed off-site individual from airborne radiological release points at Y-12 during 2022 was 0.5 mrem. This dose is well below the NESHAP standard of 10 mrem and is less than 0.2 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. Chapter 7 discusses how the airborne radionuclide dose was determined.

Lastly, the UPF is being designed and constructed to house some of the processes that are currently in existing production buildings. The UPF project was issued a construction air permit (967550P) in March 2014. With concurrence from TDEC Air Division, the UPF was included in the 2018 update of Y-12's Title V operating permit 571832. The UPF construction air permit was incorporated into the Y-12 Title V air permit on February 18, 2019. The Title V air permit was administratively extended until a new permit is issued. The UPF project will be maintained on inactive status until operational readiness and startup.

4.4.1.3. Quality Assurance

Quality assurance (QA) activities for the Radiological NESHAP Program are documented in the *Y-12 National Security Complex Quality Assurance Project Plan National Emission Standards for Hazardous Air Pollutants Radionuclide Emission Measurements* (CNS 2020). The plan satisfies the QA requirements in 40 CFR 61, Method 114, for ensuring that radionuclide air emission measurements from Y-12 are representative to known levels of precision and accuracy and that administrative controls are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC Regulation 0400-30-38, "Emission Standards for Hazardous Air Pollutants" (TDEC 2022b). The plan ensures the quality of Y-12 radionuclide emission measurements data from the continuous samplers and minor radionuclide release points. It specifies the procedures for managing activities affecting data quality. QA objectives for completeness, sensitivity, accuracy, and precision are discussed. Major programmatic elements addressed in the QA plan are the sampling and monitoring program, emissions characterization, analytical program, and minor source emission estimates.

4.4.1.4. Source-Specific Criteria Pollutants

Proper maintenance and operation of a number of control devices (e.g., high-efficiency particulate air filters and scrubbers) are key to controlling emissions of criteria pollutants. The primary source of criteria pollutants at Y-12 is the steam plant, where only natural gas and Number 2 fuel oil are permitted to be burned. Actual versus allowable emissions from the steam plant are listed in Table 4.9.

Particulate emissions from point sources result from many operations throughout Y-12. Compliance is demonstrated through several activities, including monitoring the operations of control devices, limiting process input materials, and using certified readers to conduct emission evaluations of visible stacks.

Use of solvent 140/142, methanol, and vertrel throughout Y-12 and volatile organic compounds (VOCs) from the steam plant are primary sources of VOC emissions. Material mass balances and engineering calculations are used to determine annual emissions. The calculated amounts of solvent 140/142 and methanol emitted for CY 2022 are 8,294.39 lb (4.15 tons) and 46,022 lb (15.25 tons), respectively.

4.4.1.5. Mandatory Reporting of Greenhouse Gas Emissions Under 40 CFR 98

40 CFR 98, "Mandatory Reporting of Greenhouse Gases," establishes mandatory reporting requirements for owners and operators of certain facilities that directly emit GHGs and for certain fossil fuel suppliers and industrial GHG suppliers. The purpose of the rule is to collect accurate and timely data on GHG emissions that can be used to inform future policy decisions.

The rule requires reporting annual emissions of carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, perfluorochemicals, and other fluorinated gases (e.g., nitrogen trifluoride and hydrofluorinated ethers). These gases are often expressed in metric tons of carbon dioxide equivalent (CO_2e).

Y-12 is subject only to the Subpart A general provisions and reporting from stationary fuel combustion sources covered in 40 CFR 98, Subpart C, "General Stationary Fuel Combustion." Currently, the rule does not require control of GHGs; rather, it requires only that sources emitting above the 25,000 CO_2e threshold level monitor and report emissions.

The Y-12 Steam Plant is subject to this rule. The steam plant consists of four boilers. The maximum heat input capacity of each boiler does not exceed 99 million Btu/h. Natural gas is the primary fuel source for the boilers; Number 2 fuel oil is a backup fuel source. Other limited, stationary combustion sources are metal forming operations and production furnaces that use natural gas. In Building 9212, a gas-fired furnace used for drying wet residues and burning solids in a recovery process has a maximum heat input of 700,000 Btu/h. In Building 9215, 10 natural gas torches, each at 300 standard ft^3/h, are used to preheat tooling associated with a forging and forming press. In Building 9204-02, natural gas is used to heat two electrolytic cells. The maximum rated heat input to the burners on each cell is 550,000 Btu/h.

All of the combustion units burning natural gas are served through the fuel supply and distribution system and are reported as combined emissions consistent with the provisions of 40 CFR 98.36(c)(3). The Tier 1 Calculation Method was used to calculate GHGs from Y-12. The amount of natural gas supplied to the site, along with the fuel use logs, provides basic information required for calculating GHG emissions.

The emissions report is submitted electronically in a format specified by the EPA. Each report is signed by a designated representative of the owner or operator, certifying under penalty of law that the report has been prepared in accordance with the requirements of the rule. The total amount of GHGs, subject to the mandatory reporting rule, emitted from Y-12, is shown in Table 4.10. The decrease in emissions from 2010 to 2017 is associated with the fact that coal is no longer burned since the natural gas-fired steam plant became operational. The slight increase in

CO_2e emissions was because fuel oil was burned for a few days in December 2018. A slightly decrease in CO_2e emissions in 2022 was primarily due to no oil and less natural gas being burned in the steam plant boilers.

Table 4.10. Greenhouse gas emissions from Y-12 stationary fuel combustion sources

Year	GHG emissions (metric tons CO_2e)
2010	97,610
2011	70,187
2012	63,177
2013	61,650
2014	58,509
2015	51,706
2016	50,671
2017	50,292
2018	51,010
2019	45,971
2020	46,126
2021	43,812.7
2022	43,224.2

Acronyms:
CO_2e = CO_2 equivalent
GHG = greenhouse gas
Y-12 = Y-12 National Security Complex

4.4.1.6. Hazardous Air Pollutants (Nonradiological)

Beryllium emissions from machine shops are regulated under a state-issued permit and are subject to a limit of 10 g/24 h. Compliance is demonstrated through a onetime stack test and through monitoring of control device operations. Hydrogen fluoride is used at one emission source, and emissions are controlled through the use of scrubber systems. The beryllium control devices and the scrubber systems were monitored during 2022 and were found to be operating properly.

Methanol is released as fugitive emissions (e.g., pump and valve leaks) as part of the brine and methanol system. Methanol is subject to state air permit requirements; however, due to the nature of its release (fugitive emissions only), no specific emission limits or mandated controls exist.

Mercury is a significant legacy contaminant at Y-12, and cleanup is being addressed by DOE EM. Like methanol emissions, mercury air emissions from legacy sources are fugitive in nature and, therefore, are not subject to specific air emission limits or controls. On-site monitoring of mercury is conducted as discussed in Section 4.4.2.1.

In 2007, EPA vacated a proposed Maximum Achievable Control Technology standard that was intended to minimize hazardous air pollutant emissions. At that time, a case-by-case Maximum Achievable Control Technology review was conducted as part of the construction-permitting process for the Y-12 replacement steam plant. The new natural gas-fired steam plant became operational on April 20, 2010, and coal is no longer combusted. Specific conditions aimed at minimizing hazardous air pollutant emissions from the new steam plant were incorporated into the operating permit issued on January 9, 2012, as discussed in Section 4.4.1. In addition, the boiler Maximum Achievable Control Technology standard was revised and reissued on January 31, 2013. TDEC issued a minor modification to the Title V air permit on October 29, 2014, which included the new boiler Maximum Achievable Control Technology requirements. The new requirements (work practice standards) include conducting annual tune-ups and a onetime energy assessment of the boilers to meet these requirements.

The steam plant has no numeric emission limit requirements. The new rule requires that a onetime energy assessment for the steam plant must be completed on or after January 1, 2008. The new rule requires that tune-ups for the boilers must be completed 13 months from the previous tune-ups. To comply with that requirement, an energy assessment for the Y-12 Steam Plant, performed by a qualified energy assessor, was completed in July 2013. The tune-ups for boilers were completed on February 21 and 22, 2022.

Unplanned releases of hazardous air pollutants are regulated through risk management planning regulations. Y-12 personnel have determined no processes or facilities contain inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to Clean Air Act, Title III, Section 112(r), "Accidental Release Prevention/Risk Management Plan Rule." Therefore, Y-12 is not subject to that rule. Procedures are in place to continually review new processes and/or process changes against the rule thresholds.

EPA has created multiple national regulations to reduce air emissions from reciprocating internal combustion engines. Two types of federal air standards are applicable to reciprocating internal combustion engines—new source performance standards (40 CFR 60, Subpart IIII), and NESHAP (40 CFR 63, Subpart DDDDD). The compression ignition engines and generators located at Y-12 are subject to these rules. EPA is concerned how reciprocating internal combustion engines are used and the emissions generated from these engines in the form of both hazardous air pollutants and criteria pollutants.

All previous stationary, emergency engines and generators were listed in Y-12's Title V air permit application as insignificant activities. However, on January 16, 2013, EPA finalized revisions to standards to reduce air pollution from stationary engines that generate electricity and power equipment at sites of major sources of hazardous air pollutants. Regardless of engine size, the rules apply to any existing, new, or reconstructed stationary reciprocating internal combustion engine located at a major source of hazardous air pollutant emissions.

To comply with the rules, Y-12 prepared a significant permit modification to its Title V (Major Source) Operating Air Permit to add numerous stationary, emergency use engines and generators located throughout Y-12. The permit application was submitted to TDEC on May 6, 2013, for review and approval. TDEC downgraded the significant modification to a minor modification per EPA's review and request. In a prior, updated permit application for renewal of Y-12's Title V (Major Source) Operating Air Permit dated March 9, 2011, Y-12 staff identified 40 CFR 60, Subpart IIII, and Standards of Performance for Stationary Compression Ignition Internal Combustion Engines, as requirements applicable to the stationary, emergency use engines located at Y-12. TDEC issued Y-12 a minor permit modification to the Title V air permit on March 3, 2014, for the emergency engines and generators. Compliance for the engines and generators is determined through monthly records of the operation of the engines and generators that are recorded through a nonresettable hour meter on each engine and generator. Documentation of how many hours are spent for emergency operation, maintenance checks and readiness testing, and nonemergency operation must be maintained. Each engine and generator must use only diesel fuel with low sulfur content (15 parts per million) and an acetane index of 40. The vendor, Rogers Petroleum, supplied a onetime statement certifying that all diesel fuel will contain no more than 15 parts per million of sulfur by weigh; and will either have a minimum cetane index of 40 or a maximum aromatic content of 35 volume percent.

Since the above rules were adopted into Tennessee Air Pollution Control Regulations 0400-30, Chapters 38 and 39, the emergency engines and generators can be considered an insignificant activity if the potential to emit is below the significance thresholds (less than 5 tons/yr of each criteria pollutant and less than 1,000 lb/yr of any hazardous air pollutant evaluated at a 500 h/yr limit). There was also a change to Chapter 9 of Tennessee Air Pollution Control Regulations that allows for stationary engines to be eligible to be considered insignificant activities. Condition D14 of the Title V Operating Air Permit 571832 was amended to incorporate new language specifying stationary reciprocating internal combustion engines are eligible to be considered insignificant activities that must comply with any underlying applicable rules associated with a stationary internal combustion engine.

The emergency engines and generators are used to provide power for critical systems in the event of electrical power failures and outages at Y-12. The engines and generators operate exclusively as emergency engines and generators. Based upon historical usage of the emergency engines, generators, and fire water pumps, and EPA's 500 h default assumption (maximum hour usage), calculations verify and confirm that potential emissions from each stationary, emergency, internal combustion engine less than 645 hp qualifies, or should be reclassified as an insignificant activity, because the potential to emit is well below the significance thresholds of less than 5 tons/yr of each regulated air pollutant that is not a hazardous air pollutant, and less than 1,000 lb/yr of any hazardous air pollutant, in accordance with Tennessee Air Pollution Control Regulations 1200-03-09-.04(5)(a)4(i). Approximately 95 percent of Y-12's stationary, emergency engines, generators, and fire water pumps are considered and/or reclassified as an insignificant activity in accordance with the regulation. These engines are listed in Y-12's Title V air permit.

4.4.2. Ambient Air

To understand the complete picture of ambient air monitoring in and around Y-12, data must be considered from on- and off-site monitoring conducted specifically for Y-12, DOE reservation-wide monitoring, and on- and off-site monitoring conducted by EPA and TDEC personnel.

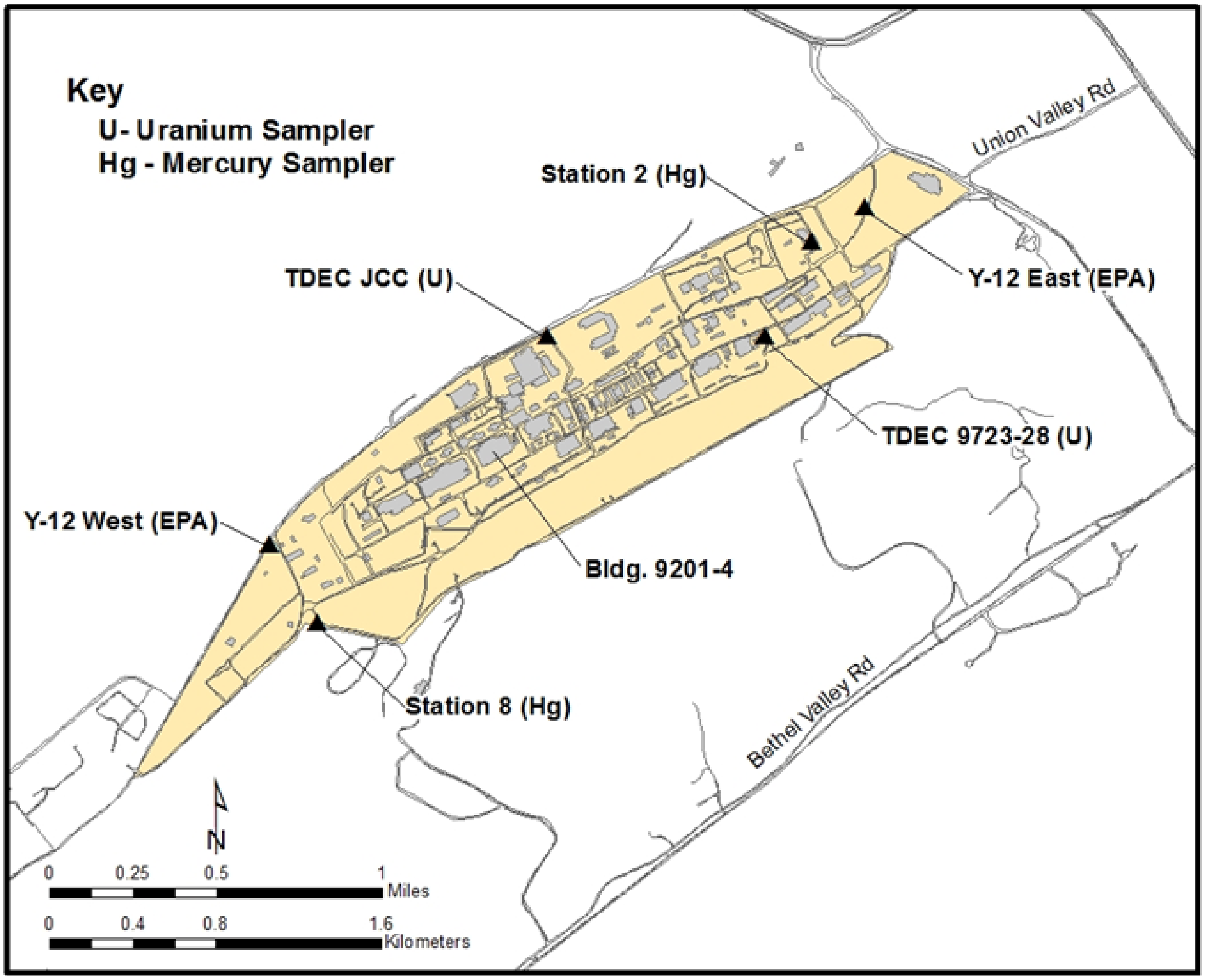
No federal regulations, state regulations, or DOE orders require ambient air monitoring within the Y-12 boundary; however, on-site ambient air monitoring for mercury and radionuclides is conducted as a best management practice. With the reduction of plant operations and improved emission and administrative controls, levels of measured pollutants have decreased significantly during the past several years. In addition, major processes that emit EU and DU are equipped with stack samplers that have been reviewed and approved by EPA to meet requirements of the NESHAP regulations.

4.4.2.1. Mercury

The Y-12 Ambient Air Monitoring Program for mercury was established in 1986 as a best management practice. The objectives of the program have been to maintain a database of mercury concentrations in ambient air, to track long-term spatial and temporal trends in ambient mercury vapor, and to demonstrate protection of the environment and human health from releases of mercury to the atmosphere. Originally four monitoring stations were operated at Y-12, including two within the former West End Mercury Area at Y-12. The two atmospheric mercury monitoring stations currently operating at Y-12—AAS2 and AAS8—are located near the east and west boundaries, respectively (Figure 4.12). Since their establishment in 1986, AAS2 and AAS8 have monitored mercury in ambient air continuously with the exception of short intervals of downtime because of electrical or equipment outages.

In addition to the monitoring stations located at Y-12, two additional monitoring sites were operated—a reference site (Rain Gauge 2) was operated on Chestnut Ridge in the Walker Branch Watershed for a 20-month period in 1988 and 1989 to establish a reference concentration and a site was operated at New Hope Pond for a 25-month period from August 1987 to September 1989.

To determine mercury concentrations in ambient air, airborne mercury vapor is collected by pulling ambient air through a sampling train consisting of a Teflon filter and an iodinated-charcoal sampling trap. A flow-limiting orifice upstream of the sampling trap restricts airflow through the sampling train to about 1 L/min. Actual flows are measured bi-weekly with a calibrated Gilmont flowmeter in conjunction with the bi-weekly change-out of the sampling trap. The charcoal in each trap is analyzed for total mercury using cold vapor atomic fluorescence spectrometry after acid digestion. The average concentration of mercury vapor in ambient air for each 14-day sampling period is then calculated by dividing the total mercury per trap by the volume of air pulled through the trap during the corresponding 14-day sampling period.



Acronyms:
EPA = US Environmental Protection Agency (sampler)
TDEC = Tennessee Department of Environment and Conservation
JCC = Jack Case Center

Figure 4.12. Locations of ambient air monitoring stations at Y-12

As reported previously, average mercury concentration at the ambient air monitoring sites has declined significantly since the late 1980s. Recent average annual concentrations at the two boundary stations are comparable to concentrations measured in 1988 and 1989 at the Chestnut Ridge reference site (Table 4.11). Average mercury concentration at the AAS2 site for 2022 is 0.0025 μg/m^3 (N = 25), comparable to averages measured since 2003. After an increase in average concentration at AAS8 for the period 2005 through 2007, thought to be possibly due to increased demolition and decommissioning work on the west end, the average concentration at AAS8 for 2022 was 0.0025 μg/m^3 (N = 25), similar to levels reported since 2008 and the early 2000s.

Table 4.11 summarizes the 2022 mercury results with results from the 1986 through 1988 period included for comparison. Figure 4.20 illustrates temporal trends in mercury concentration for the two active mercury monitoring sites for the period since the inception of the program in 1986 through 2022 [parts (a) and (b)] and seasonal trends at AAS8 from 1994 through 2022 [part (c)]. The dashed line superimposed on the plots in Figure 4.13(a) and (b) is the EPA reference concentration of 0.3 μg/m^3 for chronic inhalation exposure. The large increase in mercury concentration at AAS8 observed in the late 1980s [part (b)] was thought to be related to disturbances of mercury-contaminated soils and sediments during installation of the Perimeter Intrusion Detection and Assessment System and storm drain restoration projects underway at that time within the West End Mercury Area. In Figure 4.13(c), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2022.

Table 4.11. Summary of data for the Y-12 Ambient Air Monitoring Program for mercury, CY 2022

Ambient air monitoring stations	Mercury vapor concentration (μg/m^3)			
	2022 Minimum	2022 Maximum	2022 Average	1986–1988[a] Average
AAS2 (east end of the Y-12 Complex)	0.0001	0.0045	0.0025	0.010
AAS8 (west end of the Y-12 Complex)	0.0010	0.0049	0.0025	0.033
Reference site, Rain Gauge 2 (1988[b])	N/A	N/A	N/A	0.006
Reference site, Rain Gauge 2 (1989[c])	N/A	N/A	N/A	0.005

[a] *Period in late 1980s with elevated ambient air mercury levels; shown for comparison.*
[b] *Data for period from February 9 through December 31, 1988.*
[c] *Data for period from January 1 through October 31, 1989.*
Acronyms:
AAS = ambient air (monitoring) station   CY = calendar year

In conclusion, 2022 average mercury concentrations at the two mercury monitoring sites were comparable to reference levels measured for the Chestnut Ridge reference site in 1988 and 1989. More importantly, measured concentrations continue to be well below current environmental and occupational health standards for inhalation exposure to mercury vapor (i.e., the National Institute for Occupational Safety and Health recommended exposure limit of 50 μg/m^3, time-weighted average for up to a 10-h workday, 40-h workweek; the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 μg/m^3 as a time-weighted average for a normal 8-h workday and 40-h workweek; and the current EPA reference concentration of 0.3 μg/m^3 for elemental mercury for a continuous inhalation exposure to the human population without appreciable risk of harmful effects during a lifetime).

4.4.2.2. Quality Control

A number of QA/quality control (QC) steps are taken to ensure the quality of the data for Y-12 mercury in the Ambient Air Monitoring Program.

An hour meter records the actual operating hours between sample changes. This allows for correction of total flow in the event of power outages during the weekly sampling interval.

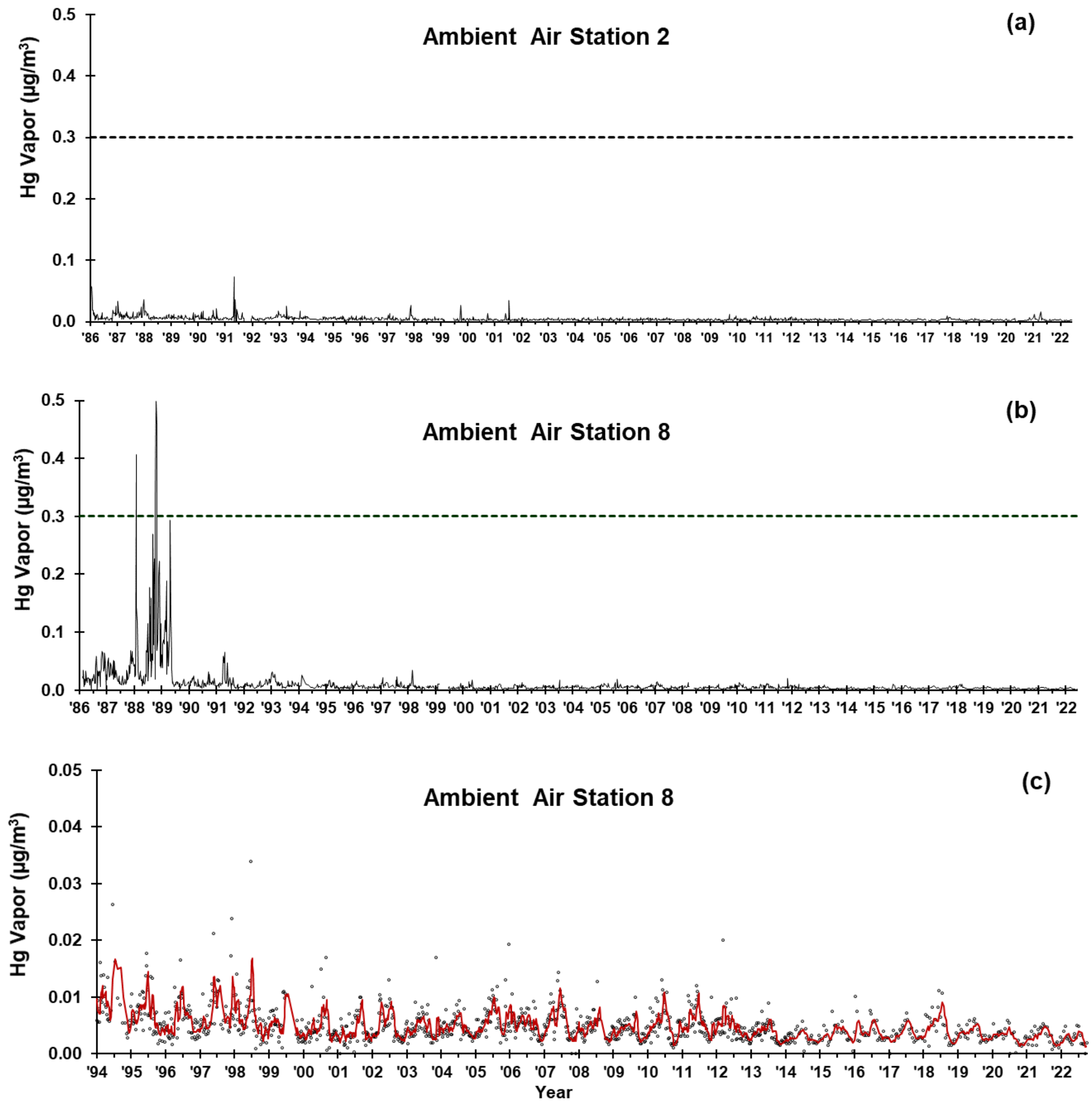


Figure 4.13. Temporal trends in mercury vapor concentration for the boundary monitoring stations at Y-12, July 1986 to December 2022 [(a) and (b)] and January 1994 to December 2022 for ambient air station 8 [(c)]

In Figure 4.13, the dashed lines superimposed on (a) and (b) represent the EPA reference concentration of 0.3 µg/m³ for chronic inhalation exposure. In (c) (note different concentration scale), a monthly moving average has been superimposed over the data to highlight seasonal trends in mercury at AAS8 from January 1993 to December 2021, with higher concentrations generally measured during the warm weather months.

The Gilmont correlated flowmeter, used for measuring flows through the sampling train, is purchased annually or, if not new, shipped back to the manufacturer annually for calibration in accordance with standards set by the National Institute of Standards and Technology.

A minimum of 5 percent of the samples in each batch submitted to the analytical laboratory are blank samples. The blank sample traps are submitted “blind” to verify trap blank values and to serve as a field blank for diffusion of mercury vapor into used sample traps during storage before analysis.

To verify the absence of mercury breakthrough, 5 percent to 10 percent of the field samples have the front (upstream) and back segments of the charcoal sample trap analyzed separately. The absence of mercury above blank values on the back segment confirms the absence of breakthrough.

Chain-of-custody forms track the transfer of sample traps from the field technicians all the way to the analytical laboratory.

A field performance evaluation is conducted annually by the project manager to ensure that proper procedures are followed by the sampling technicians. No problems were noted during sample collection at time of evaluation. The evaluation was conducted on November 22, 2022.

Analytical QA/QC requirements include the following:

- Use of prescreened and/or laboratory purified reagents.
- Analysis of at least two method blanks per batch.
- Analysis of standard reference materials.
- Analysis of laboratory duplicates (one per 10 samples; any laboratory duplicates differing by more than 10 percent at five or more times the detection limit are to be rerun [third duplicate] to resolve the discrepancy).
- Archiving all primary laboratory records for at least 1 year.

4.4.2.3. Ambient Air Monitoring Complementary to Y-12 Ambient Air Monitoring

Ambient air monitoring is conducted at multiple locations near ORR to measure radiological and other selected parameters. These monitors are operated in accordance with DOE orders. Their locations were selected so that areas of potentially high exposure to the public are monitored continuously for parameters of concern. This monitoring provides direct measurement of airborne concentrations of radionuclides and other hazardous air pollutants, allows facility personnel to determine the relative level of contaminants at the monitoring locations during an emergency, verifies that the contributions of fugitive and diffuse sources are insignificant, and serves as a check on dose-modeling calculations. As part of the ORR network, an ambient air station located in the Scarboro Community of Oak Ridge (Station 46) measures off-site impacts of Y-12 operations. This station is located near the theoretical area of maximum public pollutant concentrations as calculated by air quality modeling. ORR network stations are also located at the east end of Y-12 (Station 40) and just south of the city Country Club Estates neighborhood (Station 37).

In addition to this monitoring, TDEC and EPA perform ambient air monitoring to characterize the region in general and to characterize and monitor DOE operations locally.

Specific to Y-12 operations, there are three uranium ambient air monitors within the Y-12 boundary that, since 1999, have been used by TDEC personnel in their environmental monitoring program. Each monitor uses 47-mm borosilicate glass-fiber filters to collect particulates as air is pulled through the units. The monitors control airflow with a pump and rotometer set to average about 2 standard ft^3/min. During 2012, these uranium monitors at Stations 4, 5, and 8 were phased out of service, and three additional high volume samplers (Figure 4.12) are now being used by TDEC to provide isotopic uranium monitoring capability. These are located at Station 2, on the east side of the Jack Case Center, and on the south side of the Building 9723-28 change house. EPA performs ambient air monitoring on the east end of the plant near the intersection of Scarboro Road and Bear Creek Road and on the west end of the plant near the intersection of Bear Creek Road and Old Bear Creek Road. This monitoring station was relocated near Station 8, as depicted in Figure 4.12.

In addition, TDEC DOE Oversight Division air quality monitoring includes several other types of monitoring on ORR, such as the following:

- RADNet air monitoring
- Fugitive radioactive air emission monitoring
- Ambient VOC air monitoring
- Perimeter air monitoring
- Real-time monitoring of gamma radiation
- Ambient gamma radiation monitoring using external dosimetry
- Program-specific monitoring associated with infrastructure-reduction activities

Results of these activities are summarized in annual status reports, which are issued by the TDEC DOE Oversight Division.

The state of Tennessee also operates a number of regional monitors to assess ambient concentrations of criteria pollutants such as sulfur dioxide, particulate (various forms), and ozone for comparison against ambient standards. The results are summarized and available through EPA and state reporting mechanisms.

4.5. Water Quality Program

Water quality is monitored at Y-12 to satisfy the NPDES permit and the Industrial Wastewater Discharge Permit. It is also monitored in real time to indicate potential adverse conditions that could be causing an impact on water quality in Upper EFPC.

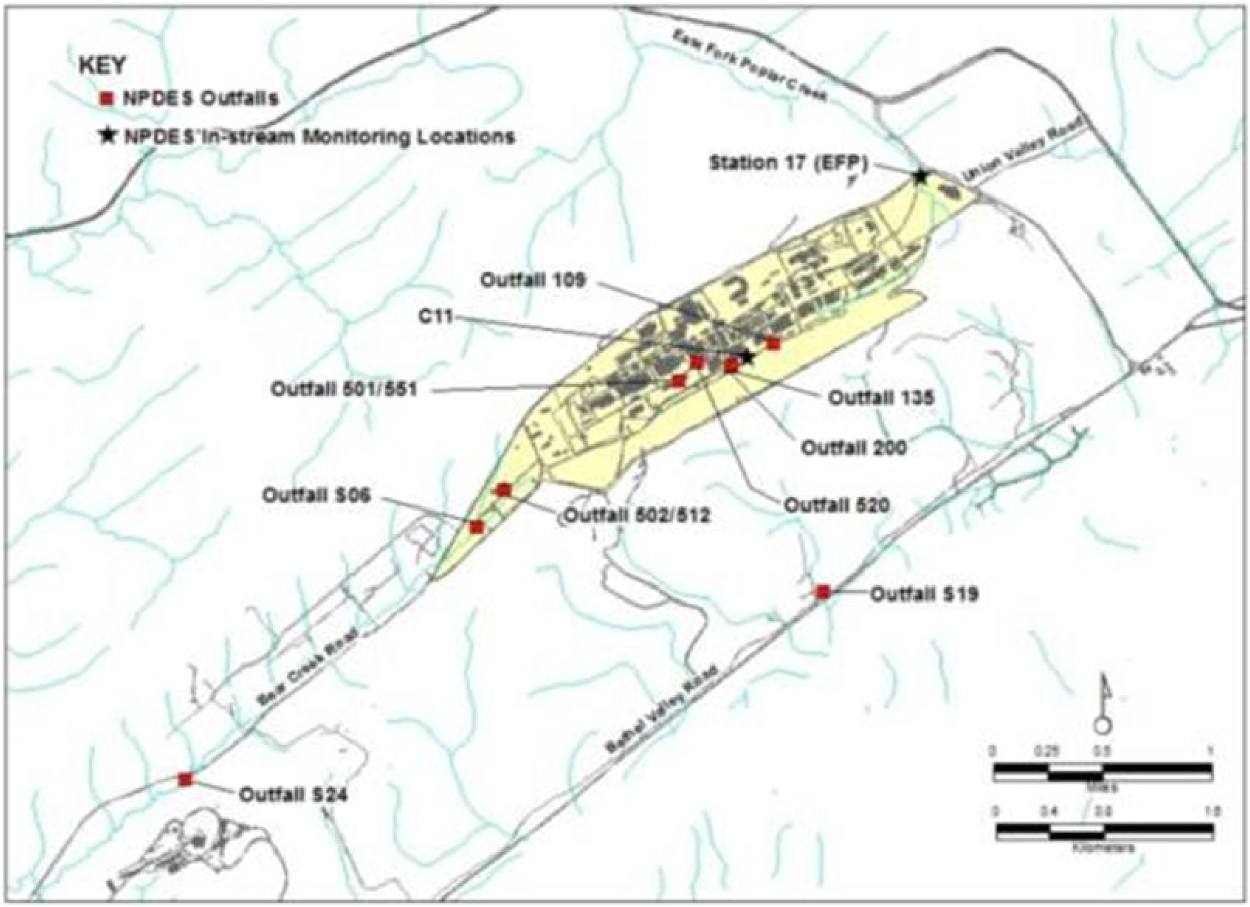
4.5.1. National Pollutant Discharge Elimination System Permit and Compliance Monitoring

For January through September 2022, the Y-12 NPDES permit (TN0002968) required sampling, analysis, and reporting for about 56 outfalls. Major outfalls are shown in Figure 4.14. A new NPDES permit became effective October 1, 2022. (The new permit is currently under appeal in part. Y-12 is working with the regulators to resolve.) The number of outfalls changes as they are eliminated or consolidated or if permitted discharges are added. Currently, Y-12 has outfalls and monitoring points in EFPC, Bear Creek, and several tributaries on the south side of Chestnut Ridge, all of which eventually drain to the Clinch River.

Discharges to surface water allowed under the permit include storm drainage; cooling water; cooling tower blowdown; steam condensate; and treated process wastewaters, including effluents from wastewater treatment facilities. Groundwater inflow into sumps in building basements and infiltration to the storm drain system are also permitted for discharge to the creek. The monitoring data collected by sampling and analyzing permitted discharges are compared with NPDES limits where applicable for each parameter. Some parameters, defined as monitor only, have no specified limits.

The water quality of surface streams near Y-12 is affected by current and legacy operations. Discharges from Y-12 processes flow into EFPC before the water exits Y-12. EFPC eventually flows through the City of Oak Ridge to Poplar Creek and into Clinch River. Bear Creek water quality is affected by area source runoff and groundwater discharges. The NPDES permit requires regular monitoring and storm water characterization in Bear Creek and several of its tributaries.

Requirements of the NPDES permit for 2022 were satisfied, and monitoring of outfalls and instream locations indicated excellent compliance. Data obtained as part of the NPDES program, along with other events and observations, are provided in a monthly discharge monitoring report to TDEC. The percentage of compliance with permit discharge limits for 2022 was 100 percent, as shown in Tables 4.12 and 4.13.



Acronyms:
EFP = East Fork Poplar *NPDES = National Pollutant Discharge Elimination System*

Figure 4.14. Major Y-12 National Pollutant Discharge Elimination System outfalls and monitoring locations

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, January–September 2022

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 501 (Central Pollution Control)							
	pH, standard units			[a]	9.0	[b]	0
	Total suspended solids			31.0	40.0	[b]	0
	Total toxic organic				2.13	[b]	0
	Hexane extractables			10	15	[b]	0
	Cadmium	0.16	0.4	0.07	0.15	[b]	0
	Chromium	1.0	1.7	0.5	1.0	[b]	0
	Copper	1.2	2.0	0.5	1.0	[b]	0
	Lead	0.26	0.4	0.1	0.2	[b]	0
	Nickel	1.4	2.4	2.38	3.98	[b]	0
	Nitrate/Nitrite				100	[b]	0
	Silver	0.14	0.26	0.05	0.05	[b]	0
	Zinc	0.9	1.6	1.48	2.0	[b]	0
	Cyanide	0.4	0.72	0.65	1.2	[b]	0
	PCB				0.001	[b]	0
Outfall 502 (West End Treatment Facility)							
	pH, standard units			[a]	9.0	100	1
	Total suspended solids		31		40	100	1
	Total toxic organic				2.13	100	1
	Hexane extractables			10	15	100	1
	Cadmium		0.4		0.15	100	1
	Chromium		1.7		1.0	100	1
	Copper		2.0		1.0	100	1
	Lead		0.4		0.2	100	1
	Nickel		2.4		3.98	100	1
	Nitrate/Nitrite				100	100	1
	Silver		0.26		0.05	100	1
	Zinc		0.9		1.48	100	1
	Cyanide		0.72		1.20	100	1
	PCB				0.001	100	1
Outfall 512 (Groundwater Treatment Facility)							
	pH, standard units			[a]	9.0	100	9
	PCB				0.001	100	1
Outfall 520							
	pH, standard units			[a]	9.0	[b]	0
Outfall 200 (North/South pipes)							
	pH, standard units			[a]	9.0	100	40
	Hexane extractables			10	15	100	10
	Cadmium			0.001	0.023	100	9

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, January–September 2022 (continued)

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
	IC_{25} *Ceriodaphnia*			37% Minimum		100	1
	IC_{25} *Pimephales*			37% Minimum		100	1
	Total residual chlorine			0.024	0.042	100	9
Outfall 551							
	pH, standard units			[a]	9.0	100	39
	Mercury			0.002	0.004	100	39
Outfall C11							
	pH, standard units			[a]	9.0	100	10
Outfall 135							
	pH, standard units			[a]	9.0	100	10
	IC_{25} *Ceriodaphnia*			9% Minimum		100	1
	IC_{25} *Pimephales*			9% Minimum		100	1
Outfall 109							
	pH, standard units			[a]	9.0	100	5
	Total residual chlorine			0.010	0.017	100	3
Outfall S19							
	pH, standard units			[a]	9.0	100	1
Outfall S06							
	pH, standard units			[a]	9.0	100	2
Outfall S24							
	pH, standard units			[a]	9.0	100	3
Outfall EFP							
	pH, standard units			[a]	9.0	100	10
Category I outfalls							
	pH, standard units			[a]	9.0	100	34
Category II outfalls							
	pH, standard units			[a]	9.0	100	12
	Total residual chlorine				0.5	100	13
Category III outfalls							
	pH, standard units			[a]	**9.0**	**100**	**6**
	Total residual chlorine			[a]	**0.5**	**100**	**6**

[a] *Not applicable.*
[b] *No discharge.*
Acronyms:
IC_{25} = 25-percent inhibition concentration
PCB = polychlorinated biphenyl
Y-12 = Y-12 National Security Complex

Table 4.13. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, October–December 2022

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 501 (Central Pollution Control)							
	pH, standard units			[a]	9.0	[b]	0
	Total suspended solids			31.0	40.0	[b]	0
	Total toxic organic				2.13	[b]	0
	Hexane extractables			10	15	[b]	0
	Cadmium	0.16	0.4	0.07	0.15	[b]	0
	Chromium	1.0	1.7	0.5	1.0	[b]	0
	Copper	1.2	2.0	0.5	1.0	[b]	0
	Lead	0.26	0.4	0.1	0.2	[b]	0
	Nickel	1.4	2.4	2.38	3.98	[b]	0
	Nitrate/Nitrite				100	[b]	0
	Silver	0.14	0.26	0.05	0.05	[b]	0
	Zinc	0.9	1.6	1.48	2.0	[b]	0
	Cyanide	0.4	0.72	0.65	1.2	[b]	0
	PCB				0.001	[b]	0
Outfall 502 (West End Treatment Facility)							
	pH, standard units			[a]	9.0	100	0
	Total suspended solids		31		40	100	0
	Total toxic organic				2.13	100	0
	Hexane extractables			10	15	100	0
	Cadmium		0.4		0.15	100	0
	Chromium		1.7		1.0	100	0
	Copper		2.0		1.0	100	0
	Lead		0.4		0.2	100	0
	Nickel		2.4		3.98	100	0
	Nitrate/Nitrite				100	100	0
	Silver		0.26		0.05	100	0
	Zinc		0.9		1.48	100	0
	Cyanide		0.72		1.20	100	0
	PCB				0.001	100	0
Outfall 512 (Groundwater Treatment Facility)							
	pH, standard units			[a]	9.0	100	3
	PCB				0.001	100	0
Outfall 551							
	pH, standard units			[a]	9.0	100	12
	Mercury			0.002	0.004	100	12

Table 4.13. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, October–December 2022 (continued)

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall C11 (Instream EFPC)							
	Temperature				30.5	100	1
	pH			[a]	9.0	100	1
	Ammonia (as N) Summer			1.01	2.02	100	1
	Ammonia (as N) Winter			1.92	3.84	100	0
	Cyanide			0.0052	0.022	100	1
	Cadmium			0.0043	0.0118	100	1
	Copper			0.0407	0.064	100	1
	Lead			0.0244	0.6265	100	1
	Nickel			0.189	1.705	100	1
	Silver				0.0081	100	1
	Zinc			0.646	0.641	100	1
	Selenium			0.0031	0.020	100	1
	Total Residual Chlorine			0.011	0.019	100	1
Outfall C03 (Instream EFPC)							
	Temperature				30.5	100	1
	pH			[a]	9.0	100	1
	Ammonia (as N) Summer			1.01	2.02	100	1
	Ammonia (as N) Winter			1.92	3.84	100	0
	Cyanide			0.0052	0.022	100	1
	Cadmium			0.0043	0.0118	100	1
	Copper			0.0407	0.064	100	1
	Lead			0.0244	0.6265	100	1
	Nickel			0.189	1.705	100	1
	Silver				0.0081	100	1
	Zinc			0.646	0.641	100	1
	Selenium			0.0031	0.020	100	1
	Total Residual Chlorine			0.011	0.019	100	1

Table 4.13. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, October–December 2022 (continued)

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall EFP (Station 17)							
	Temperature				30.5	100	1
	pH			*a*	9.0	100	1
	Ammonia (as N) Summer			1.01	2.02	100	1
	Ammonia (as N) Winter			1.92	3.84	100	0
	Cyanide			0.0052	0.022	100	1
	Cadmium			0.0043	0.0118	100	1
	Copper			0.0407	0.064	100	1
	Lead			0.0244	0.6265	100	1
	Nickel			0.189	1.705	100	1
	Silver				0.0081	100	1
	Zinc			0.646	0.641	100	1
	Selenium			0.0031	0.020	100	1
	Total Residual Chlorine			0.011	0.019	100	1

**Limits are under appeal.*
[a] Not applicable.
[b] No discharge.
Acronyms:
IC25 = 25-percent inhibition concentration
PCB = polychlorinated biphenyl
Y-12 = Y-12 National Security Complex

4.5.2. Radiological Monitoring Plan and Results

Y-12 has a radiological monitoring plan to address compliance with DOE orders that is provided to TDEC as a matter of comity under NPDES Permit TN0002968. Y-12 submitted results from the radiological monitoring plan quarterly as an addendum to the NPDES Discharge Monitoring Report. There were no discharge limits set by the NPDES permit for radionuclides; the requirement is to monitor and report. In October 2022, the new NPDES permit became effective, and the requirement for a radiological monitoring plan was removed. The radiological monitoring plan was developed based on an analysis of operational history, expected chemical and physical relationships, and historical monitoring results.

Under the existing plan, effluent monitoring is conducted at four types of locations: treatment facilities, other point source and area source discharges, instream locations, and storm water runoff from production area roofs. Operational history and past monitoring results provide a basis for parameters routinely monitored under the plan (Table 4.14). The *Radiological Monitoring Plan for the Oak Ridge Y-12 National Security Complex: Surface Water* (B&W Y-12 2012) was revised and reissued in January 2012 and again in October 2020. The revised plan was implemented on November 1, 2020. This revision added Outfall 109 and roof runoff from production areas.

Table 4.14. Radiological parameters monitored at Y-12, 2020

Parameters	Specific isotopes	Rationale for monitoring
Uranium isotopes	^{238}U, ^{235}U, ^{234}U, total U, weight % ^{235}U	These parameters reflect the major activity, uranium processing, throughout the history of Y-12 and are the dominant detectable radiological parameters in surface water.
Fission and activation products	^{90}Sr, ^{99}Tc, ^{137}Cs	These parameters reflect a minor activity at Y-12, processing recycled uranium from reactor fuel elements from the early 1960s to the late 1980s, and will continue to be monitored as tracers for beta and gamma radionuclides, although their concentrations in surface water are low.
	^{3}H	Tritium is not expected to be high in fuel elements, because tritium is produced primarily as an activation product in reactor coolants. Tritium is highly mobile and is detected in groundwater samples associated with the S-3 Site.
Transuranium isotopes	^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$	These parameters are related to recycle uranium processing. Monitoring has continued because of their half-lives and presence in groundwater.
Other isotopes of interest	^{232}Th, ^{230}Th, ^{228}Th, ^{226}Ra, ^{228}Ra	These parameters reflect historical thorium processing and natural radionuclides necessary to characterize background radioisotopes.

Acronym:
Y-12 = Y-12 National Security Complex

Radiological monitoring during storm water events is part of the storm water monitoring program. Uranium is monitored at three major EFPC storm water outfalls, two instream monitoring locations, and an outfall on Bear Creek. In addition, the monthly 7-d composite sample for radiological parameters taken at Station 17 on EFPC likely includes rain events.

Radiological monitoring plan locations sampled in 2022 are noted on Figure 4.15. Table 4.15 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards for radionuclides measured in 2022. Radiological data were well below the allowable derived concentration standards.

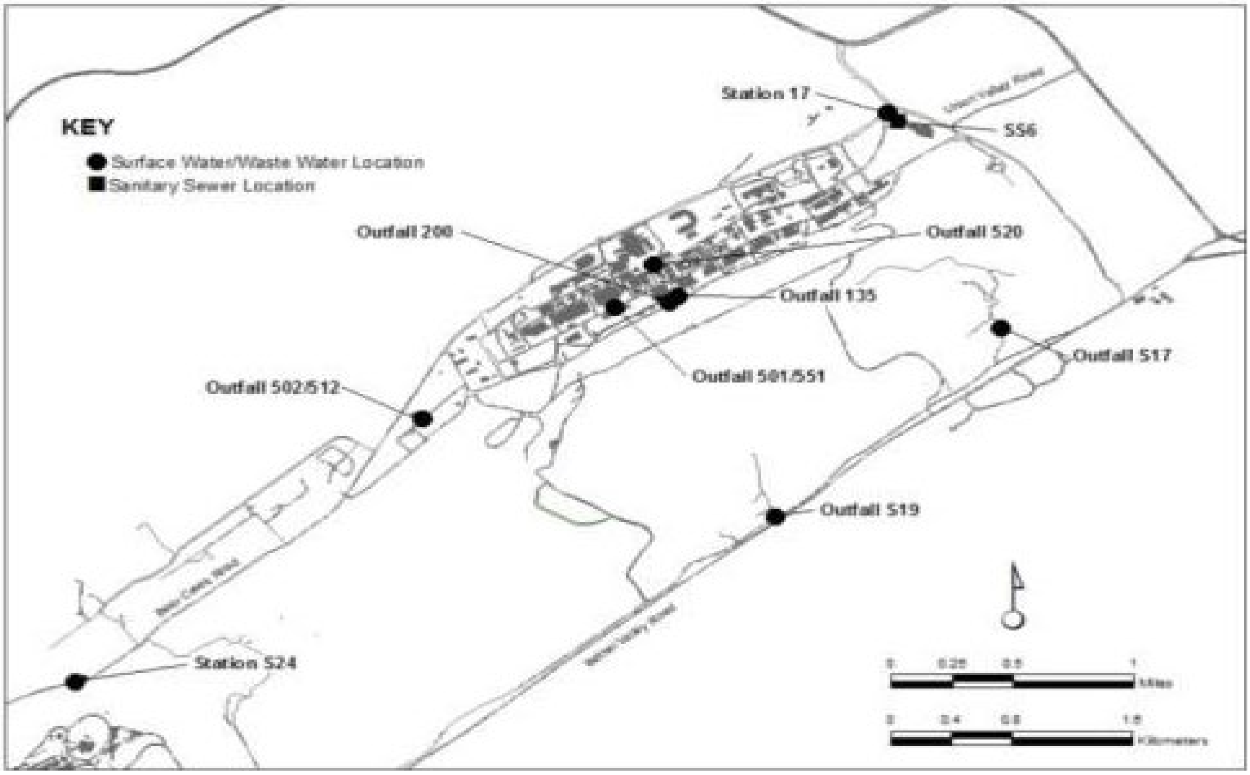


Figure 4.15. Surface water and sanitary sewer radiological sampling locations at Y-12

Table 4.15. Summary of Y-12's radiological monitoring plan sample requirements and 2022 results

Location	Sample frequency	Sample type	Sum of derived concentration standards percentages
Y-12 wastewater treatment facilities			
Central Pollution Control Facility	1/batch	Composite during batch operation	No flow
West End Treatment Facility	1/batch	24-h composite	0.45
Groundwater Treatment Facility	4/yr	24-h composite	1.5
Central Mercury Treatment Facility	4/yr	24-h composite	0.33
Other Y-12 point and area source discharges			
Outfall 109	4/yr	24 h composite	1.3
Outfall 135	4/yr	24-h composite	0.53
Kerr Hollow Quarry	1/yr	24-h composite	0.18
Rogers Quarry	1/yr	24-h composite	0.044
Y-12 instream locations			
Outfall S24	1/yr	7-d composite	4.4
East Fork Poplar Creek, complex exit (east)	1/month	7-d composite	0.86
North/south pipes	1/month	24-h composite	1.6
Y-12 Production roof runoff			
9215 Fan Room	4/yr	Grab during rain	16
Stack 47	4/yr	Grab during rain	33

Acronym: *Y-12 = Y-12 National Security Complex*

In 2022, the total mass of uranium and associated curies released from Y-12 at the easternmost monitoring station, Station 17 on Upper EFPC, was 167 kg or 0.071 Ci, as shown in Table 4.16.

Table 4.16. Uranium release from Y-12 to the off-site environment as liquid effluent, 2014–2022

Year	Quantity released	
	Ci[a]	kg
Station 17		
2014	0.061	90
2015	0.068	116
2016	0.045	88
2017	0.080	154
2018	0.084	205
2019	0.079	203
2020	0.082	173
2021	0.063	139
2022	0.071	167

[a] 1 Ci = 3.7E+10 Bq.

Acronym:

Y-12 = Y-12 National Security Complex

Figure 4.16 illustrates a 6-year trend of these releases. The total release is calculated by multiplying the average concentration (g/L) by the average flow (million gal/d). Converting units and multiplying by 365 d/yr yields the calculated discharge.

Y-12 is permitted to discharge domestic wastewater to the City of Oak Ridge's publicly owned treatment works. Radiological monitoring of the sanitary sewer system discharge is conducted and reported to the city, although no city-established radiological limits exist. Alpha and beta levels are measured weekly, and subsequent uranium analyses are performed if the alpha or beta levels are above prescribed levels. Potential sources of radionuclides discharging to the sanitary sewer have been identified in previous studies at Y-12 as part of an initiative to meet goals to keep levels as low as reasonably achievable. Results of radiological monitoring were reported to the City of Oak Ridge in 2022 quarterly monitoring reports.

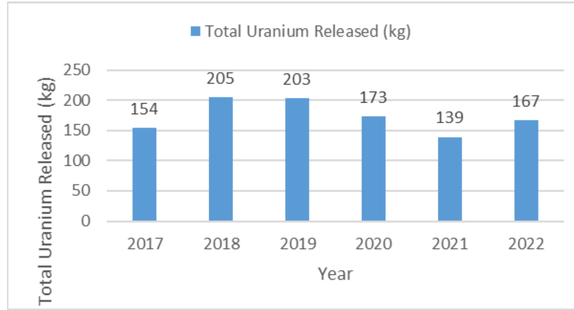


Figure 4.16. Six-year trend of Y-12 uranium releases to East Fork Poplar Creek

4.5.3. Storm Water Pollution Prevention

A new NPDES permit was issued to Y-12 with an effective date of October 2022. The October 2022 NPDES permit implements several changes to the storm water program. The changes include new requirements for the storm water pollution prevention as well as new sampling requirements and locations.

The new permit requirements are reflected in the Y-12 storm water pollution prevention plan, which identifies areas that can reasonably be expected to contribute contaminants to surface water bodies via storm water runoff and describes the development and implementation of storm water management controls to reduce or eliminate the discharge of such pollutants. This plan requires characterizing storm water by sampling during storm events, implementing measures to reduce storm water pollution, facility inspections, and employee training.

The new permit sampling requirements include a major change in the removal of sector benchmarks comparisons for storm water sampling results and the introduction of permit-specific benchmarks and alert values. For the October 2022 NPDES permit, storm water monitoring will be performed in 2023 on two levels—category outfalls and wet weather locations. Y-12 also completed the storm water monitoring under the previous permit requirements that were initiated at the beginning of 2022. The prior NPDES permit defined Y-12 as a fabricated metal products industry and required storm water monitoring be conducted for three additional "sectors." These sectors are defined in the Tennessee Storm Water Multi-Sector General Permit for Industrial Activities, Permit No. TNR050000, effective July 19, 2020. Some sectors have prescribed benchmark values. The benchmark and median values used for comparison purposes in this report are provided in the prior Y-12 NPDES permit.

Storm water sampling was conducted in 2022 during rain events that occurred on April 5, 2022; July 18, 2022; and November 11, 2022. Results were published in the *Annual Stormwater Report for the Y-12 National Security Complex* (CNS, 2022a), which was submitted to TDEC Division of Water Resources in January 2023. Consistent with permit requirements, storm water monitoring is performed each year for sector outfalls, three major outfalls that drain large areas of Y-12, and two instream monitoring locations on EFPC (Figure 4.16).

Sampling conducted in 2022 revealed the following:

- Outfall 014: The aluminum concentration was above the benchmark value. The exact cause of the aluminum result being above the benchmark for Outfall 014 is unknown; however, it is noteworthy that construction activity for a new Fire Station is underway on the Outfall 014 network.
- Outfall 067: The aluminum and nitrate plus nitrite nitrogen were both slightly above the benchmark values. The cause of the elevated results is unknown.
- Outfall S30: The total suspended solids and copper values were above the benchmark values but well below the sector median values. The cause of the elevated results is unknown.
- Outfall S17: The total suspended solids value was above the sector median value. The cause of the elevated result is unknown.
- Outfall S18: The total suspended solids value was above the sector median value. Operations at the ORR Landfill are likely the cause of the elevated result.
- Outfall S06: The magnesium concentration exceeds both the benchmark and sector median values, and the cyanide concentration is slightly above the sector median value. The geology of this portion of the Tennessee valley typically results in abnormally high levels of magnesium, and the cause of the elevated cyanide result is unknown.

An area of concern continues to be the concentration of mercury being measured in the discharge from Outfall 014. Since the first unexpected, elevated result in 2013 (7.12 µg/L), this sector outfall has been on an annual monitoring schedule; however, no monitoring was conducted in 2018 or 2019 due to the degraded condition of the outfall piping and the inability to gather reliable flow rate data. Maintenance work on Outfall 014 has now been completed, and sampling was resumed in 2020. Data collected to date are presented in Table 4.17.

Table 4.17. Mercury concentrations at Outfall 014

CY	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mercury concentration (µg/L)	7.12	0.892	9.11	0.49	0.237	N/A	N/A	1.66	4.5	1.03

Acronyms: *CY = calendar year   N/A = not available*

4.5.4. Ambient Surface Water Quality

A network of real-time monitors located at three instream locations along Upper EFPC is used to monitor key indicators of water quality. The Surface Water Hydrological Information Support System is available for real-time water quality measurements, such as pH, temperature, dissolved oxygen, conductivity, and chlorine. The locations are shown in Figure 4.17. The primary function of the Surface Water Hydrological Information Support System is to indicate potential adverse conditions that could be causing an impact on water quality in Upper EFPC. It is operated as a best management practice.

Additional sampling of springs and tributaries is conducted in accordance with Y-12's Groundwater Protection Program to monitor trends throughout the three hydrogeologic regimes (see Section 4.6).

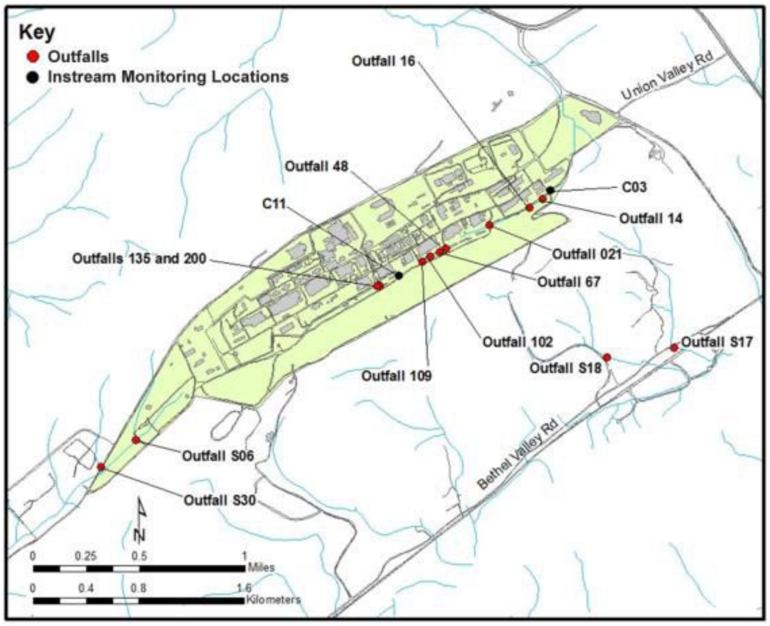


Figure 4.17. Y-12 storm water monitoring locations, East Fork Poplar Creek

4.5.5. Industrial Wastewater Discharge Permit

Industrial and Commercial User Wastewater Discharge Permit 1-91 defines requirements for discharging wastewaters to the sanitary sewer system as well as prohibitions for certain types of wastewaters. It prescribes requirements for monitoring certain parameters at the East End Sanitary Sewer Monitoring Station. The permit sets limits for most parameters. Samples for gross-alpha and gross-beta are taken in a weekly 24-h composite sample. The sample is analyzed for uranium if the alpha or beta values exceed certain levels. Other parameters (including oil and grease, solids, and biological oxygen demand) are monitored on a monthly basis. Metals and organic parameters are monitored once per quarter. Results of compliance sampling are reported quarterly. Flow is measured continuously at the monitoring station.

As part of the City of Oak Ridge's pretreatment program, city personnel use the east end monitoring station (also known as SS6) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct compliance inspections twice a year.

Monitoring results from 2022 are listed in Table 4.18. Two permit limits were exceeded in 2022. There was one exceedance of the 2,100-gal/min instantaneous flow limit and one exceedance of the 500,000 gpd quarterly flow limit. To reduce storm water inflow and infiltration, a project has been initiated to evaluate and rehabilitate approximately 15,000 linear feet of the Y-12 sewage collection system. The project has evaluated the collection system via smoke tests and video inspection and is now performing needed repairs identified during the evaluation. The collection system refurbishment involves manhole relining, pipe bursting, installing cured in place piping, and other repairs. The repair work was completed in the B-449 and C-409A networks. Flow data evaluation indicates this project has reduced inflow and infiltration.

Table 4.18. Y-12 discharge point SS6

Effluent parameter	Number of samples	Average value	Daily maximum (gal/min)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Max flow rate (gal/min)	Continuous	N/A	2,100	N/A	1
Flow (average kgpd) January through March	90	550	N/A	500[b]	1
Flow (average kgpd) April through June	91	374	N/A	500[b]	0
Flow (average kgpd) July through September	92	398	N/A	500[b]	0
Flow (average kgpd) October through December	92	413	N/A	500[b]	0
pH (standard units)	19	N/A	N/A	9 and 6[c]	0
Biochemical oxygen demand	14	<36	N/A	300	0
Kjeldhal nitrogen	13	24.7	N/A	45	0
Phenols—total recoverable	19	<0.072	N/A	0.15	0
Oil and grease	13	<8.4	N/A	25	0
Suspended solids	13	63	N/A	200	0
Cyanide	13	0.0043	N/A	0.006	0
Arsenic	5	<0.0011	N/A	0.01	0
Cadmium	5	<0.0004	N/A	0.0033	0
Chromium, hexavalent	4	<0.006	N/A	0.053	0
Copper	5	0.022	N/A	0.14	0
Iron	5	0.670	N/A	10	0
Lead	5	<0.002	N/A	0.049	0
Mercury	12	0.00104[d]	N/A	0.035[d]	0
Nickel	5	<0.004	N/A	0.021	0
Silver	5	<0.0057	N/A	0.05	0
Zinc	5	0.131	N/A	0.35	0
Molybdenum	5	0.0246	N/A	0.05[e]	N/A
Selenium	5	<0.002	N/A	0.01[e]	N/A
Toluene	4	<0.005	N/A	0.005[e]	N/A
Ammonia	5	19.8	N/A	0.10[e]	N/A
Methanol	4	<1.0	N/A	1.0[e]	N/A
Benzene	4	<0.005	N/A	0.005[e]	N/A
1,1,1-Trichloroethane	4	<0.005	N/A	0.005[e]	N/A
Ethylbenzene	4	<0.005	N/A	0.005[e]	N/A
Carbon tetrachloride	4	<0.005	N/A	0.005[e]	N/A
Chloroform	4	0.005	N/A	0.005[e]	N/A
Tetrachloroethene	4	0.0043	N/A	0.005[e]	N/A
Trichloroethene	4	<0.005	N/A	0.005[e]	N/A
trans-1,2-Dichloroethene	4	<0.005	N/A	0.005[e]	N/A
Methylene chloride	4	<0.005	N/A	0.005[e]	N/A

[a] *Industrial and commercial user wastewater permit limits.*
[b] *Average daily flow allowed in gal/d.*
[c] *Maximum and minimum value.*
[d] *Units are lb/d.*
[e] *This parameter does not have a permit limit. This value is the required detection limit. All units are mg/L unless noted otherwise.*
Acronyms: *kgpd = thousand gallons per day N/A = not applicable Y-12 = Y-12 National Security Complex*

4.5.6. Quality Assurance and Quality Control

The Environmental Monitoring Management Information System is used to manage surface water monitoring data at Y-12. It uses standard sample definitions to ensure that samples are taken at the correct location at a specified frequency using the correct sampling protocol.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Using standard operating procedures for sample collection and analysis.
- Using chain-of-custody and sample identification, customized chain-of-custody documents, and sample labels provided by the Environmental Monitoring Management Information System.
- Standardizing, calibrating, and verifying instruments.
- Training sample technicians.
- Preserving, handling, and decontaminating samples.
- Using QC samples (i.e., field and trip blanks, duplicates, and equipment rinses).

Surface water data are entered directly by the analytical laboratory into the Laboratory Information Management System on the day of approval. The Environmental Monitoring Management Information System routinely accesses the Laboratory Information Management System electronically to capture pertinent data. Generally, the system will store data in the form of concentrations.

A number of electronic data management tools enable automatic flagging of data points and allow monitoring and trending of data over time. Field information on all routine samples taken for surface water monitoring is entered in the Environmental Monitoring Management Information System, which also retrieves data nightly from the analytical laboratory. The system then performs numerous data checks, including comparisons of the individual results against any applicable screening criteria, regulatory thresholds, compliance limits, best management practices, or other water quality indicators, and produces required reports.

4.5.7. Biomonitoring Program

The NPDES permit for Y-12 (TN0002968, Part III, Section E) contains chronic toxicity testing requirements. These requirements specify that chronic toxicity testing (a 3-Brood *Ceriodaphnia dubia* survival and reproduction test and a 7-day fathead minnow larval survival and growth test) is required to determine whether the effluent is contributing chronic toxicity to the receiving water. Prior to October 2022, these tests were required annually at Outfalls 135 and 200. A new permit became effective on October 1, 2022, increasing the testing frequency to quarterly, reducing testing to only Outfall 200, and changing the permit limits. Chronic toxicity testing is to be performed using 100 percent effluent and the dilution series shown in Table 4.19, where both the previous and current permit requirements are detailed.

Table 4.20 summarizes the results of the 2022 outfall biomonitoring tests in terms of the 25-percent inhibition concentration (IC_{25}), which is the concentration (i.e., a percentage of full-strength effluent diluted with laboratory control water) of each outfall effluent that causes a 25-percent reduction in the survival or reproduction of water fleas (*Ceriodaphnia dubia*) or the survival or growth of fathead minnow (*Pimephales promelas*) larvae (with respect to these same endpoints for these animals measured in control laboratory water). The lower the value of the IC_{25}, the more toxic the effluent. According to the NPDES permit, toxicity is demonstrated if the IC_{25} is less than or equal to the permit limit. The permit limit for the previous permit was 9-percent whole effluent for Outfall 135 and 37-percent whole effluent for Outfall 200, and the permit limit for the current permit (effective October 1, 2022) is 50-percent whole effluent for Outfall 200.

Table 4.19. Serial dilutions for whole effluent toxicity testing, as a percent of effluent, before October 2022 and after October 1, 2022, with the new permit

Before October 2022						
Outfall 200	Control	0.25 x Permit limit	0.50 x Permit limit	Permit limit	(100+Permit limit)/2	100% Effluent
	0	9.3	18	37	74	100
Outfall 135	Control	0.25 x Permit limit	0.50 x Permit limit	Permit limit	2 x Permit limit	4 x Permit limit
	0	2.3	4.5	9	18	36
Starting October 1, 2022						
Outfall 200	Control	0.25 x Permit limit	0.50 x Permit limit	Permit limit	(100+Permit limit)/2	100% Effluent
	0	12.5	25	50	75	100

Note: *The effluent water is diluted with control laboratory water.*

Table 4.20. Y-12 biomonitoring program summary information for Outfalls 200 and 135, 2022

Water collection dates	Outfall	Test type	Test organism	End point	Metric[a]	IC_{25}[b] (%)
Annual test on previous permit, July 2022						
07/13/22–07/20/22	135	Chronic	Fathead minnow (*Pimephales promelas*)	Survival Growth	IC_{25} IC_{25}	>36% >36%
			Water fleas (*Ceriodaphnia dubia*)	Survival Reproduction	IC_{25} IC_{25}	>36% >36%
07/13/22–07/20/22	200	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival Reproduction	IC_{25} IC_{25}	>100% >100%
			Fathead minnow (*Pimephales promelas*)	Survival Growth	IC_{25} IC_{25}	>100% >100%
First quarterly test on current permit, November 2022						
11/02/22–11/09/22	200	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival Reproduction	IC_{25} IC_{25}	>100% >100%
			Fathead minnow (*Pimephales promelas*)	Survival Growth	IC_{25} IC_{25}	>100% >100%

[a] *IC25 is summarized for the discharge monitoring locations (Outfalls 200 and 135).*

[b] *IC25 as a percentage of full-strength effluent from Outfalls 200 and 135 diluted with laboratory control water. IC25 is the concentration that causes a 25-percent reduction in water fleas (Ceriodaphnia dubia) survival or reproduction or fathead minnow (Pimephales promelas) survival or growth; 36 percent is the highest concentration of Outfall 135 tested.*

Acronyms:

IC25 = 25-percent inhibition concentration

Y-12 = Y-12 National Security Complex

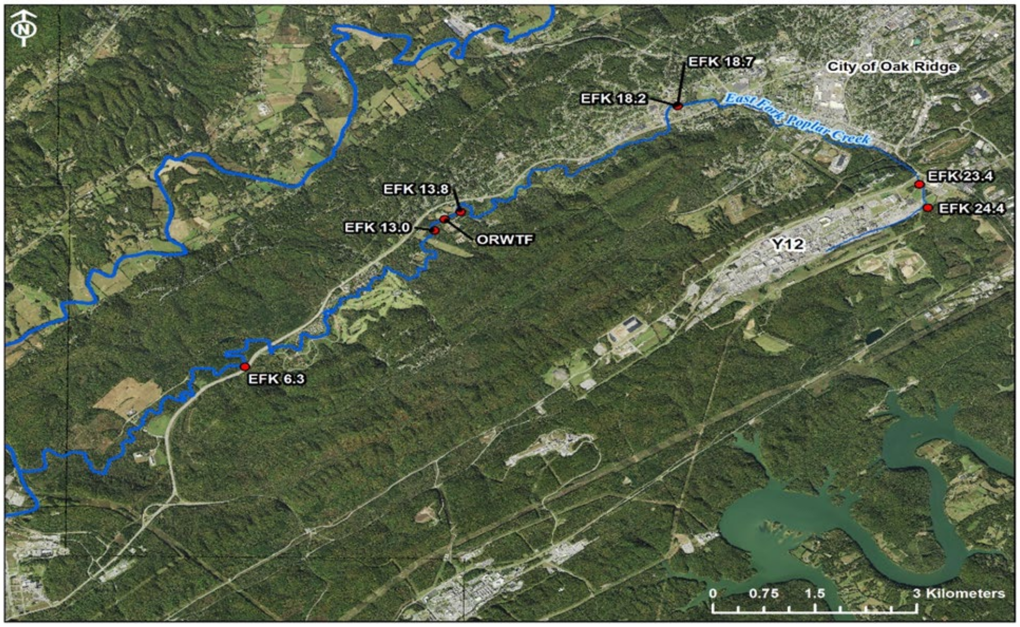
Note: *Annual NPDES permit testing was conducted in July 2022 with effluent from Outfalls 200 and 135. Effluent from Outfall 135 did not reduce fathead minnow (Pimephales promelas) survival or growth or water fleas' (Ceriodaphnia dubia) survival or reproduction by 25 percent or more at any of the tested concentrations compared to the control treatment. For both species, the IC_{25} for survival, growth, or reproduction was greater than 36 percent (the highest concentration of this effluent that was tested) (Table 4.19). Effluent from Outfall 200 did not reduce fathead minnow (Pimephales promelas) survival or growth or water fleas' (Ceriodaphnia dubia) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was greater than 100 percent (Table 4.19). With the current permit (effective October 1, 2022), quarterly NPDES permit testing was conducted in November 2022 with effluent from Outfall 200. Effluent from Outfall 200 did not reduce fathead minnow (Pimephales promelas) survival or growth or water fleas' (Ceriodaphnia dubia) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was greater than 100 percent (Table 4.19).*

4.5.8. Biological Monitoring and Abatement Program

The NPDES permit issued for Y-12 mandates a Biological Monitoring and Abatement Program, with the objective of demonstrating that the effluent limitations established for the facility protect the classified uses of the receiving stream—EFPC. The 2022 program sampling efforts reported in this chapter follow the NPDES-required *Y-12 Biological Monitoring and Abatement Program Plan* (Brandt et al. 2013). Y-12's program, which has been monitoring the ecological health of EFPC since 1985, currently consists of three major tasks that reflect complementary approaches to evaluating the effects of Y-12 discharges on the aquatic integrity of EFPC—bioaccumulation monitoring, benthic macroinvertebrate community monitoring, and fish community monitoring. Data collected on contaminant bioaccumulation and the composition and abundance of communities of aquatic organisms directly evaluate the effectiveness of abatement and remedial measures in improving ecological conditions in the stream.

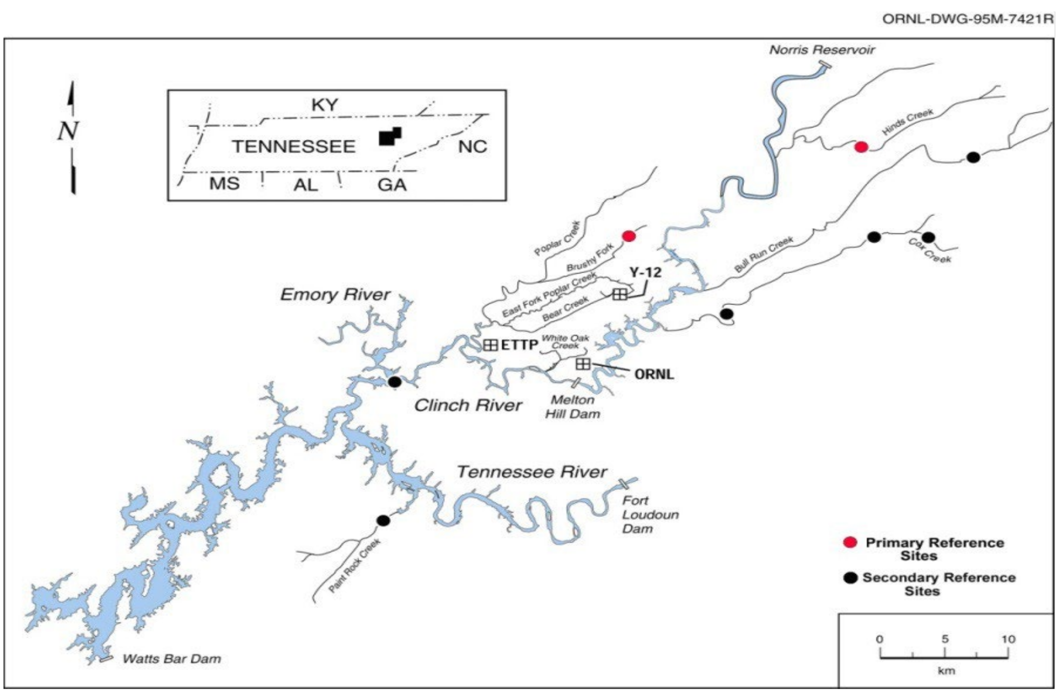
Monitoring is currently being conducted at seven primary EFPC sites (Figures 4.18 and 4.19), although sites may be excluded or added depending on the specific objectives of the various tasks. The primary sampling sites include Upper EFPC at EFPC kilometers (EFKs) 24.4 and 23.4, located upstream and downstream of Lake Reality, respectively; EFKs 18.7 and 18.2, located off ORR and below an area of intensive commercial and light industrial development, respectively; EFKs 13.8 and 13.0, located upstream and downstream of the Oak Ridge Wastewater Treatment Facility, respectively; and EFK 6.3, located about 1.4 km downstream of the ORR boundary (Figure 4.22). Brushy Fork at Brushy Fork kilometer 7.6 is used as a reference stream in two Biological Monitoring and Abatement Program tasks (fish and macroinvertebrate community tasks). Hinds Creek at Hinds Creek kilometer 20.6 is also used as a reference for the macroinvertebrate community monitoring task.

Generally, the number of invertebrate and fish species in EFPC has increased over the last three decades (primarily in the upstream sites), demonstrating that the overall ecological health of the stream continues to improve. However, the pace of improvement in Upper EFPC near Y-12 has slowed in recent years, and fish and invertebrate communities continue to have fewer species than the corresponding communities in reference streams.



Acronyms:
EFK = East Fork Poplar Creek kilometer
ORWTP = Oak Ridge Wastewater Treatment Plant
Y-12 = Y-12 National Security Complex

Figure 4.18. Biological monitoring sites in East Fork Poplar Creek relative to Y-12



Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Figure 4.19. Biological monitoring reference site locations relative to Y-12

4.5.8.1. Bioaccumulation Studies

Historically, mercury and PCB concentrations in fish from EFPC have been elevated relative to fish in uncontaminated reference streams. Fish in EFPC are monitored regularly for mercury and PCBs to assess spatial and temporal trends in bioaccumulation associated with ongoing remedial activities and Y-12 operations.

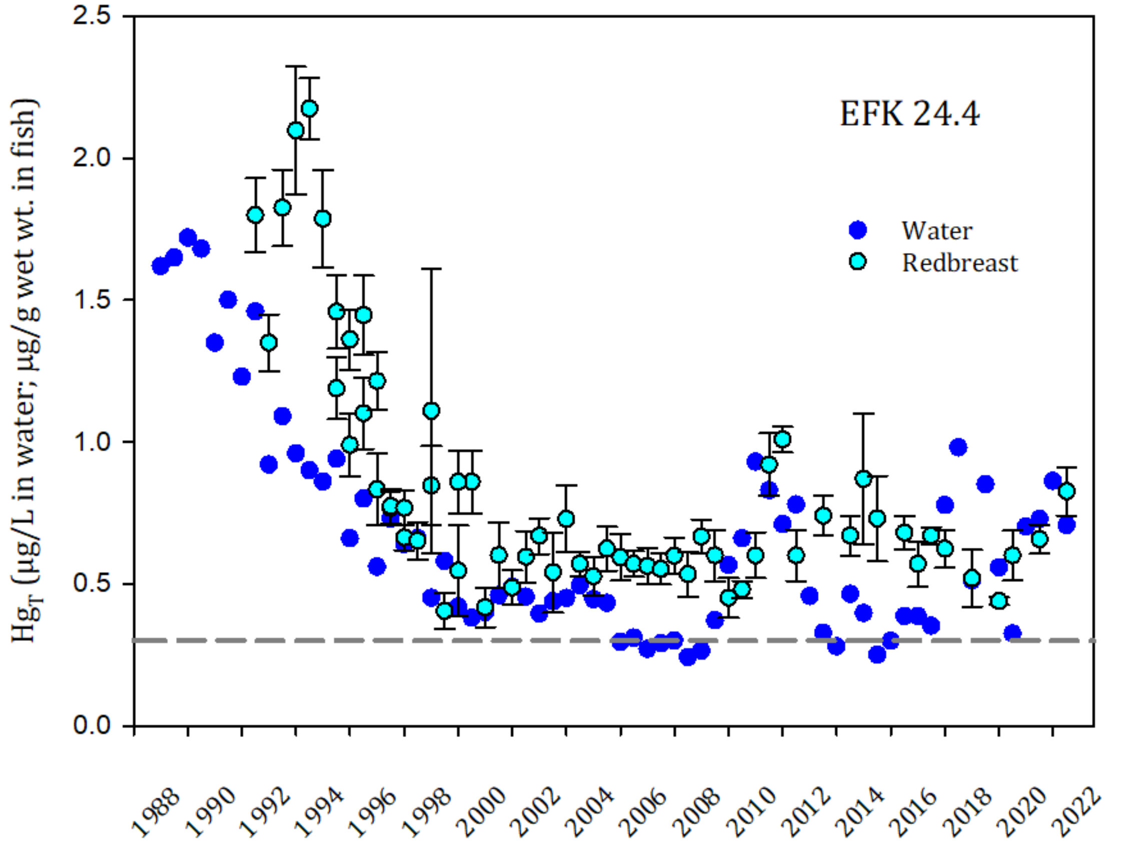
As part of this monitoring effort, redbreast sunfish (*Lepomis auritus*) and rock bass (*Ambloplites rupestris*) are collected from five sites throughout the length of EFPC and are analyzed for tissue concentrations of mercury (twice yearly) (Figure 4.20) and PCBs (annually) (Figure 4.21). Mercury concentrations remained higher in fish from EFPC in 2022 than in fish from reference streams. Elevated mercury concentrations in fish from the upper reach of EFPC indicate that Y-12 remains a continuing source of mercury to fish in the stream.

Figure 4.20 shows temporal trends for mercury concentrations in water collected from EFK 23.4 (Station 17) and in fish collected just upstream of this monitoring station at EFK 24.4. Waterborne mercury concentrations in the upper reach of EFPC have decreased substantially over the years in response to various remedial actions, first over the 1990s time period and then again in response to the Big Springs Treatment System in 2006. Significant fluctuations in aqueous mercury concentrations (thought to be the result of storm drain relining and cleanout) have been seen at EFK 23.4 since 2009. In July 2018, aqueous mercury concentrations spiked as a result of a onetime flux of mercury that occurred during construction and demolition activities at the west end of Y-12. The elevated mercury concentrations were associated with toxicity and a fish kill (Mathews et al. 2019, 2020). Aqueous mercury concentrations at Station 17 were elevated in 2022, and mean mercury concentrations in fish collected at EFK 24.4 increased slightly in 2022 (0.83 µg/g), remaining above the EPA-recommended ambient water quality criterion for mercury (0.3 µg/g mercury as methylmercury in fish fillet).

The relationship between aqueous total mercury concentrations and fish tissue concentrations is complex. Aqueous mercury concentrations vary by orders of magnitude throughout the various watersheds across ORR, but fish tissue concentrations tend not to vary greatly (twofold to threefold). Multiple ongoing investigations are being conducted to better understand mercury bioaccumulation dynamics in EFPC and to better predict how remedial changes may impact mercury concentrations in fish in the future.

The mean total PCB concentration in sunfish fillets at EFK 23.4 was 0.17 µg/g in FY 2022, slightly lower than concentrations seen in FY 2021 (0.20 µg/g) (Figure 4.21). Regulatory guidance and human health risk levels have varied widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criterion for both individual Aroclors and total PCBs is 0.00064 µg/L under the recreation designated-use classification and is the target for PCB focused total maximum daily loads, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudoun; TDEC 2010a, 2010b, 2010c).

In the state of Tennessee, assessments of impairment for water body segments, as well as public fishing advisories, are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2-µg/g PCBs in fish fillets was used for advisories, and then for many years, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. Most recently, the water quality criterion has been used to calculate the fish tissue concentration triggering impairment and a total maximum daily load (TDEC 2019b). This concentration is 0.02-µg/g PCBs in fish fillets (TDEC 2010a, 2010b, 2010c). The mean fish PCB concentration in Upper EFPC, 0.20 µg/g in fish fillets, is well above this concentration.



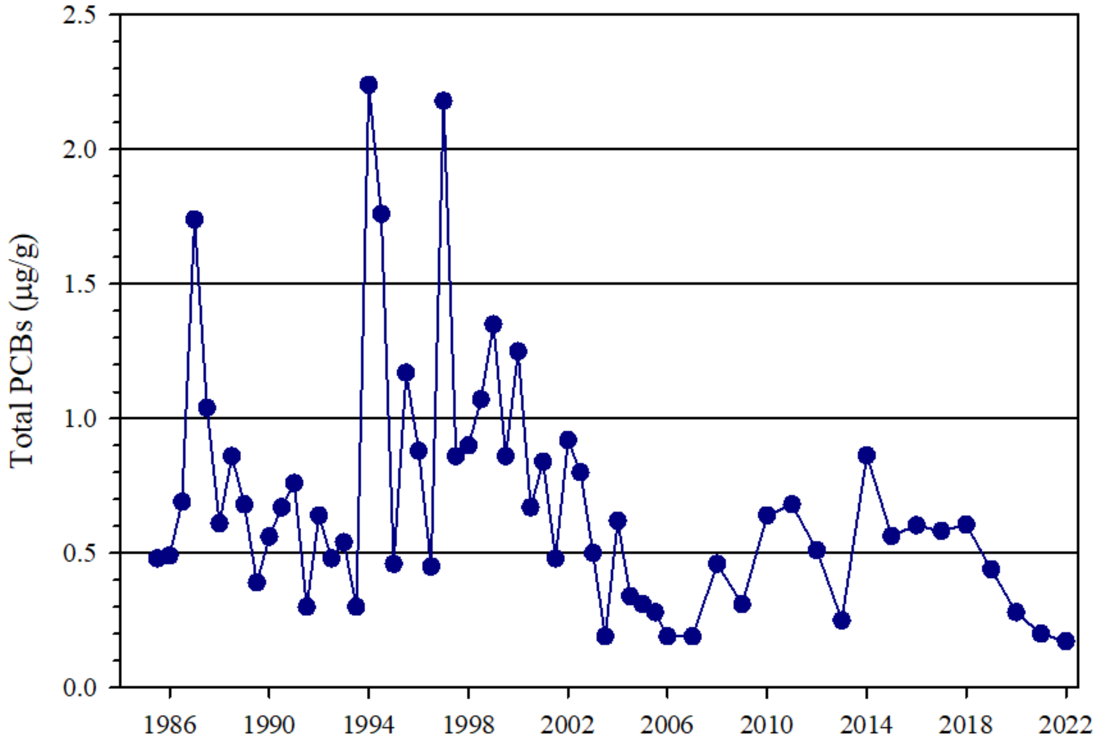
Notes:

1. *Dashed gray line represents the ambient water quality criterion for methylmercury in fish fillets (0.3 µg/g).*
2. *Water: At East Fork Poplar Creek kilometer 23.4.*
3. *Fish: At East Fork Poplar Creek kilometer 24.4.*

Acronym:

EFK = East Fork Poplar Creek kilometer

Figure 4.20. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek, 1988–2022



Note: *At East Fork Poplar Creek kilometer 23.4.*
Acronym:
PCB = polychlorinated biphenyl

Figure 4.21. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets, 1986–2022

4.5.8.2. Benthic Invertebrate Surveys

Monitoring the benthic macroinvertebrate community continued in the spring of 2022 at three sites in EFPC and at one reference stream (Hinds Creek). There have been long-term changes in the macroinvertebrate community at EFPC sites since monitoring began in 1986 (Figure 4.22).

Total taxa richness (number of taxa and sample) increased at EFK 24.4 from 1986 until the mid-2000s and then remained steady for approximately 14 years (Figure 4.22). After flow management ended in 2014, total taxa richness decreased at EFK 24.4 and has remained at these lower values since that time, with the exception of an increase in 2021 to a value similar to that measured before 2014, before decreasing again in 2022.

Total taxa richness at EFK 23.4 steadily increased since monitoring began, and values also decreased after flow management ceased (Figure 4.22). In 2022, total taxa richness increased at EFK 23.4, reaching a value comparable to values observed from 2015 to 2019.

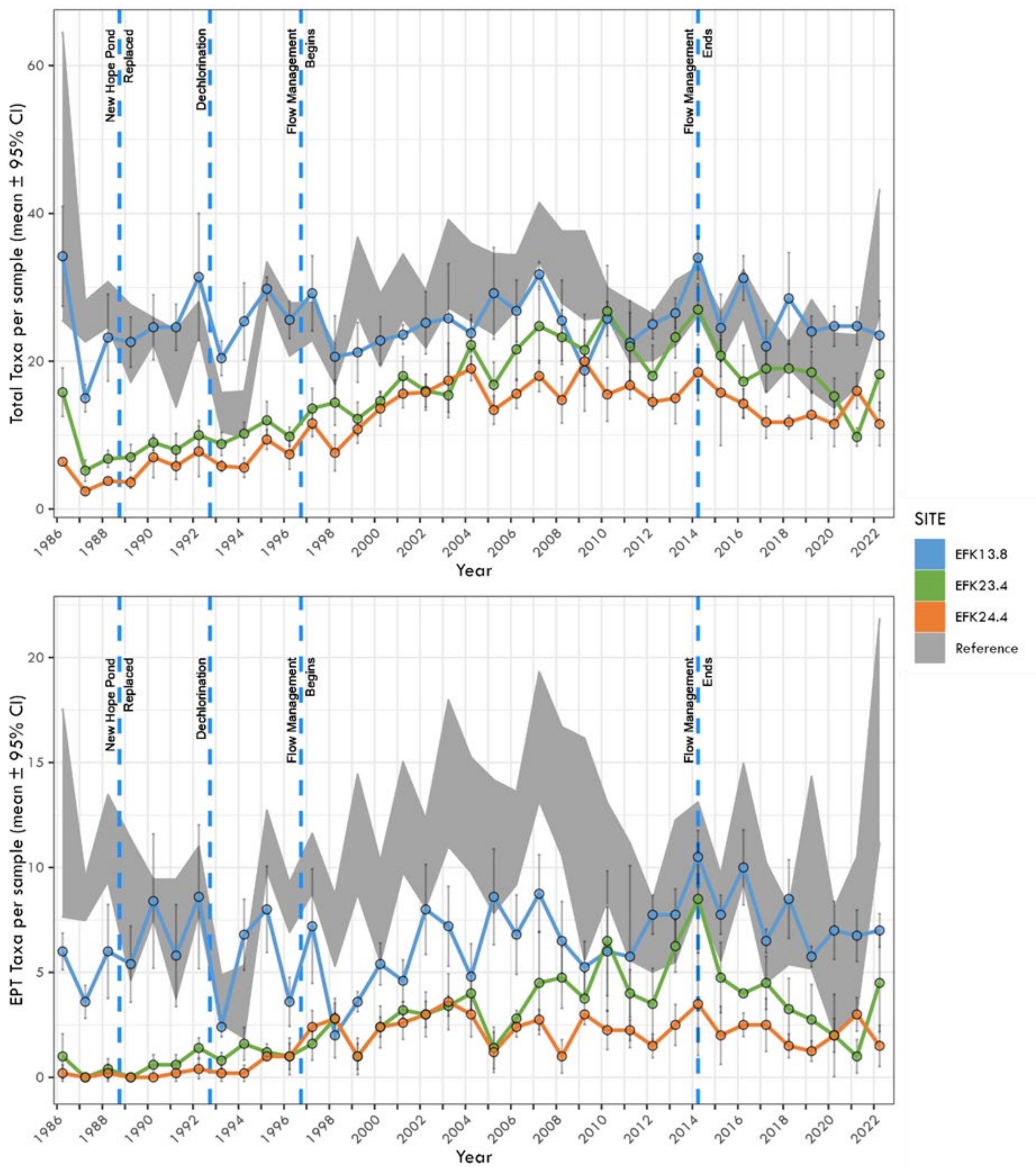
Total taxa richness at EFK 13.8 and the reference sites has been fairly consistent over the entire monitoring period (Figure 4.22). Total taxa richness at EFK 24.4 has consistently been lower than at the reference sites throughout the monitoring period, while total taxa richness at EFK 13.8 has generally fallen within or above the 95-percent confidence interval of reference site values, especially in the past decade (Figure 4.22). Total taxa richness at EFK 23.4 was lower than the 95-percent confidence interval of the reference sites from 1986 to 2009, but since then total taxa richness has mostly been within the 95-percent confidence interval of the reference sites (Figure 4.22).

Temporal patterns in the number of pollution-intolerant taxa (ephemeroptera, plecoptera, and trichoptera [EPT] taxa richness) were similar to those observed for total taxa richness (Figure 4.22). EPT taxa richness at EFK 24.4 was very low (less than 1 EPT taxa and sample) from 1986 until 1994 and then increased slightly (greater than 1 but less than 5 taxa per sample) until 2014. Since 2014, EPT taxa richness has generally been slightly lower, with values in 2022 decreasing from the highest values observed in the past 8 years during 2021 (Figure 4.22).

EPT taxa richness at EFK 23.4 steadily increased since 1986 but decreased after flow management ended (Figure 4.22). In 2022, EPT taxa richness at EFK 23.4 increased to values comparable to those observed from 2017 to 2019 following the lowest values observed in recent years in 2021 (Figure 4.22). EPT taxa richness at EFKs 24.4 and 23.4 has typically been lower than the 95-percent confidence interval of EPT taxa richness at the reference streams, indicative of degraded conditions.

The number of pollution-intolerant taxa at EFK 13.8 has remained fairly steady during the monitoring period, although with large interannual variation. EPT taxa richness values at EFK 13.8 have been within the reference site confidence limits since 2012, with the exception of 2022, which was below the confidence limits (Figure 4.22).

The implications of ending flow management in 2014 on invertebrate communities in EFPC are still uncertain. After flow augmentation ceased, EPT taxa richness at EFK 23.4 has consistently declined until 2022 (Figure 4.22). EPT taxa richness at EFK 24.4 has also shown a slight decrease since flow augmentation ended, with some recovery evident in 2020 and 2021, though this recovery was erased in 2022 (Figure 4.22). The effects of ending flow augmentation on Lower EFPC (EFK 13.8) do not seem as evident, which makes sense as flow augmentation contributed a smaller percentage of total discharge at downstream sites. The long-term effects of ending flow management on the invertebrate community in EFPC will become more evident as conditions stabilize and additional data become available.



Notes:

1. *Top: Total taxonomic richness (mean number of taxa per sample with 95 percent confidence interval).*
2. *Bottom: Taxonomic richness of the pollution-intolerant taxa (ephemeroptera, plecoptera, and trichoptera [EPT]) (i.e., mean number of EPT taxa per sample with 95 percent confidence interval). April 1986–2022.*
3. *The timing of various activities within the watershed is shown with vertical blue lines.*
4. *Reference streams are Brushy Fork and Hinds Creek; however, Brushy Fork was not sampled in 2002 due to lack of access to the survey site.*

Acronyms:

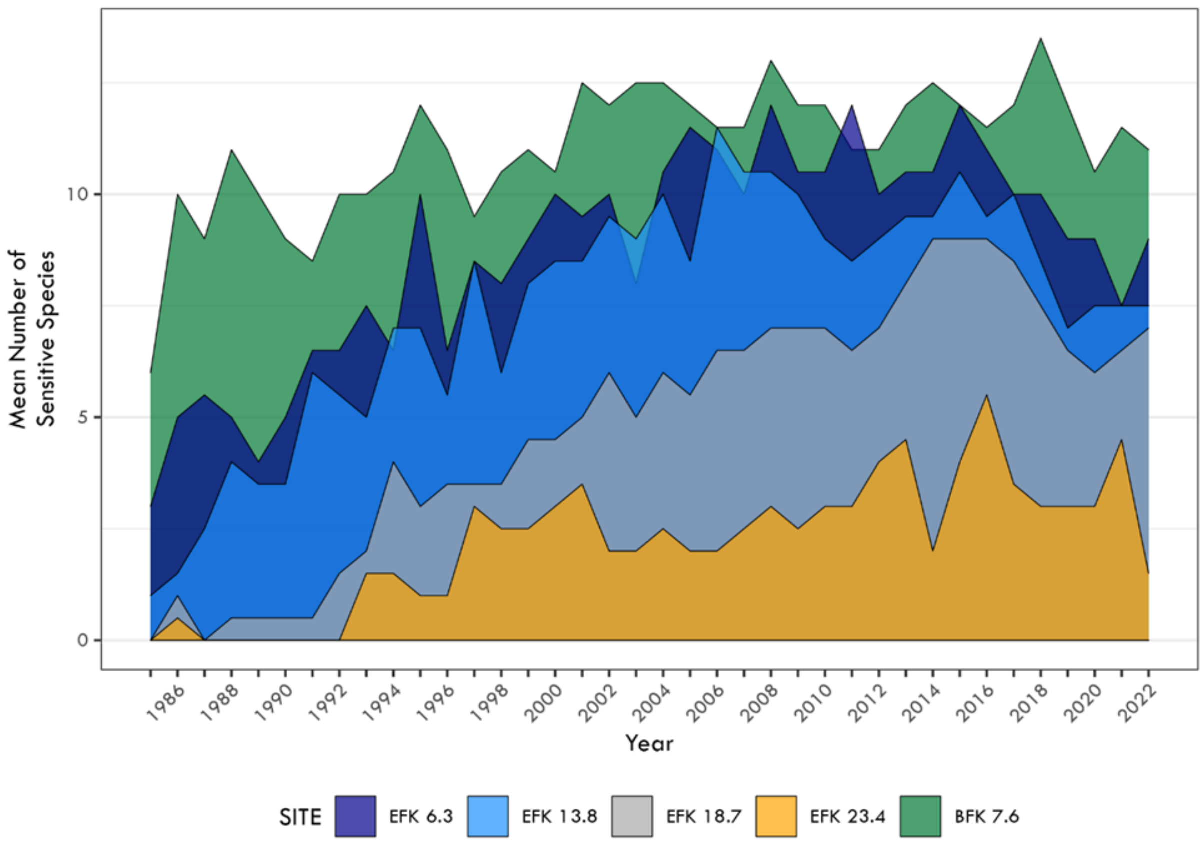
EFK = East Fork Poplar Creek kilometer

EPT = ephemeroptera, plecoptera, and trichoptera

Figure 4.22. Benthic macroinvertebrate communities in three sites along East Fork Poplar Creek and the 95 percent confidence interval for two nearby reference streams

4.5.8.3. Fish Community Monitoring

Fish communities were monitored in the spring and fall of 2022 at five sites along EFPC and at a comparable local reference stream (Brushy Fork). In the past three decades, overall species richness, density, biomass, and number of pollution-sensitive fish species improved at all sampling locations below Lake Reality. Some seasonal conditions, such as flooding and drought, can cause minor fluctuations in values but rarely cause long-term impacts on larger systems such as EFPC. However, some species of fish are considered sensitive, require very specific habitat conditions to survive, and can only tolerate a narrow range of environmental disturbance. The mean number of sensitive species at four sites in EFPC and the reference stream is shown in Figure 4.23, dramatically highlighting major improvements in the fish community in the middle to lower sections (EFKs 6.3 and 13.8) of the stream. However, the EFPC fish community continues to lag behind the reference stream community (Brushy Fork kilometer 7.6) in the most important metrics of fish diversity and community structure, especially at the monitoring sites closest to Y-12 (EFKs 23.4 and 24.4).

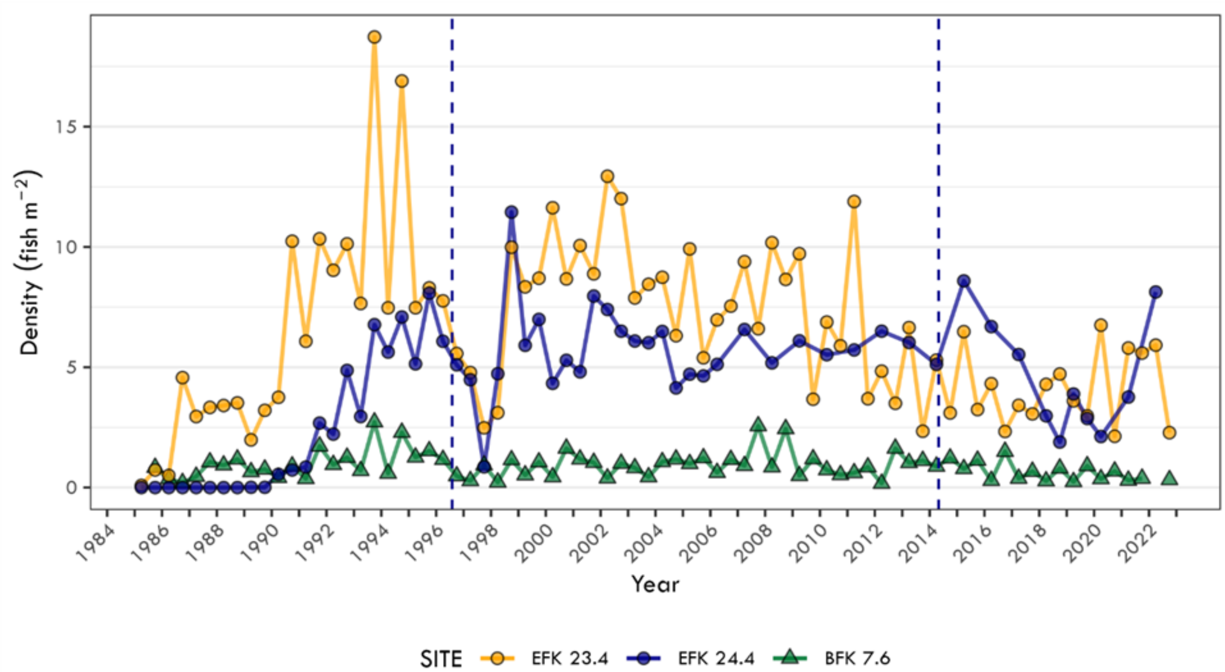


Notes:
1. *Mean sensitive species richness refers to the number of species.*
2. *Reference site is Brushy Fork.*

Acronyms:
3. *BFK = Brushy Fork kilometer* *EFK = East Fork Poplar Creek kilometer*

Figure 4.23. Comparison of mean sensitive species richness collected each year from four sites in East Fork Poplar Creek and a reference site, 1985–2022

Fish communities in Upper EFPC in 2022 continued to fluctuate in density. Reduced stream flows associated with the termination of flow augmentation from Melton Hill in April 2014 and occasional unexpected fish kills are likely factors driving the decrease in fish densities in these upper sites (Figure 4.24). Despite this, fish diversity remained relatively consistent. Very high densities are not always a positive indicator of fish health, and the most abundant species within these sites continue to be those that are considered tolerant. Continued monitoring will provide additional insight into these variabilities.



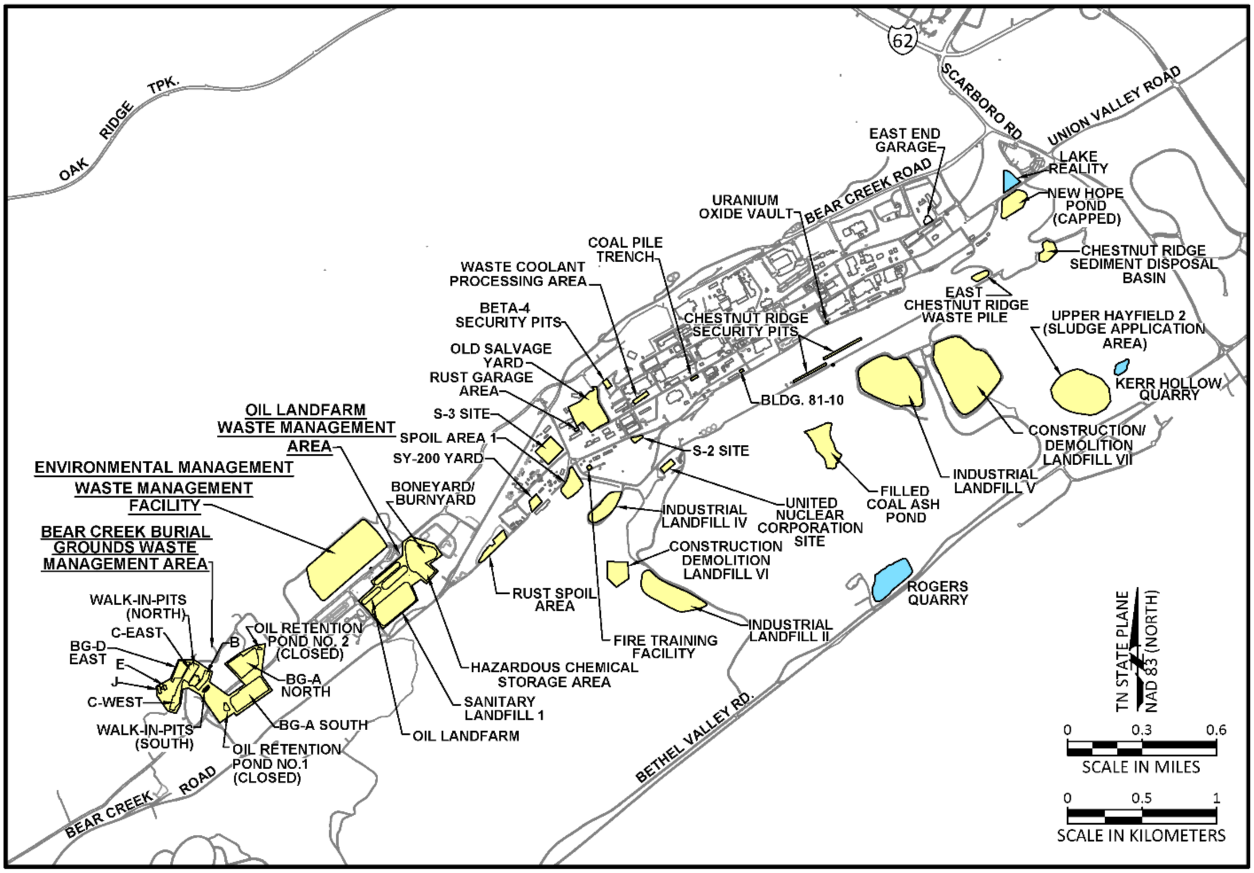
Notes:
1. *Access to the Brushy Fork site was restricted in spring 2022, and no samples were collected.*
2. *The interval of time between the dashed lines represents the period of flow management in East Fork Poplar Creek.*
3. *Fish density refers to the number of fish per m^2.*
4. *Reference site is Brushy Fork.*

Acronyms:
BFK = Brushy Fork kilometer *EFK = East Fork Poplar Creek kilometer*

Figure 4.24. Fish density for two sites in Upper East Fork Poplar Creek and a reference site, 1996–2022

4.6. Groundwater at the Y-12 National Security Complex

Groundwater is monitored to comply with federal, state, and local requirements and to determine the environmental impact from legacy and current operations. There are approximately 190 known or potential sources of contamination identified in the Federal Facility Agreement for Y-12 (DOE 2022a). Groundwater monitoring provides information on the nature and extent of contamination, which is used to identify actions needed to protect the worker, public, and environment. Figure 4.25 depicts major source areas where groundwater is monitored.



Acronyms: *BLDG. = Building RD = Road*

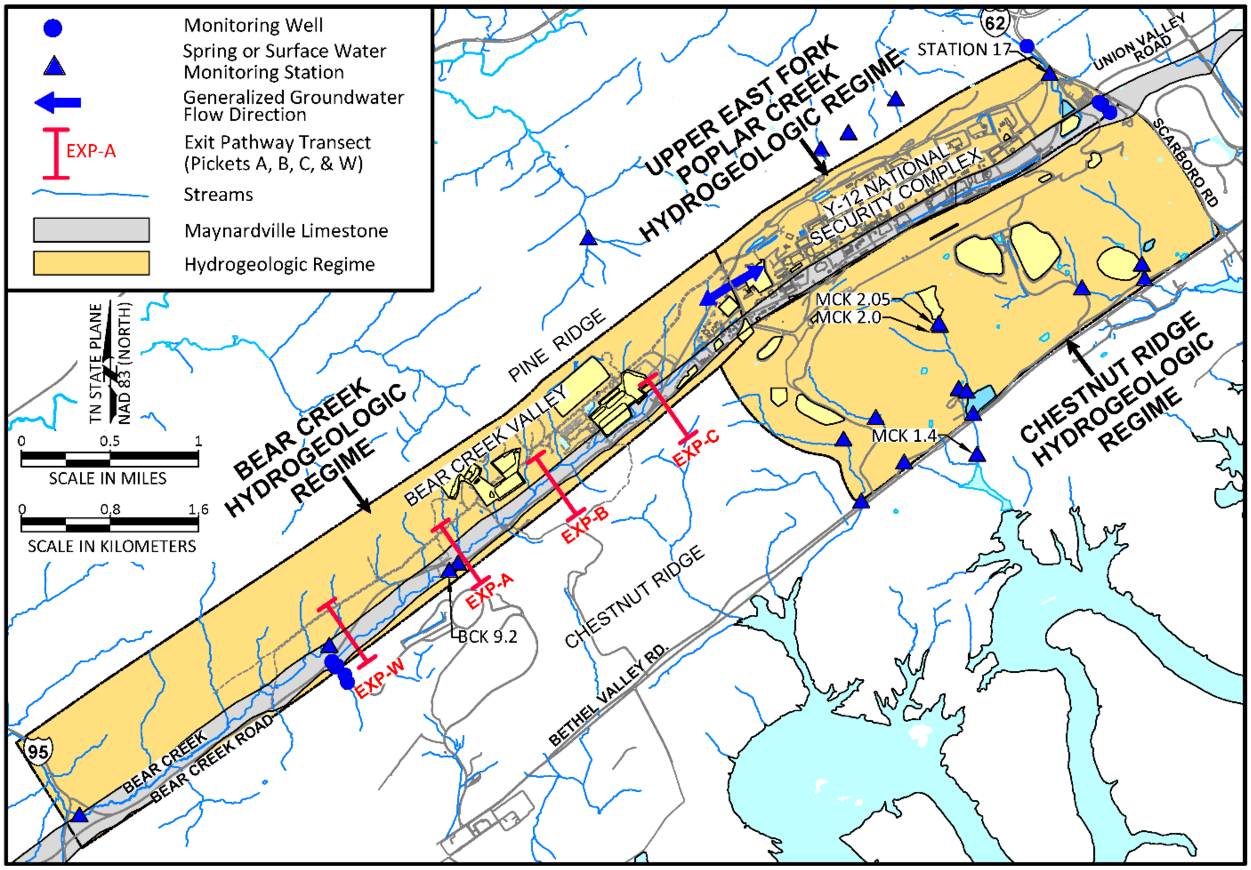
Figure 4.25. Known or potential contaminant source areas where groundwater is monitored at Y-12

4.6.1. Hydrogeologic Setting

Y-12 is divided into three hydrogeologic regimes—Bear Creek, Upper EFPC, and Chestnut Ridge (Figure 4.26). Most of the Bear Creek and Upper EFPC regimes are underlain by shale, siltstone, and sandstone bedrock, which act as an aquitard. An aquitard can contain water but does not readily yield that water to pumping wells. However, the southern portion of the Bear Creek and Upper EFPC regimes is underlain by the Maynardville Limestone, which is part of the Knox aquifer. (An aquifer more readily yields water to pumping wells.) The Chestnut Ridge regime is almost entirely underlain by the Knox aquifer.

In general, groundwater flow in the water table interval follows the topography; therefore, it flows off areas of higher elevation into the valleys and then flows parallel to the valley, along geologic strike (Figure 4.27). Shallow flow in the Bear Creek and Upper EFPC regimes diverges from a topographic and groundwater divide located near the western end of Y-12. In the Chestnut Ridge regime, a groundwater divide nearly coincides with the crest of the ridge. On Chestnut Ridge, shallow groundwater flow tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs in Bethel Valley to the south and Bear Creek Valley to the north.

In Bear Creek Valley, groundwater in the intermediate and deep intervals moves through fractures in the aquitard, converging on and then moving through fractures and solution conduits in the Maynardville Limestone (Figure 4.26). Karst development in the Maynardville Limestone has a significant impact on groundwater flow in the water table and intermediate intervals. Groundwater flow rates in Bear Creek Valley vary; they are slow within the deep interval of the fractured non-carbonate rock (less than 10 ft/yr) but can be quite rapid within solution conduits in the Maynardville Limestone (10 to 5,000 ft/d).

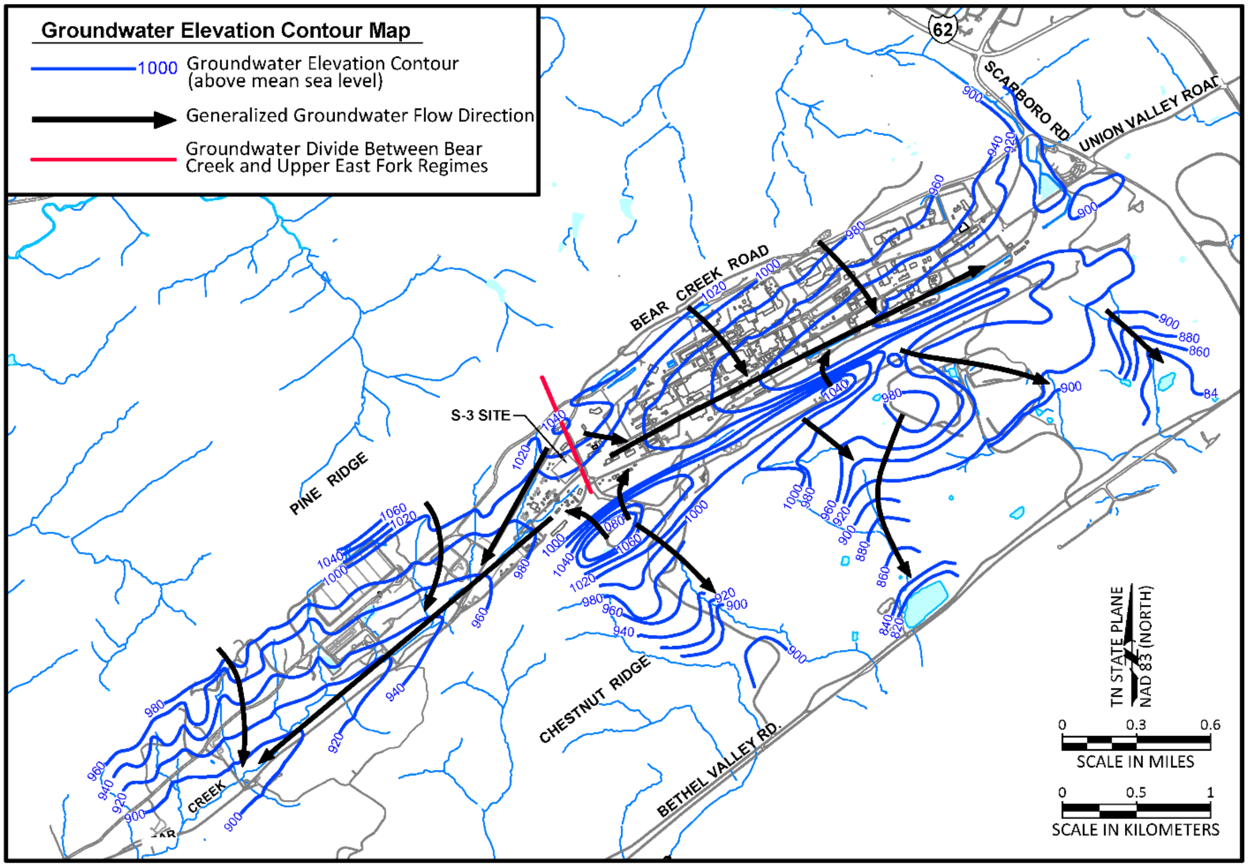


Acronym: *MCK = McCoy Branch kilometer*

Figure 4.26. Hydrogeologic regimes, flow directions, perimeter/exit pathway locations, and position of Maynardville Limestone at Y-12

Contaminants are transported, along with flowing groundwater, through the pore spaces, fractures, or solution conduits of the hydrogeologic system. Strike-parallel transport of some contaminants can even occur within the aquitard units for significant distances, where they discharge to surface water tributaries or underground utility and storm water distribution systems in Y-12's industrial area. For example, elevated levels of nitrate (a contaminant from legacy waste disposals) within the fractured bedrock of the aquitard are known to extend east and west from the S-2 and S-3 sites for thousands of feet. Extensive VOC contamination from multiple sources is observed in both the Bear Creek and Upper EFPC regimes and to a lesser extent in the Chestnut Ridge regime. VOCs (e.g., petroleum products, coolants, and solvents) in groundwater within the fractured bedrock of the aquitard units can remain close to source areas for long durations. This is because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and very slowly diffuse back out of the matrix when concentration gradients change before migrating to exit pathways, where more rapid transport occurs for longer distances.

Groundwater flow in the Chestnut Ridge regime is through fractures and solution conduits in the Knox Group aquifer. Discharge points for intermediate and deep flow are not well-known. However, following the crest of the Chestnut Ridge, water table elevations decrease from west to east, demonstrating an overall easterly trend in groundwater flow.



Acronym: *RD = Road*

Figure 4.27. Groundwater elevation contours and flow directions at Y-12

4.6.2. Groundwater Monitoring

Groundwater monitoring in CY 2022 was performed as part of Y-12's Groundwater Protection Program, DOE EM programs such as the Water Resources Restoration Program, and other projects. Compliance requirements were met by monitoring 200 wells and 58 surface water locations and springs (Table 4.21). (Locations sampled for research projects are not included in the wells and locations monitored for compliance requirements.)

Specific wells of interest, based on CY 2022, data are discussed later in this section. Figure 4.38 shows the locations of perimeter/exit pathway stations that are routinely monitored.

Table 4.21. Summary of groundwater monitoring at the Y-12 National Security Complex, 2022

Purpose for which monitoring was performed					
	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Number of active wells	57	33	110	42	242
Number of other monitoring stations (e.g., springs, seeps, and surface water)	36	7	15	3	61
Number of samples taken[e]	289	289	137	23	738
Number of analyses performed	11,572	7,708	15,108	1,650	36,038
Percentage of analyses that are non-detects	61.0	87.8	69.3	NA	70.7
Ranges of results for positive detections, VOCs (μg/L)[f]					
Chloroethenes	0.11-3700	6.1-6.93	1-52,000	NA	
Chloroethanes	0.14-310	71.6-72.6	1-1,400	NA	
Chloromethanes	0.34-1100	0.52-1.82	1-880	NA	
Petroleum hydrocarbons	0.27-5500	ND	1-560	NA	
Uranium (mg/L)	0.000075-0.4	0.00007-0.00677	0.000514-72.8	NA	
Nitrates (mg/L)	0.022-4900	ND	0.0591-9,150	73-1,100	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross-alpha activity	0.99-360	1.52-13.5	0-30,000	NA	
Gross-beta activity	0.58-4000	2.66-44.3	0-19000	NA	

[a] Monitoring to comply with Comprehensive Environmental Response, Compensation, and Liability Act requirements.
[b] Solid waste landfill detection monitoring and CERCLA landfill detection monitoring.
[c] DOE Order surveillance monitoring.
[d] Research-related groundwater monitoring associated with activities of the DOE Oak Ridge Field Research Center and Ecosystems and Networks Integrated with Genes and Molecular Assemblies.
[e] The number of unfiltered samples, excluding duplicates, determined for unique location/date combinations.
[f] These ranges reflect concentrations of individual contaminants (not summed VOC concentrations):

- *Chloroethenes—includes tetrachloroethene; trichloroethene; 1,2-dichloroethene (cis- and trans-); 1,1-dichloroethene; and vinyl chloride.*
- *Chloroethanes—includes 1,1,1-trichloroethane; 1,2-dichloroethane; and 1,1-dichloroethane.*
- *Chloromethanes—includes carbon tetrachloride, chloroform, and methylene chloride.*
- *Petroleum hydrocarbon—includes benzene, toluene, ethylbenzene, and xylene.*

[g] pCi = 3.7×10^{-2} Bq

Acronyms:
NA = not analyzed
ND = not detected
VOC = volatile organic compound

Water quality results of groundwater monitoring activities in CY 2022 are presented in the 2022 groundwater monitoring report (CNS 2023). The groundwater sampling technicians shown in Figure 4.28 are taking water quality samples from a well in the East Fork regime near the former New Hope Pond site.

Monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FYs 2022 and 2023 Water Resources Restoration Program sampling and analysis plans (UCOR 2021, 2022b, respectively) and the annual CERCLA remediation effectiveness reports (DOE 2022b, 2023).

Six monitoring wells were installed near the S-3 Site by Ecosystems and Networks Integrated with Genes and Molecular Assemblies (ENIGMA) research group in 2022. No wells were plugged and abandoned in 2022.

Figure 4.28. Groundwater monitoring well sampling at Y-12

4.6.3. Groundwater Quality

Historical monitoring shows that four primary contaminants adversely affect groundwater quality at Y-12: nitrate, VOCs, metals, and radionuclides. Of those, VOCs are the most widespread. Uranium and ^{99}Tc are the radionuclides of greatest concern. Trace metals (e.g., arsenic, barium, cadmium, chromium, and mercury), the least extensive groundwater contaminants, generally occur close to source areas because of their high adsorption characteristics. Data show that plumes from multiple source units have mixed with one another and that contaminants are not always easily associated with a single source.

4.6.3.1. Upper East Fork Poplar Creek Hydrogeologic Regime

Among the three hydrogeologic regimes, the Upper EFPC regime contains most of the known and potential sources of contamination. (Summary descriptions of waste management sites shown on Figure 4.25 were provided in previous year ASERs and are not repeated this year.) Contaminants from the S-3 site (nitrate and ^{99}Tc) and VOCs from multiple source areas are observed in groundwater in the western portion of the Upper EFPC regime, whereas groundwater in the eastern portion of the regime is predominantly contaminated with VOCs.

Plume Delineation

Sources of contaminants monitored during CY 2022 include the S-2 site, Fire Training Facility, S 3 site, Waste Coolant Processing Facility, former petroleum USTs, New Hope Pond, Old Salvage Yard, and process/production buildings throughout Y-12.

The S-3 site is near the hydrologic divide that separates the Upper EFPC regime from the Bear Creek regime and has contributed groundwater contamination to both regimes. Contaminant plumes in both regimes (shown in orange shading on Figures 4.41, 4.43, 4.44, and 4.45) are elongated as a result of preferential transport of contaminants parallel to strike (parallel to the valley axis) in both the Knox aquifer and the fractured bedrock of the aquitard.

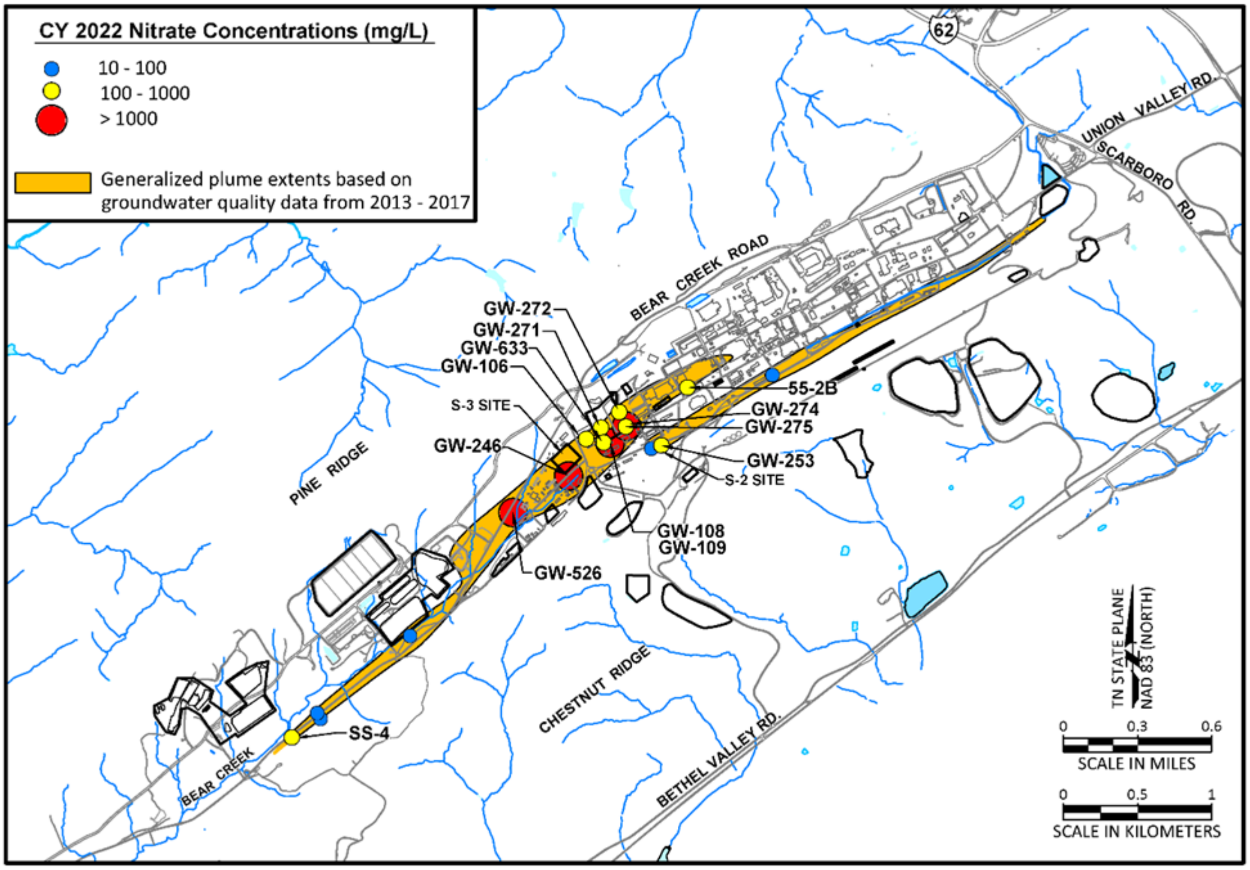
The plumes depicted reflect the average concentrations and radioactivity in groundwater between CYs 2013 and 2017. The circular icons presented on the plume maps (Figures 4.29, 4.31, 4.32, and 4.33) represent CY 2022 monitoring results for the Upper EFPC regime (discussed in this section), the Bear Creek regime (discussed in Section 4.6.3.2), and the Chestnut Ridge regime (discussed in Section 4.6.3.3).

Nitrate

Nitrate is highly soluble and moves easily with groundwater. In the central and western portions of Upper EFPC, nitrate concentrations exceed the 10-mg/L drinking water standard. (A list of the national drinking water standards is presented in Appendix C.) The two primary sources of nitrate contamination are the S 2 and S-3 sites. Formerly, these were ponds that received large quantities of nitric acid wastes. In CY 2022, there was a maximum nitrate concentration of 9,150 mg/L in well GW 275. This well is located approximately 396 m (1,300 ft) east of the S-3 site and is screened in the shallow-intermediate bedrock interval about 20 m (65 ft) below ground surface (Figure 4.29).

Increasing concentration trends are indicated by the nitrate data for wells 55-2A, 55-2B, 55-2C, and GW-275 in the East Fork regime (Figure 4.30). Considering the mobility of nitrate, the increasing trends suggest increased flux of nitrate via some of the fracture flowpaths in the Nolichucky Shale east of the S-3 site. This is consistent with both the heterogeneous transport characteristics of the groundwater flow system as well as described in the conceptual model for contaminant transport from the S-3 site, whereby the center of mass of the nitrate (and other intermixed contaminants) plume in the Nolichucky Shale east of the site continues to slowly move eastward via permeable flowpaths (e.g., bedding plane fractures) that parallel geologic strike (DOE 1998).

The nitrate trends for wells 55-2A/55-2B/55-2C appear fairly stable since CY 2010, and the nitrate trend at well GW-275 appears to be decreasing since 2017, which demonstrates the continued eastward strike-parallel migration of the nitrate plume. Nitrate trends in the groundwater at well clusters reflect conditions at different depth intervals at the same location. Whereas wells 55-2A/55-2B/ 55-2C show similar nitrate trends, divergent nitrate trends occur at wells GW-274/GW-275 (decreasing and increasing). The decreasing trend at well GW-274 likely reflects higher groundwater flow (flushing) in the shallow groundwater system.



Acronyms: *CY = calendar year* *Rd = Road*

Figure 4.29. Nitrate in groundwater at Y-12, 2022

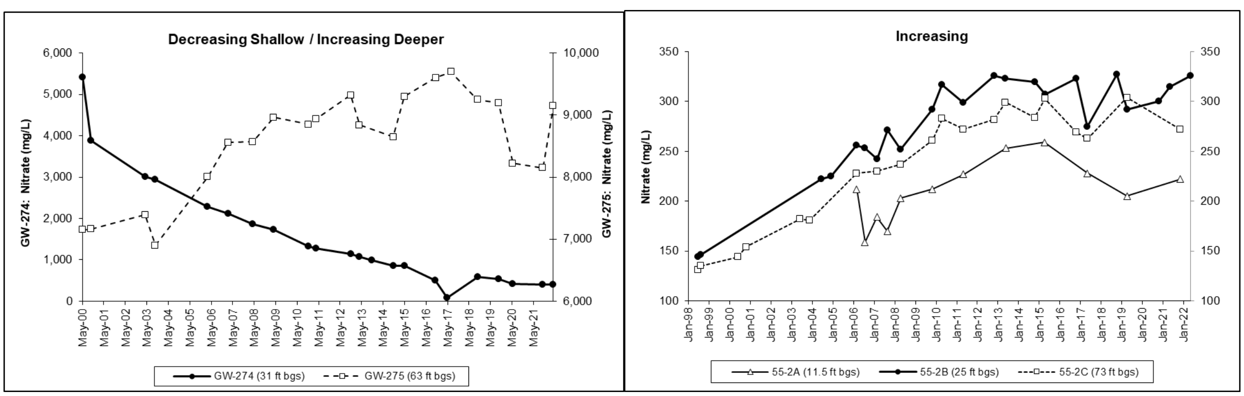


Figure 4.30. Nitrate concentration trends in surveillance monitoring wells GW-274/GW-275 and 55-2A/55-2B/55-2C in the East Fork regime

Trace Metals

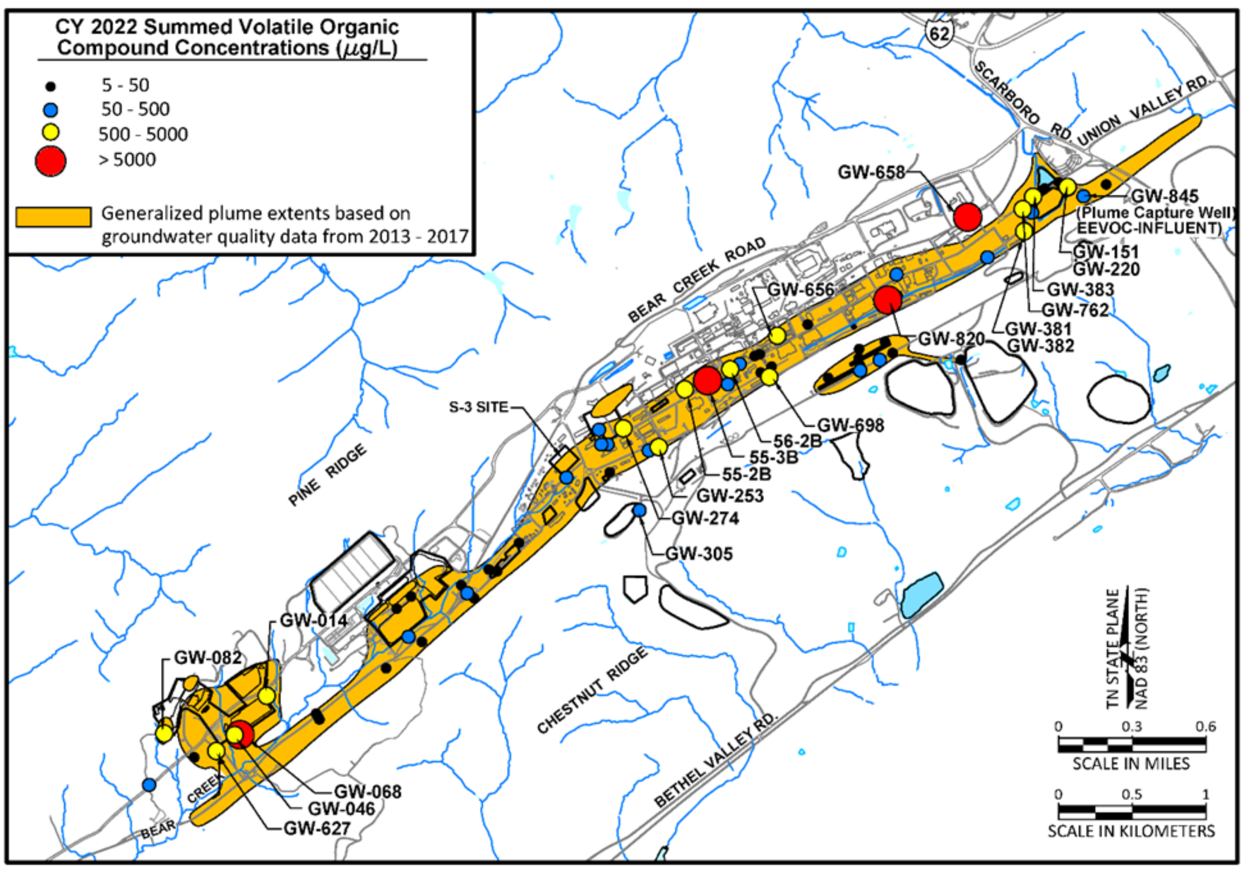
In CY 2022, barium, beryllium, cadmium, chromium, copper, nickel, thallium, and uranium exceeded primary drinking water standards in groundwater in the Upper EFPC regime. Uranium was found predominately downgradient of the S-2, S-3, and New Hope Pond sites. Trace metal concentrations above standards occur adjacent to source areas because of their low solubility and high adsorption to the clay-rich soils and bedrock.

VOCs

VOCs, the most widespread contaminants in the Upper EFPC regime, consist of chlorinated and petroleum hydrocarbons. In CY 2022, the highest summed concentration of dissolved chlorinated hydrocarbons (60,696 μg/L) was again at well 55-3B in the western portion of Y-12, adjacent to currently inactive manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons was again at well GW-658 (11,358 μg/L) at the closed East End Garage.

Most monitoring results are consistent with data from previous years because a dissolved plume of legacy VOCs in the bedrock zone extends eastward from the S-3 site over the entire length of the regime (Figure 4.31). Additional sources are the Waste Coolant Processing Facility, fuel facilities (Rust Garage and East End Garage), and other waste disposal and production areas.

Chloroethene compounds (tetrachloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE], and vinyl chloride) tend to dominate the VOC plume in the western and central portions of the Upper East Fork regime. However, PCE is almost ubiquitous throughout, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant VOCs in the eastern portion of the regime.



Acronyms:
CY = calendar year
Rd = road
EEVOC = East End Volatile Organic Compound

Figure 4.31. Summed volatile organic compounds in groundwater at Y-12, 2022

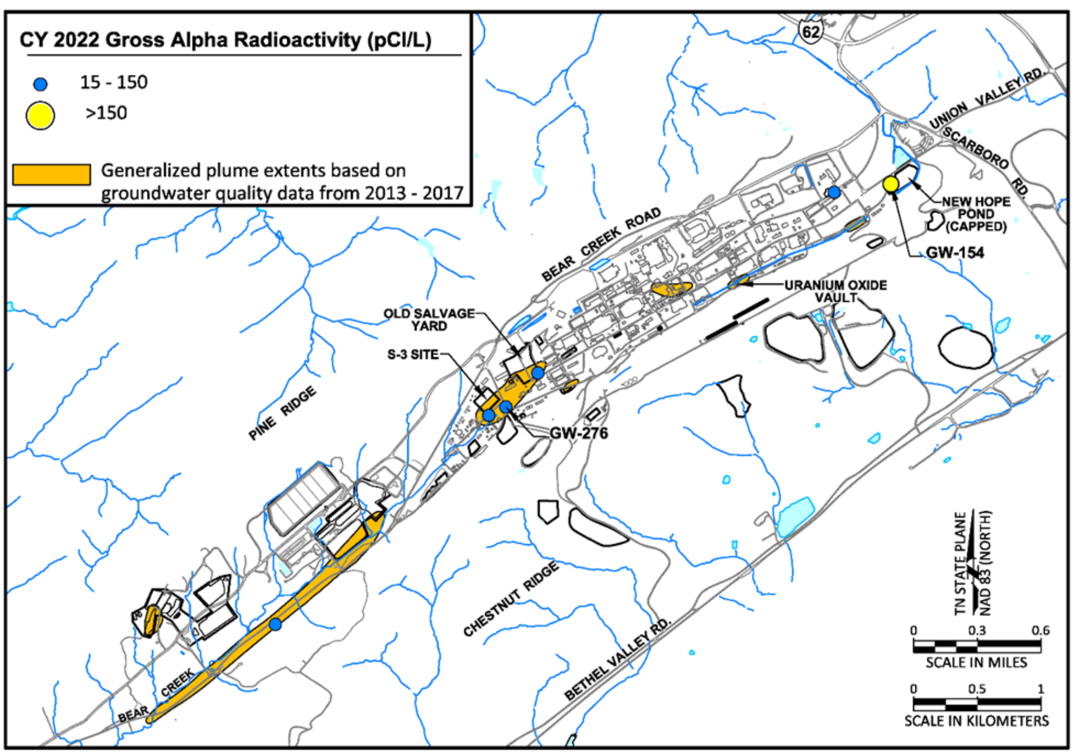
Variability in concentration trends of chlorinated and petroleum VOCs is seen within the Upper EFPC regime. Increasing trends have been observed in wells associated with the Rust Garage, Old Salvage Yard, and S-3 site; and some legacy sources at production/process facilities in central areas. While data from most monitoring wells have remained relatively constant since the late 1980s/early 1990s, some wells show trends in recovery from legacy contamination, especially where petroleum hydrocarbons are the predominant contaminant. For example, while GW-658 has the highest dissolved concentration of petroleum hydrocarbons in the regime, the concentration is an order of magnitude lower than measured in the same well in 1992 and 1993 (>100,000 mg/l).

Radionuclides

The primary alpha-emitting radionuclides found in the Upper EFPC regime during CY 2022 are isotopes of uranium. Exceedances of the drinking water standard for gross-alpha (15 pCi/L) have been observed near the S-3 site, Old Salvage Yard, and other western source areas; in the central areas near production facilities and the Uranium Oxide Vault; and also in the east end near the former oil skimmer basin at the former inlet to New Hope Pond, which was capped in 1988. In CY 2022, the maximum occurrence of gross-alpha activity in groundwater in the Upper EFPC regime was 360 pCi/L, again at well GW-154 near the former oil skimmer basin as shown in Figure 4.32.

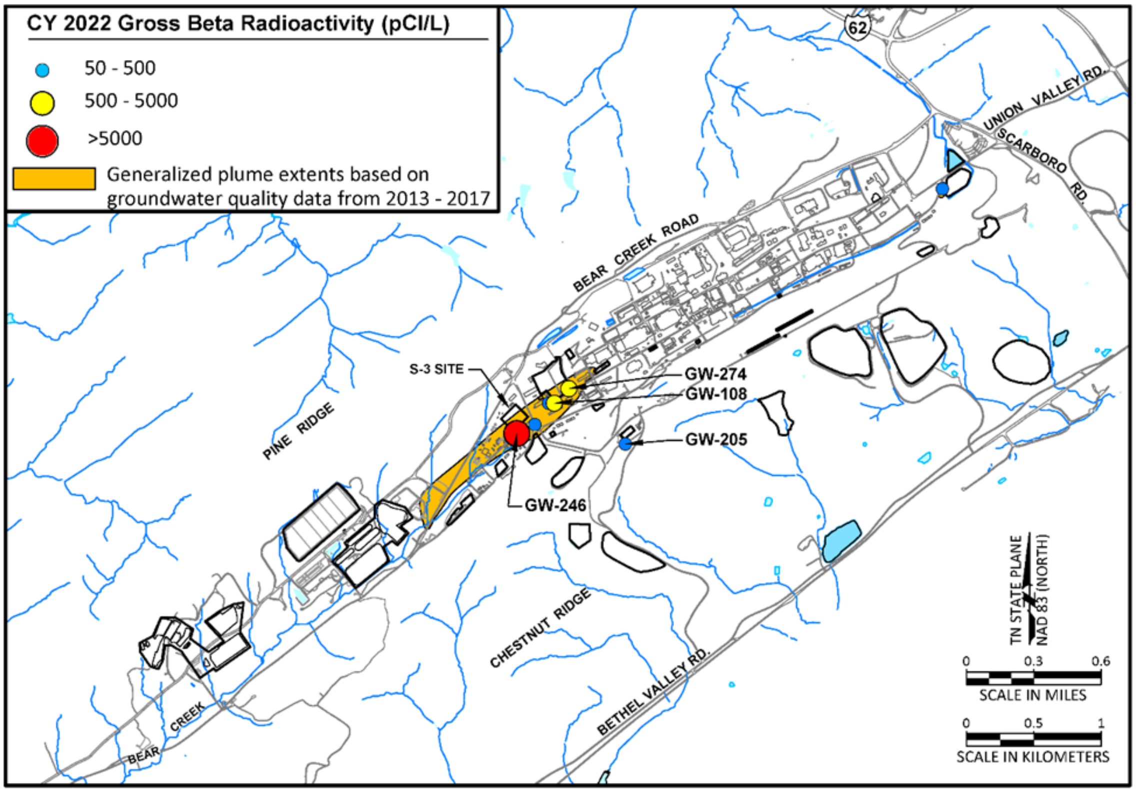
The primary beta-emitting radionuclides observed in the Upper EFPC regime are ^{99}Tc and isotopes of uranium. Historically, elevated gross-beta activity in groundwater shows a pattern similar to that observed for gross-alpha activity as shown in Figure 4.33.

Technetium-99 is the primary contaminant exceeding the gross-beta screening level of 50 pCi/L; the source is the S-3 site. The highest gross-beta activity in groundwater was observed during CY 2022 from well GW-108 (4,000 pCi/L), lower than the 4,750 pCi/L measured in CY 2021 and down from a maximum gross-beta (21,300 pCi/L) in CY 2008 in the same well.



Acronyms: *CY = calendar year Rd = road*

Figure 4.32. Gross-alpha activity in groundwater at Y-12, 2022



Acronyms: *CY = calendar year* *Rd = road*

Figure 4.33. Gross-beta activity in groundwater at Y-12, 2022

Exit Pathway and Perimeter Monitoring

In the Upper EFPC regime, VOCs have been observed at depths of up to 500 ft below ground surface. The deep fractures and solution channels in the Maynardville Limestone (the primary exit pathway) appear to be well connected and facilitate contaminant migration into Union Valley off-site to the east of Y-12.

Because of off-site migration of contaminants, a plume capture system (the East End VOC Treatment System) was constructed in and around well GW-845 (shown on Figure 4.31) and began continuous operation in October 2000. Groundwater is pumped from the Maynardville Limestone at about 95 L/min (25 gal/min), passes through a treatment system to remove the VOCs, and then discharges to Upper EFPC. The effectiveness of this system is reported annually in remediation effectiveness reports published by DOE EM (DOE 2022b, 2023).

Monitoring wells near the plume capture system continue to show an encouraging response. The trends near the East End VOC plume show that contaminants in shallow-intermediate wells located perpendicular to strike across lithologic units from the plume capture system installed in GW 845 may be mobilized by the system. However, no downgradient detection of these compounds is apparent; therefore, migration is limited. An example is observed in the Westbay system installed in well GW-722. This multiport well, located downgradient from the East End VOC Treatment System, allows sampling of several vertically discrete zones within the Maynardville Limestone. Monitoring results from well GW-722 indicate reductions in VOCs due to the plume capture system, derived from summed VOC levels above 1,000 µg/L before the treatment system was installed to below 50 µg/L in the last 4 years.

Five zones in well GW-722 were sampled in CY 2022, with four zones showing summed VOCs greater than 5 µg/L. Four zones exceeded the drinking water standard for carbon tetrachloride, with the highest concentration (27 µg/L) measured at zone 722-17 (385 ft below ground surface). Zone 722-20 (333 ft below ground surface) also exceeded the drinking water standard for PCE at 6.4 µg/L.

In addition to the deep system in the eastern portion of the Upper EFPC regime, VOCs have also been observed in shallow groundwater where it flows north-northeast (mimicking the flow of the creek) east of the New Hope Pond site and Lake Reality. In this area, GW-832 has been installed in a distribution channel underdrain associated with former New Hope Pond. During CY 2022, the summed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (20.2-29.2 µg/L).

Upper EFPC flows north, exiting Y-12 through a gap in Pine Ridge. As mentioned previously, shallow groundwater mimics the creek and also moves through this exit pathway. One well in this pathway gap was monitored in CY 2022, and no groundwater contaminants were observed above primary drinking water standards.

Perimeter sampling locations continue to be monitored north and northwest of Y-12 to evaluate possible contaminant transport, even though those locations are considered unlikely contaminant exit pathways. One of the stations monitored is a tributary that drains the north slope of Pine Ridge and discharges into the adjacent Scarboro community. One location monitors an upper reach of Mill Branch, which discharges into the residential areas along Wiltshire Drive. The remaining location monitors Gum Hollow Branch as it flows adjacent to the Country Club Estates community. There were no indications that contaminants were being discharged from the ORR into those communities.

Union Valley Monitoring

Groundwater monitoring data obtained in the early 1990s provided the first indication that VOCs were being transported off the ORR through the deep Maynardville Limestone exit pathway. The Upper EFPC remedial investigation (DOE 1998) discussed the nature and extent of VOC contamination in Union Valley.

In CY 2022, monitoring locations in Union Valley continued, showing overall decreasing or low concentration stable trends. Vinyl chloride at 1.7 µg/L (below the maximum contaminant level of 2 mg/L) was detected at monitoring well GW-230, located east of Illinois Avenue in the University of Tennessee Arboretum (off the map and approximately 3,500 ft east of the ORR boundary). A groundwater flow divide west of well GW-230, coincident with Scarboro Creek, Illinois Avenue, and a gap in Chestnut Ridge, probably restricts transport of VOCs from the ORR further east (MMES 1995). This would indicate that the VOCs observed in the well are from a source other than Y-12.

Under the terms of an interim Record of Decision, administrative controls (i.e., restrictions on potential future groundwater use) have been established and maintained. Additionally, the previously discussed plume capture system (well GW-845) was installed to mitigate groundwater migration contaminated with VOCs into Union Valley (DOE 1997a).

In July 2006, the Agency for Toxic Substances and Diseases Registry—the principal federal public health agency charged with evaluating the human health effects of exposure to hazardous substances in the environment—published *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation*, in which groundwater contamination across the ORR was evaluated (ATSDR 2006). In the report, it was acknowledged that groundwater contamination exists throughout the ORR, but the authors concluded there is no public health hazard from exposure to contaminated groundwater originating on the ORR. At that time, the Y-12 East End VOC groundwater contaminant plume was acknowledged as the only confirmed, off-site, contaminant plume migrating across the ORR boundary. The report recognized that institutional and administrative controls established in the Record of Decision do not provide for reduction in toxicity, mobility, or volume of contaminants of concern, but it concluded the controls protect public health to the extent that they limit or prevent community exposure to contaminated groundwater in Union Valley.

4.6.3.2. Bear Creek Hydrogeologic Regime

Located west of Y-12 in Bear Creek Valley, the Bear Creek regime is bounded to the north by Pine Ridge and to the south by Chestnut Ridge. The regime encompasses the portion of Bear Creek Valley extending from the west end of Y-12 to State Highway 95. Descriptions of waste management sites in the Bear Creek regime and shown on Figure 4.25 were provided in previous year ASERs and are not repeated this year.

Plume Delineation

The primary contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides. The S-3 site is a source of all four contaminants. The Bear Creek Burial Grounds and Oil Landfarm waste management areas are sources of uranium, other trace metals, and VOCs. Chlorinated hydrocarbons and PCBs have been observed in groundwater as deep as 82 m (270 ft) below the Bear Creek Burial Grounds (MMES 1990).

Contaminant plume boundaries are constrained by the bedrock formations (particularly the Nolichucky Shale) that underlie the waste disposal areas in the Bear Creek regime. This fractured aquitard unit is north of and adjacent to the exit pathway unit, the Maynardville Limestone (an aquifer). The elongated shape of the plumes in the Bear Creek regime is the result of preferential transport of the contaminants parallel to strike (parallel to the valley axis).

The plumes in the Bear Creek regime (Figures 4.29, 4.31, 4.32, and 4.33) represent the average concentrations and radioactivity between CYs 2013 and 2017. The circular icons presented on the figures represent CY 2022 monitoring results.

Nitrate

CY 2022 data indicate nitrate in groundwater continues to exceed the drinking water standard (10 mg/L) in an area that extends west from the S-3 site. The highest nitrate concentration (2,040 mg/L) was observed at well GW-246 adjacent to the S-3 site at a depth of 76.5 ft below ground surface. Historically, elevated concentrations of nitrate (>1,000 mg/L) have been detected at greater depths (>700 ft below ground surface) near the S-3 site.

In CY 2022, a concentration exceeding the drinking water standard was detected in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site, from spring location SS-4 (500 mg/L). However, this value is considered an outlier, as this is over an order of magnitude higher than previous concentrations of nitrate found at the spring. The spring was resampled in the summer and fall of CY 2022 and returned to previous concentrations levels at 12 mg/L and 11 mg/L, respectively.

Natural attenuation processes have reduced nitrate levels in the shallow groundwater downgradient of the site, as illustrated by the low CY 2022 nitrate result (7.24 mg/L) for aquitard well GW-537, which had nitrate concentrations above the drinking water maximum contaminant level until CY 2021, as shown in Figure 4.34. This indicates more efficient natural attenuation of nitrate in the shallow flow system, including seasonal discharge of nitrate-contaminated groundwater to the surface drainage network in Bear Creek Valley, compared to the substantially slower attenuation of nitrate in less permeable groundwater flow/contaminant transport pathways deeper in the bedrock.

Under the conceptual model for contaminant transport in the valley, elevated nitrate concentrations in the shallow groundwater from well GW-537 (1,285 in CY 1992 and 8.44 mg/L in CY 2020) were sustained by nitrate-contaminated groundwater upwelling from deeper flowpaths in the Nolichucky Shale (DOE 1997a).

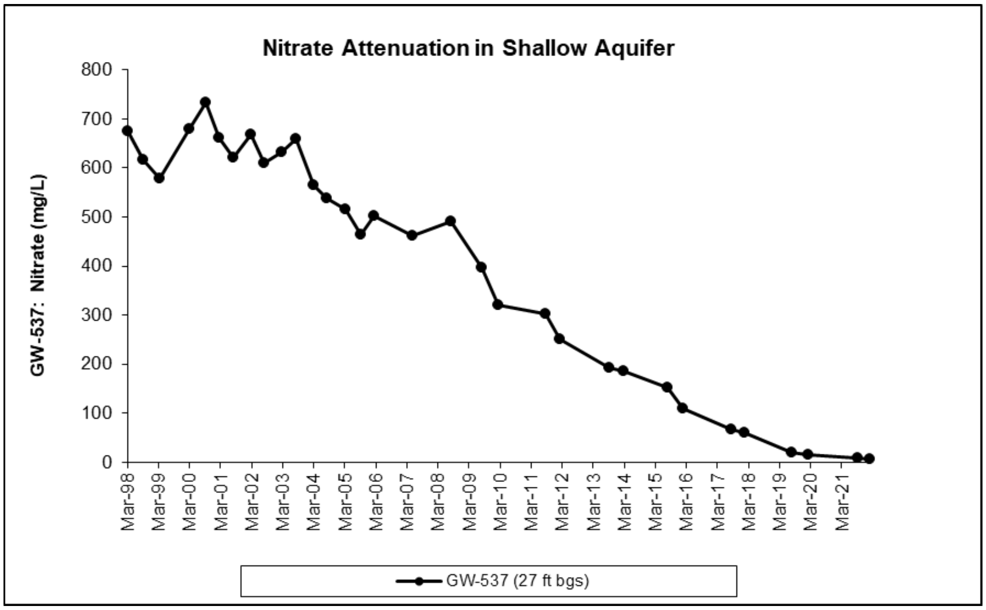


Figure 4.34. Nitrate trend in surveillance monitoring well GW-537, Bear Creek Regime, 1998–2022

Trace Metals

During CY 2022, barium, beryllium, cadmium, nickel, and uranium were identified as trace metal contaminants in the Bear Creek regime that exceeded primary drinking water standards. Elevated concentrations of many of the trace metals were observed at shallow depths near the S-3 site. Disposal of acidic liquid wastes at the S-3 site reduced the pH of the groundwater, which allows the metals to remain in solution longer and migrate further from the source area. In other areas of the Bear Creek regime, where natural geochemical conditions prevail, the trace metals may occur sporadically and in close association with source areas because conditions are typically not favorable for dissolution and migration.

The most prevalent trace metal contaminant is uranium. There has been a decrease in uranium in Bear Creek since 1990 (Table 4.22); however, uranium concentrations in the upper reaches of Bear Creek have been stable, indicating that this contaminant still presents an impact to surface water and groundwater.

Table 4.22. Nitrate and uranium concentrations in Bear Creek

Bear Creek Monitoring Station (distance from S-3 site)	Contaminant	Average Concentration[a] (mg/L)			
		1990–1999	2000–2009	2010–2019	2020–2022
BCK[b]-11.84 to 11.97	Nitrate	91.9	75.2	43.4	26.0
(~0.5 miles downstream)	Uranium	1.61	0.124	0.183	0.162
BCK-09.20 to 09.47	Nitrate	12.4	11.3	4.8	2.68
(~2 miles downstream)	Uranium	0.096	0.115	0.061	0.052
BCK-04.55	Nitrate	3.8	2.5	0.96	2.98
(~5 miles downstream)	Uranium	0.033	0.028	0.018	0.015

[a] *Excludes results that do not meet data quality objectives.*
[b] *BCK = Bear Creek kilometer, measured upstream from the confluence with East Fork Poplar Creek.*

VOCs

VOCs are widespread in groundwater in the Bear Creek regime. The primary compounds are PCE; TCE; cis-1,2-DCE; vinyl chloride; and 1,1 dichoroethane. In most areas, they are dissolved in groundwater and can occur in bedrock at depths up to 92 m (300 ft) below ground surface. VOCs that occur in groundwater of the fractured bedrock aquitard units are found within about 305 m (1,000 ft) laterally of source areas.

The highest concentration observed in CY 2022 occurred in the Nolichucky Shale aquitard at the Bear Creek Burial Ground waste management area, with a maximum summed VOC concentration of 6,580 µg/L in well GW-068; cis 1,2-dichloroethene at 2,900 µg/L, 1,1-dichloroethane at 1,400 µg/L, and vinyl chloride at 1,200 µg/L comprised most of the summed total. The summed VOC concentrations of GW-626 show wide temporal concentration fluctuations that do not display any consistently increasing or decreasing long-term trend.

The indeterminate long-term trends probably reflect the combined influence of (1) the large volume of VOC in the subsurface at the Bear Creek Burial Ground source area, (2) low permeability of the groundwater flow/transport pathways monitored by the wells, and (3) minimal natural attenuation of the VOCs during residence/transport in the subsurface. The relative significance of the increasing trend for GW-627 shown in Figure 4.35 depends on a combination of multiple variable factors, notably the permeability and connectivity of the flowpaths that could allow influx of VOCs from sources areas located in the shallow aquifer.

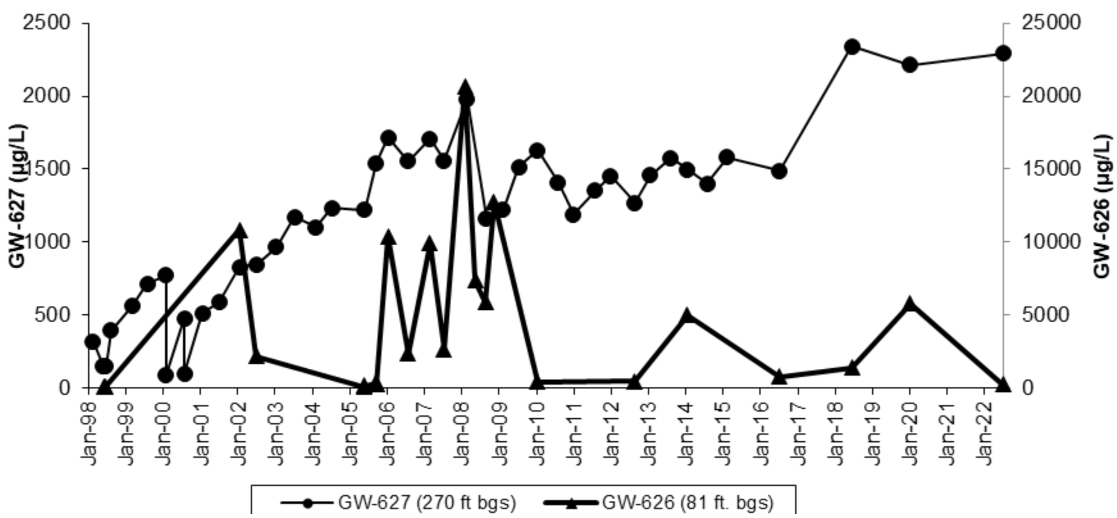


Figure 4.35. Indeterminate and increasing VOC trends in surveillance monitoring wells GW-626 and GW-627, Bear Creek Regime

Radionuclides

As in the EFPC regime, the primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. The extent of radionuclides in groundwater in the Bear Creek regime during CY 2022 was based primarily on measurements of gross-alpha and gross-beta activity. If the gross-alpha activity in a well exceeded 15 pCi/L (the drinking water standard for gross-alpha activity), then one (or more) of the alpha-emitting radionuclides (e.g., uranium) is assumed to be present and, at certain monitoring locations, is evaluated isotopically. A similar rationale is used for gross-beta activity that exceeds 50 pCi/L. Technetium-99, a more volatile radionuclide, is qualitatively screened by gross-beta activity analysis.

Groundwater in the Bear Creek regime with elevated gross-alpha activity occurs near the S-3 site and the Oil Landfarm waste management areas. In the bedrock interval, gross-alpha activity has exceeded 15 pCi/L in groundwater in the fractured bedrock of the aquitard units only near source areas (Figure 4.33).

In CY 2022, the highest gross-alpha activity observed in a monitoring well in the Bear Creek regime (79 pCi/L) was in GW-276, which is adjacent to the S-3 site (see Figure 4.32).

In CY 2022, the highest gross-beta activity in groundwater in the Bear Creek regime was at well GW-246 (8,700 pCi/L) which is also adjacent to the S-3 site (see Figure 4.33).

Exit Pathway and Perimeter Monitoring

Bear Creek, which flows over the Maynardville Limestone (the primary exit pathway for groundwater) in much of the Bear Creek regime, is the principal exit pathway for surface water. Studies have shown the surface water in Bear Creek, the springs along the valley floor, and the groundwater in the Maynardville Limestone are hydraulically connected. Surveys have identified gaining (groundwater discharging into surface waters) and losing (surface water discharging into a groundwater system) reaches of Bear Creek. The western exit pathway monitoring well transect (EXP-W) serves as the perimeter well location for the Bear Creek regime (Figure 4.26).

Exit pathway monitoring continues at four Exit Pathway Transects (A, B, C, and W; see Figure 4.26) also referred to as pickets, and selected springs and surface water stations. Data obtained during CY 2022 indicate groundwater is contaminated above drinking water standards in the Maynardville Limestone as far as Picket W. The drinking water standard for gross-alpha was exceeded (26 pCi/L) in deep well GW-710. Historically, this well has presented elevated levels of gross-alpha activity. At 164.6 m (540 ft) below ground surface, the well is affected by deep brine water that likely contains radium and radon, which could account for the elevated gross-alpha activity. Concentration trends throughout the exit pathway continue to be generally stable to decreasing, as shown in Figure. 4.36.

In CY 2022, GW-713 in exit pathway transect W showed a trace concentration (0.48 μg/L) of TCE (below drinking water standards), thus indicating migration of contaminants potentially thousands of feet from likely sources areas to the east (e.g., Boneyard/Burnyard, the S-3 site, or Spoil Area 1). TCE is sporadically detected in GW-713 but has never been detected above drinking water standards.

Surface water samples collected in CY 2022 indicate water in Bear Creek contains many of the same compounds found in the groundwater. Uranium concentrations exceeding the drinking water standard have been observed in surface water west of the Burial Grounds as far as Picket W. The concentrations in the creek generally decrease with distance downstream of the waste disposal sites (Table 4.20).

Exit pathway monitoring stations sampled in CY 2022 show that gross-alpha activity in the Maynardville Limestone and the surface waters of Bear Creek was undetectable at SS-5. This location is over 3,353 m (11,000 ft) west of the S-3 site and, in the recent past, has shown activities of 31 pCi/L in CY 2017, 19 pCi/L in CY 2018, 17 pCi/L in CY 2019, and 16 pCi/L in CY 2021, continuing with the decreasing trend.

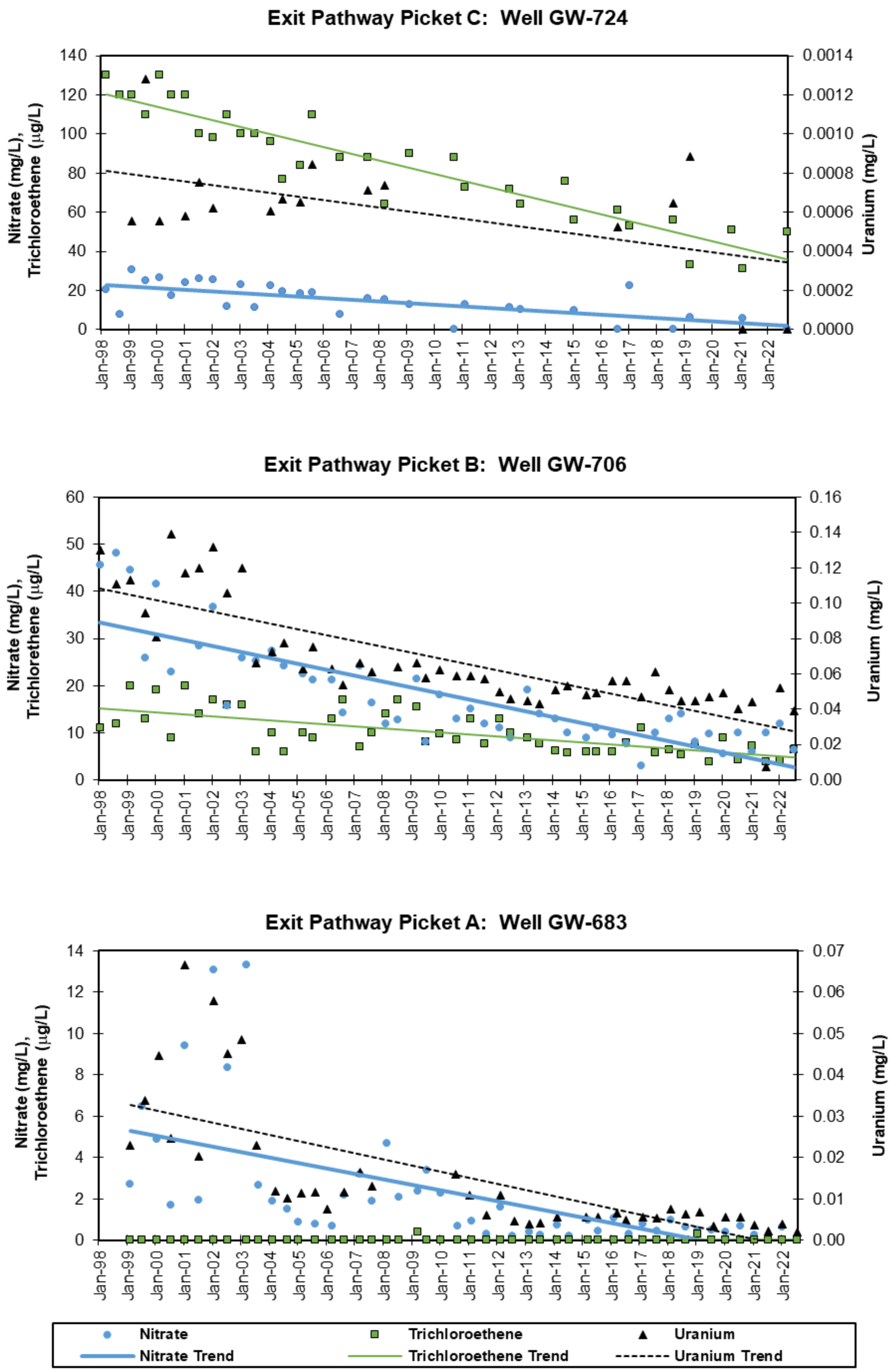


Figure 4.36. Concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime, 2022

4.6.3.3. Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge hydrogeologic regime is flanked to the north by Bear Creek Valley and to the south by Bethel Valley Road (Figure 4.25). The regime encompasses the portion of Chestnut Ridge extending from Scarboro Road, east of the complex, to Dunaway Branch, located just west of Industrial Landfill II. Descriptions of waste management sites in the Chestnut Ridge regime and shown on Figure 4.26 were provided in previous year ASERs and are not repeated this year.

The Chestnut Ridge Security Pits area is the primary source of groundwater contamination in the regime. Contamination from the security pits is distinct and does not mingle with plumes from other sources.

Plume Delineation

The extent of the VOC plume at the Chestnut Ridge Security Pits is reasonably well defined in the water table and shallow bedrock zones. With two possible exceptions, historical monitoring indicates the VOC plume from the Chestnut Ridge Security Pits has shown minimal migration in any direction (<305 m [<1,000 ft]).

Data obtained during CY 2022 indicate the western lateral extent of the VOCs plume at the site has not changed significantly. VOC contaminants at a well about 458 m (1,500 ft) southeast and downgradient of the Chestnut Ridge Security Pits continue to show some migration of the eastern plume has occurred. Additionally, previously performed dye tracer test results and the intermittent detection of trace concentrations of VOCs (similar to those found in wells adjacent to the Chestnut Ridge Security Pits) at a natural spring about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that Chestnut Ridge Security Pits contaminants have migrated further than the monitoring well network indicates. However, as in CY 2020 and CY 2021, no VOCs were detected at this spring in CY 2022.

The Chestnut Ridge Security Pits plume in the Chestnut Ridge regime (shown by orange shading on Figure 4.31) represents the average VOC concentrations between CYs 2013 and 2017. The circular icons presented on the figure represent CY 2022 monitoring results.

Nitrate

Nitrate concentrations continue to be below the drinking water standard at all monitoring stations in the Chestnut Ridge regime in CY 2022.

Trace Metals

Concentrations of arsenic above drinking water standards have been observed in two surface water monitoring locations downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA Record of Decision (DOE 1996). Under the decision, migration of contaminated effluent from the Filled Coal Ash Pond is reduced by a constructed wetland area. In recent years, it became apparent the wetland efficiency was decreasing, in part, because of erosion channels forming around the wetland. During CY 2019, a maintenance activity was conducted at the site to improve the aquatic habitat for plant growth and to increase retention time for water within the wetland. The elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area. In CY 2022, the passive wetland treatment area continued to be effective in reducing arsenic.

VOCs

Overall, concentrations of VOCs in groundwater at the Chestnut Ridge Security Pits have decreased since 1988. Summed VOC concentrations above the drinking water standard were observed at five monitoring wells associated with the Chestnut Ridge Security Pits—GW-176 (20 µg/L), GW-179 (9 µg/L), GW-180 (11 µg/L), GW-322 (18 µg/L), and GW-612 (13 µg/L) during CY 2022.

At Industrial Landfill IV, VOCs have been observed in the groundwater since 1992. Well GW-305, located immediately to the southeast of the facility (Figure 4.31), exhibited increasing trends of summed VOCs from 1992 to 2014 but have stabilized since with the CY 2022 concentration at

78.53 μg/L. GW-305 was sampled in January and July 2022 with results for 1,1 DCE of 6.1 μg/L and 6.93 μg/L, respectively. Both were below the drinking water standard (7 μg/L).

Radionuclides

In CY 2022, no gross-alpha above the drinking water standards of 15 pCi/L was observed in the Chestnut Ridge hydrogeologic regime. However, gross-beta was detected above the drinking water standard of 50 pCi/L at monitoring well GW-205 (51pCi/L). This well is associated with the United Nuclear Corporation Site.

Exit Pathway and Perimeter Monitoring

Contaminant and groundwater flowpaths in the karst bedrock underlying the Chestnut Ridge regime have not been well characterized. Tracer studies have been conducted that show groundwater from Chestnut Ridge discharging into Scarboro Creek (approximately 9,000 ft from the Chestnut Ridge Security Pits) and other tributaries that feed into Melton Hill Lake. However, no springs or surface streams that represent discharge points for groundwater have been conclusively correlated to a waste management unit or operation at Y-12 that is a known or potential groundwater contaminant source. Springs along Scarboro Creek are monitored for water quality, and trace concentrations of VOCs are intermittently detected. The detected VOCs are suspected to originate from the Chestnut Ridge Security Pits; however, this has not been confirmed. In CY 2022, three springs along Scarboro Creek were sampled with no detected concentrations of VOCs.

Monitoring natural groundwater exit pathways is a basic monitoring strategy in a karst regime, such as that of Chestnut Ridge. Perimeter springs and surface water tributaries were monitored to determine whether contaminants are exiting the downgradient (southern) side of the regime. Five springs and three surface water monitoring locations were sampled during CY 2022. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards.

4.6.4. Emerging Contaminants

Per- and polyfluoroalkyl substances (PFAS) are emerging contaminants that constitute a large family of fluorinated chemicals. The persistence and mobility of some PFAS, combined with decades of widespread use in industrial processes, certain types of firefighting foams, and consumer products, have resulted in their being present in environmental media at trace levels across the globe. It was not until the early 2010s that analytical methods to detect a limited number of PFAS became widely available and had detection limits in water low enough to be commensurate with levels of potential human health effects. Toxicological studies have raised concerns regarding the bioaccumulative nature and potential health concerns of some PFAS (CNS 2022a).

The following actions and activities were conducted at Y-12 during CY 2022 to address these emerging contaminants of concern:

- Y-12 remained compliant with new DOE requirements pertaining to PFAS storage, use, and disposal during CY 2022 (DOE, 2021a, DOE 2021b).
    - No PFAS-containing aqueous film-forming foam (AFFF) was used for training purposes, and no new AFFF systems were installed in CY 2022. Existing AFFF systems are only approved for use in fire emergencies.
    - Measures were taken to minimize fire protection personnel and the environment from exposure to PFAS-containing AFFF.
    - PFAS-containing AFFF is stored in accordance with DOE orders and directives, laws, and regulations. No disposal of PFAS-containing AFFF occurred during CY 2022.
    - No new releases or spills of PFAS-containing AFFF occurred in CY 2022.

- Current and historic uses of 176 PFAS or PFAS-related substances are being tracked using the Y-12 Hazardous Material Information System. No PFAS substances were used in excess of the EPCRA TRI reporting threshold during CY 2022.
- One waste storage building (9720-09) has an AFFF fire suppression system.
- Y-12 has a fire department and fire training facility on-site. The Y-12 Fire Department has one firetruck with a foam induction system that uses a fluorine-free foam.
- No production-related activities, equipment, or processes are known to have generated or released PFAS to the environment. However, a number of products/chemicals containing PFAS have been used in small quantities, primarily in the Analytical Chemistry laboratories and in the Development facilities.

4.7. Quality Assurance Program

Y-12's QA Program establishes a quality policy and requirements for the Y-12 site. Management requirement E-SD-0002, *Quality Assurance Program Description*, details the methods used to carry out work processes safely and securely and in accordance with established procedures (CNS 2022b). It also describes mechanisms in place to seek continuous improvements by identifying and correcting findings and preventing recurrences.

Many factors can potentially affect the results of environmental data-collection activities, including sampling personnel, methods, and procedures; field conditions; sample handling, preservation, and transport; personnel training; analytical methods; data reporting; and recordkeeping. QA programs are designed to minimize these sources of variability and control all phases of the monitoring process.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Using work control processes and standard operating procedures for sample collection and analysis.
- Using chain-of-custody and sample identification procedures.
- Standardizing, calibrating, and verifying instruments.
- Training sample technicians and laboratory analysts.
- Preserving, handling, and decontaminating samples.
- Using QC samples, such as field and trip blanks, duplicates, and equipment rinses.

Y-12 Environmental Sampling Services are responsible for field sampling activities, sample preservation and handling, chain-of-custody, and field QC sample transport in accordance with Y-12 Environmental Compliance internal procedures. Environmental Sampling Services developed a Standards and Calibration Program that conforms to ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories* (ISO 2017), and provides a process for uniform standardization, calibration, and verification of measurement and test equipment. The Standards and Calibration Program ensures measurements are made using appropriate, documented methods; traceable standards; appropriate measurement and test equipment of known accuracy; trained personnel; and technical best practices.

Analytical results may be affected by a large number of factors inherent to the measurement process. Laboratories that support Y-12 environmental monitoring programs use internal QA/QC programs to ensure the early detection of problems that may arise from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Internal laboratory QA/QC programs include routine calibrations of counting instruments; yield determinations; include frequent use of check sources and background counts, replicate and spiked sample analyses, and matrix and reagent blanks; and include maintenance of control charts to indicate analytical deficiencies. These activities are supported by the use of standard materials or reference materials (e.g., materials of known composition that are used in the calibration of instruments, methods standardization, spike additions for recovery tests, and other practices). Certified standards traceable to National Institute of Standards and Technology, DOE sources, or EPA are used (when available) for such work.

Y-12's Analytical Chemistry Organization QA Manual describes QA Program elements; customer-specific requirements; certification program requirements; federal, state, and local regulations; and waste acceptance criteria. As a government-owned, contractor-operated laboratory that performs work for DOE, the Analytical Chemistry Organization laboratory operates in accordance with DOE Order 414.1D, *Quality Assurance* (DOE 2011c).

Other internal practices used to ensure laboratory results are representative of actual conditions include training and managing staff; maintaining adequacy of the laboratory environment; safety; controlling the storage, integrity, and identity of samples; recordkeeping; maintaining and calibrating instruments; and using technically validated and properly documented methods.

Y-12's Analytical Chemistry Organization participated in both Mixed Analyte Performance Evaluation Program studies conducted in 2021 for water, soil, and air filter matrices for metals, organics, and radionuclides. The overall acceptability rating from both studies was 97.8 percent.

Verification and validation of environmental data are performed as components of the data-collection process, which includes planning, sampling, analyzing, and performing data review. Some level of verification and validation of field and analytical data collected for environmental monitoring and restoration programs is necessary to ensure that data conform to applicable regulatory and contractual requirements.

Validation of field and analytical data is a technical review performed to compare data with established quality criteria to ensure that data are adequate for the intended use. The extent of project data verification and validation activities is based on project-specific requirements.

For routine environmental effluent monitoring and surveillance monitoring, data verification activities may include processes to check whether data have been accurately transcribed and recorded, appropriate procedures have been followed, electronic and hard copy data show one-to-one correspondence, and data are consistent with expected trends. Typically, routine data verification actions alone are sufficient to document the validity and accuracy of environmental reports. For restoration projects, routine verification activities are more contractually oriented and include checks for data completeness, consistency, and compliance with a predetermined standard or contract.

Certain projects may require a more-thorough technical validation of the data, as mandated by the project's data quality objectives. Sampling and analyses conducted as part of a remedial investigation to support the CERCLA process may generate data that are needed to evaluate risk to human health and the environment, to document that no further remediation is necessary, or to support a multimillion-dollar construction activity and treatment alternative. In these cases, the data quality objectives of the project may mandate a thorough technical evaluation of the data against rigorous predetermined criteria.

The validation process may result in identifying data that do not meet predetermined QC criteria or in the ultimate rejection of data for their intended use. Typical criteria evaluated in the validation of contract laboratory program data include the percentage of surrogate recoveries, spike recoveries, method blanks, instrument tuning, instrument calibration, continuing calibration verifications, internal standard response, comparison of duplicate samples, and sample holding times.

A due diligence analysis is performed for facilities used for the treatment, storage, or disposal of radiological and hazardous waste to ensure that each facility is well operated and maintained; has minimal environmental issues and impacts; employs personnel that are properly trained, competent, and work safely; is in compliance with regulatory requirements; and is adequately insured against personal and environmental liabilities.

This evaluation includes a review of information on the facility's compliance history, design, operations, recordkeeping and reporting requirements, emergency response procedures, closure/post-closure plans, and insurance coverage, as well as any environmental issues, remediation, litigation or regulatory agency concerns related to the facility. Y-12 is committed to limiting the number of facilities used and avoiding or discontinuing the use of facilities that present significant environmental and/or safety liability. This evaluation may rely on results of third-party accreditation assessments reported under the DOE Consolidated Audit Program.

Table 4.23 lists treatment, storage, and disposal facilities used in 2022 for the disposition of radiological and hazardous waste.

Table 4.23. Treatment, storage, and disposal facilities used to disposition radiological and hazardous waste, 2022

Facility Name	Location	Identification Number
Clean Harbors Cincinnati (Spring Grove) Facility	Cincinnati, Ohio	OHD000816629
Clean Harbors Cleveland Technical Services	Cleveland, Ohio	OHD000724153
Clean Harbors Colfax Facility	Colfax, Louisiana	LAD981055791
Clean Harbors Deer Park Incineration Facility	La Porte, Texas	TXD055141378
Clean Harbors El Dorado Incineration Facility	Ed Dorado, Arkansas	ARD069748192
Clean Harbors Grassy Mountain Landfill Facility	Clive, Utah	UTD991301748
Clean Harbors La Porte Technical Services	La Porte, Texas	TXD982290140
Clean Harbors Lone Mountain Facility	Waynoka, Oklahoma	OKD065438376
Diversified Scientific Services, Inc.	Kingston, Tennessee	TND982109142
Energy Solutions Bear Creek Processing Facility	Kingston, Tennessee	TND982157570
EnergySolutions Clive Disposal Facility	Grantsville, Utah	UTD982598898
Nevada National Security Site	Mercury, Nevada	NV3890090001
Perma-Fix of Florida, Inc.	Gainesville, Florida	FLD980711071
Safety-Kleen Systems	Smithfield, Kentucky	KYD053348108

4.8. Environmental Management and Waste Management Activities

The three sites on ORR have a rich history of research, innovation, and scientific discovery that shaped the course of the world. Unfortunately, despite their vitally important missions, they are hindered by environmental legacies remaining from past operations. The contaminated portions of ORR are on the EPA National Priorities List, which includes hazardous waste sites across the nation that are to be cleaned up under CERCLA. Areas that require cleanup or further action on ORR have been clearly defined, and DOE EM is working to clean those areas under the Federal Facility Agreement with the EPA and TDEC. The *2022 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2022a) provides detailed information on DOE EM cleanup activities.

4.8.1. Environmental Management Activities

At Y-12, DOE EM is working to address excess and contaminated facilities, remove mercury soil and groundwater contamination, and enable modernization that allows NNSA to continue its crucial national security and nuclear nonproliferation responsibilities.

Criticality Experiment Laboratory Demolished

Seventy-three years after it was built, the Criticality Experiment Laboratory (Building 9213) and all of its ancillary facilities have been demolished. Beginning in May 2022, crews worked the hot and rainy summer to demolish the 24,000-square-foot facility, which had been home to a variety of missions since its construction in 1949.

During the first decade of the building's operation, more than 9,700 experiments were conducted. Later, it supported the ORNL High Flux Isotope Reactor program. The building has been closed since 1992.

More than 4,500 cubic yards (525 truckloads) of waste was disposed. During the nearly two years of deactivation, crews prepared the building for demolition by removing, packaging, and shipping 1,496 linear feet of asbestos-insulated piping, 323 linear feet of process piping, and 8,540 square feet of other asbestos-containing material.

Biology Complex Slab Removed

Workers have finished removing the remaining slabs at the now demolished Biology Complex, readying the land for transfer to Y-12. The land is expected to be the site of the new LPF.

Dating back to the 1940s, the Biology Complex originally consisted of 11 buildings. It was constructed for recovering uranium from process streams and later used for research that led to strides in understanding genetics and the effects of radiation.

Crews completed backfilling and seeding the portion of the site where the last two buildings (Buildings 9207 and 9210) once stood. In subsequent months, slabs remaining from previous demolition of buildings at the location were removed and their footprints backfilled and graveled. Between removal of those slabs and the slabs at Buildings 9207 and 9210, more than 6,141 yd^3 of waste and debris were removed.

New Technologies Evaluated for Mercury Cleanup

DOE EM is developing new remediation technologies to address mercury releases into the environment from past operations. These technologies will support demolition of Y-12's mercury-contaminated facilities as well as soil remediation and reduction of mercury-related ecological risks.

At the Aquatic Ecology Laboratory, workers test the effectiveness of remediation technologies in a flow-through system using water from EFPC.

Researchers have conducted studies to evaluate alternative treatment chemicals on mercury flux, the effect of sorbents on mercury and methylmercury concentrations in the presence of dissolved organic matter, and the use of mussels for reducing mercury in the water column. Scientists prepared a report titled *Mercury Remediation Technology Development for Lower East Fork Poplar Creek—FY 2022 Update* (Mathews 2022) that provides findings from FY 2022 studies. Field characterization and research undertaken from 2015 to 2022 will support an evaluation of remediation alternatives for the creek in the mid-2020s.

In 2022, unmanned aerial vehicles equipped with sensors took various measurements to evaluate how organisms such as some algae, bacteria, fungi, and a variety of invertebrates (periphyton) interact in stream environments. These periphyton have been recognized to play a major role in mercury methylation and accumulation in other living organisms.

A new support tool was developed that uses watershed models to simulate remediation scenarios. With a better understanding of mercury transport in the watershed system, specific technologies and strategies can be assessed and implemented.

There have also been increased efforts to identify and demonstrate emerging technologies that will aid in addressing Y-12 mercury remediation challenges. A Mercury Review Committee consisting of members from DOE, its contractors, and subject matter experts serves as the primary resource to evaluate and select proposed new technologies. Contracting for the first technology demonstration began in 2022.

As part of the technology demonstration initiative, establishing a facility for demonstrating mercury-related technologies is being evaluated. A conceptual report was prepared that outlines the modifications needed to be able to use an existing facility on the ORR as a location for technology demonstrations. The facility modification design is in progress.

Mercury Treatment Facility Construction Progressing

Progress continued on construction of the Outfall 200 Mercury Treatment Facility. Shoring and major excavations were completed at the headworks site. Crews continued placing concrete pads and walls of the treatment plant. Crews also began erecting structural steel and continued installing underground utilities.

The facility is the linchpin for DOE EM's cleanup strategy at Y-12. This vital piece of infrastructure will open the door for demolition of Y-12's large, deteriorated, mercury-contaminated facilities and subsequent soil remediation by providing a mechanism to limit potential mercury releases into the Upper EFPC.

When operational, the facility will be able to treat 3,000 gallons of water per minute and help DOE meet regulatory limits in compliance with EPA and state of Tennessee requirements. The facility is slated to be operational in 2025.

Uranium Processing Facilities Being Deactivated

Three large former uranium processing facilities were being deactivated in FY 2022. Those facilities—Building 9201-02, Building 9201-04, and Building 9204-01—were home to the historic calutron (mass spectrometer) racetracks used for separating isotopes of uranium.

Deactivation work in these large facilities is the heavy lift leading up to demolition and is focused on removing potential hazards and environmental risks. It can take months, sometimes years, to complete all of the aspects of deactivation.

- **Building 9201-02.** The three-story facility has a footprint of 107,619 square feet. Since bringing the building to the cold and dark stage in the summer of 2021, workers have been steadily deactivating the facility. In addition to removing asbestos-contaminated materials and hazardous and universal waste, workers have drained tens of thousands of gallons of oil from large pieces of electrical equipment and, to date, have removed 184,569 pounds of lead blocks from shields that were used to support fusion experiments.

- **Building 9201-04.** With a footprint of more than 174,000 square feet, the four-story building is one of Y-12's largest high-risk facilities, with elemental mercury contaminating much of the structure.

  During the fiscal year, workers completed deactivation of the adjacent East Column Exchange equipment, which involved retrieving 2.3 tons of mercury from the processing structure's pipes and tanks. That amount is in addition to the 4.19 tons that were recovered from the West Column Exchange equipment, when it was demolished in 2018. A combined total of 6.49 tons was recovered from the East and West Column Exchange equipment, which significantly reduces potential releases to the environment at Y-12.

  As the fiscal year was ending, crews were beginning work to make Building 9201-04 cold and dark. That work includes isolating mechanical and electrical power sources so that crews can safely remove hazardous waste and prep the facility for demolition.

- **Building 9204-01.** Next to Building 9201-02 is the multi-level Building 9204-1, with a footprint of 75,012 square feet. During the fiscal year, crews removed asbestos-containing materials (e.g., floor and ceiling tile, ductwork, piping) as well as hazardous and legacy waste.

  A challenge for deactivation crews in the building is to pump out tens of thousands of gallons of water from the basement in order to perform deactivation activities there. Crews performed an infiltration study in the spring to support design of a water treatment skid to treat and discharge approximately 3 million gallons of water starting in the late winter/early spring FY 2023.

4.8.2. Waste Management Activities

Waste management is performed at multiple locations on the ORR for both solid and liquid wastes, including landfills and water treatment facilities.

4.8.2.1. Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal

Most of the waste generated during FY 2022 cleanup activities in Oak Ridge went to disposal facilities on the ORR. The Environmental Management Waste Management Facility received 7,172 waste shipments, totaling 58,404 yd^3, from cleanup projects at ETTP, ORNL, and Y-12. This engineered landfill consists of six disposal cells that only accept low-level radioactive and hazardous waste meeting specific criteria. These wastes include soil, dried sludge and sediment, building debris, and personal protective equipment.

4.8.2.2. Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities known as the ORR Landfills. In FY 2022, these three active landfills received 11,146 waste shipments, totaling 155,039 yd^3 of waste.

4.8.2.3. Wastewater Treatment

Safe and compliant treatment of more than 35.6 million gallons of wastewater and groundwater generated from both production and environmental cleanup activities was provided at various facilities during 2022:

- The West End Treatment Facility and the Central Pollution Control Facility at Y-12 processed approximately 400,000 gallons of wastewater, primarily in support of NNSA operational activities.
- The Big Springs Water Treatment System treated more than 19 million gallons of mercury-contaminated groundwater.
- The East End VOC Treatment System treated 12 million gallons of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 2.7 million gallons of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 1.6 million gallons of mercury-contaminated sump waters from Building 9201-04.

4.9. References

40 CFR 61. "National Emission Standards for Hazard Air Pollutants." *US Code of Federal Regulations*, Environmental Protection Agency, Washington, DC.

40 CFR 63. "National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters." US Code of Federal Regulations, Environmental Protection Agency, Washington DC.

40 CFR 68. *Clean Air Act*, Title III, Section 112(r), "Accidental Release Prevention/Risk Management Plan Rule." Environmental Protection Agency, Washington, DC.

40 CFR 98. "Mandatory Reporting of Greenhouse Gases." *US Code of Federal Regulations*, Environmental Protection Agency, Washington, DC.

49 CFR 173. "Shippers—General Requirements for Shipments and Packaging." *US Code of Federal Regulations*, US Department of Transportation, Washington, DC.

ANSI 2013. *Surface and Volume Radioactive Standards for Clearance*. ANSI/HPS N13.12-2013, Health Physics Society, Herndon, VA.

ATSDR 2006. *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation.* Agency for Toxic Substances and Diseases Registry, Atlanta, Georgia.

B&W Y-12 2012. *Radiological Monitoring Plan for the Oak Ridge Y-12 National Security Complex: Surface Water*. Y/TS-1704/R3, Babcock & Wilcox Technical Services Y-12, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee.

Brandt et. at. 2013. Brandt, Craig C; Christensen, Sigurd W; Greeley Jr, Mark Stephen; Mathews, Teresa J; Roy, W Kelly; Ryon, Michael G; Sabo, Karen A; and Smith, John G. *Y-12 National Security Complex Biological Monitoring and Abatement Program Plan*. ORNL/TM-2012/171/ORNL/TM-2013/71, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

BWXT 2003. *National Historic Preservation Act Historic Preservation Plan for the Y-12 National Security Complex.* Y/TS-1893, BWXT Y-12, L.L.C., Y-12 National Security Complex, Oak Ridge, Tennessee.

CNS 2020. *Y-12 National Security Complex Quality Assurance Project Plan National Emission Standards for Hazardous Air Pollutants for Radionuclide Emission Measurements.* Y/TS-874R5, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee.

CNS 2022a. *Calendar Year 2021 Groundwater Monitoring Report.* Y/SUB/22-169187/1, US Department of Energy, Y-12 National Security Complex, Oak Ridge, Tennessee.

CNS 2022b. *Quality Assurance Program Description*. E-SD-0002, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee. June.

CNS 2022c. *Spill Prevention, Control, and Countermeasure Plan for the U.S. Department of Energy Y-12 National Security Complex, Oak Ridge, Tennessee*. Y/SUB/02-001091/8, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee, October.

CNS 2023. *Calendar Year 2022 Groundwater Monitoring Report*. Y/SUB/23-169187/1, US Department of Energy Y-12 National Security Complex, Oak Ridge, Tennessee.

DOE 1996. *Record of Decision for Chestnut Ridge Operable Unit 2 (Filled Coal Ash Pond and Vicinity), Oak Ridge, Tennessee*. DOE/OR/02-1410&D3, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1997a. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*. DOE/ORR/01-

1455/V1/V6&D2, US Department of Energy, Washington, DC.

DOE 1997b. R*ecord of Decision for an Interim Action for Union Valley, Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee.* DOE/OR/02-1545&D2, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1998. *Report on the Remedial Investigation of the Upper East Fork Poplar Creek Characterization Area at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*. DOE/OR/01-1641/V1-V4&D2, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2003. *Programmatic Agreement Among the Department of Energy, Oak Ridge Operations Office, the National Nuclear Security Administration, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation Concerning the Management of Historical and Cultural Properties at the Y-12 National Security Complex*. US Department of Energy, Washington, DC, September.

DOE 2011a. *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex*. DOE/EIS-0387, US Department of Energy, National Nuclear Security Administration, Y-12 Site Office, Oak Ridge, Tennessee, February.

DOE 2011b. *Radiation Protection of the Public and the Environment.* DOE Order 458.1, approved February 11, 2011, Chg. 4 approved September 15, 2020, US Department of Energy, Washington, DC.

DOE 2011c. *Quality Assurance.* DOE Order 414.1D, approved April 25, 2011, Chg. 2 approved September 15, 2020, US Department of Energy, Washington, DC.

DOE 2011d. *Departmental Sustainability*, DOE Order 436.1A, approved April 25, 2023. US Department of Energy, Washington, DC.

DOE 2020a. *Compliance Plan, National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee.* DOE/ORO/2196, Revision 2, US Department of Energy, Washington, DC.

DOE 2021a. *Memorandum for Heads of Departmental Elements: Addressing Per- and Polyfluoroalkyl Substances at the Department of Energy.* NNSA-2021-004992, US Department of Energy, Washington, DC, David M. Turk, Deputy Secretary of Energy, September 16, 2021.

DOE 2021b. *Memorandum for Distribution: Direction to Implement Department of Energy Policy on Per- and Polyfluoroalkyl Substances*. US Department of Energy, Washington, DC, James J. McConnell, Associate Administrator for Safety, Infrastructure, and Operations, October 26, 2021.

DOE 2022a. *Federal Facility Agreement for the Oak Ridge Reservation, Appendix C, Latest Revision.* FFA-PM/22-002, DOE/OR-1014. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee. Available online at http://www/ucor/com/ettp_ffa.html.

DOE 2022b. *2022 Remediation Effectiveness Report for the US Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee*. DOE/OE/01-2916&D1, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2023. *2023 Remediation Effectiveness Report for the US Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee*. DOE/OE/01-2916&D1. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

Energy Independence and Security Act of 2007, Public Law 110-140, US Government.

EPA 1995, 1998. *Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume 1: Stationary Point and Area Sources*. US Environmental Protection Agency, Research

Triangle Park, North Carolina, January 1995, September 1998.

EPA 2021. *Final Rule—Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act*. 86 FR 55116 (EPA-HQ-OAR-2021-0044), US Environmental Protection Agency, Stratospheric Protection Division, Washington, DC, November 4, 2021.

ISO 2015. ISO 14001:2015, E*nvironmental Management Systems—Requirements With Guidance For Use*. International Organization for Standardization, Geneva, Switzerland.

ISO 2017. *General Requirements for the Competence of Testing and Calibration Laboratories.* ISO/IEC 17025:2017, International Organization for Standardization, Geneva, Switzerland.

Mathews et. al 2019. Mathews, T.; Glass-Mattie, J. D. Morris, G.; Fortner, A.; Jett, R.T.; Jones, M.; Jones, N.; DeRolph, C.; and Peterson, M. *Oak Ridge National Laboratory Toxicity Identification/Reduction Evaluation for the Y-12 National Security Complex Outfall 200.* ORNL/TM-2019/1268, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

Mathews et. al 2022. Mathews, T.,;Mayes, M.; Brooks, S.; DeRolph, C.; Johs, A.; Nair, S.; Gonez-Rodriguez, L.; Pouil, S.; Stevenson, L.; Hills, A.; Matson, P.; Martinez Collado, J. *Mercury Remediation Technology Development for Lower East Fork Poplar Creek—FY 2022 Update*. ORNL/SPR-2020/1577, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

MMES 1990. *Report and Preliminary Assessment of the Occurrence of Dense, Nonaqueous Phase Liquids in the Bear Creek Burial Grounds Hazardous Waste Disposal Unit at the Oak Ridge Y-12 Plant*. Y/TS-960. Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

MMES 1995. *Calendar Year 1994 Groundwater Quality Report for the Upper East Fork Poplar Creek Hydrogeologic Regime, Y-12 Plant, Oak Ridge, Tennessee*. Y/SUB/95-EAQ10C/2/P2, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

NCRP 1996. *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground – Vol. I and Vol II*. NCRP Report No. 123. National Council on Radiation Protection and Measurements, Bethesda, MD, 1996.

NEPA 1969. *National Environmental Policy*. Title 42, US Code Chapter 55.

NNSA 2015a. *Environmental Assessment of the Emergency Operations Center Project*. DOE/EA-2014, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, September.

NNSA 2015b. *Finding of No Significant Impact for the Emergency Operations Center Project Y-12 National Security Complex*. DOE/EA-2014, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, October.

NNSA 2016. *Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex*. DOE/EIS-0387-SA-01, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, April.

NNSA 2018. *Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex*. DOE/EIS-0387-SA 03, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, August.

NNSA 2020a. *Final Supplement Analysis for the Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex, Earthquake Accident Analysis*. DOE/EIS-0387-SA-04, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, June.

NNSA 2020b. *Environmental Assessment of the Oak Ridge Enhanced Technology and Training Center*. DOE/EA-2144, National Nuclear

Security Administration, NNSA Production Office, Oak Ridge, Tennessee, November.

NNSA 2020c. *Finding of No Significant Impact for the Environmental Assessment for the Oak Ridge Enhanced Technology and Training Center*. DOE/EA-2144, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, November.

NNSA 2021a. *Environmental Assessment for the Lithium Processing Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee*. DOE/EA-2145, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, March.

NNSA 2021b. *Finding of No Significant Impact for the Environmental Assessment for the Lithium Processing Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee*. DOE/EA-2145, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, March.

NNSA 2021c. *Environmental Assessment for the Offsite Housing of the Y-12 Development Organization at 103 Palladium Way, Horizon Center Industrial Park, Oak Ridge, Tennessee*. DOE/EA-2159, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, July.

NNSA 2021d. *Finding of No Significant Impact for the Environmental Assessment for the Lithium Processing Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee*. DOE/EA-2145, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, July.

NNSA 2021e. "NNSA Production Office Approval to Use Pre-Approved Authorized Limits for the Release and Clearance of Volumetric Radioactivity of Personal Property." COR-NP0-60 ESH-7.20.2021-919599, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, July 20, 2021.

NRC 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575, Revision 1/EPA 402-R-97-016, Revision 1/DOE/EH-0624, Revision 1. US Nuclear Regulatory Commission, Washington, DC.

NRC 2009. *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*. NUREG-1575, Supplement 1/EPA 402-R-09-001/DOE/HS-0004. US Nuclear Regulatory Commission, Washington, DC.

TDEC 2010a. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Melton Hill Reservoir: Lower Clinch River Watershed (HUC 06010207), Anderson, Knox, Loudon, and Roane Counties, Tennessee.* Tennessee Department of Environment and Conservation, Nashville, TN. 2010.

TDEC 2010b. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Watts Bar Reservoir: Watts Bar Lake Watershed (HUC 06010201), Lower Clinch River Watershed (HUC 06010207), and Emory River Watershed (HUC 06010208), Loudon, Meigs, Morgan, Rhea, and Roane Counties, Tennessee.* Tennessee Department of Environment and Conservation, Nashville, TN. 2010.

TDEC 2010c. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Fort Loudon Reservoir: Fort Loudon Lake Watershed (HUC 06010201), Blount, Knox, and Loudon Counties, Tennessee.* Tennessee Department of Environment and Conservation, Nashville, TN. 2010.

TDEC 2019a. "Public Water Systems." Chapter 0400-45-01. Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, TN. Approved February 2019.

TDEC 2019b. "General Water Quality Criteria." Chapter 0400-40-03. Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, TN. Approved September 2019.

TDEC 2022a. *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation*. TDEC-VER. 27.0, US Department of Energy, Oak Ridge Reservation, Oak Ridge, TN, October 2022.

TDEC 2022b. "Emission Standards for Hazardous Air Pollutants." TDEC Regulation 0400-30-38, Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, TN, Approved December 2022.

UCOR 2021. *Sampling and Analysis Plan for the Water Resources Restoration Program for Fiscal Year 2022 Oak Ridge Reservation, Oak Ridge, Tennessee*. UCOR-4587-R7, URS | CH2M Oak Ridge, LLC, Oak Ridge, Tennessee.

UCOR 2022a. *2022 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup.* OREM-23-7632, United Cleanup Oak Ridge, Oak Ridge, Tennessee.

UCOR 2022b. S*ampling and Analysis Plan for the Water Resources Restoration Program for Fiscal Year 2023 Oak Ridge Reservation*. Oak Ridge, Tennessee, UCOR-4587-R8, URS | CH2M Oak Ridge, LLC, Oak Ridge, Tennessee.

DOE's Oak Ridge National Laboratory is the nation's largest multiprogram science and technology laboratory. ORNL's mission has grown and expanded through the years, and now it is at the forefront of supercomputing, advanced manufacturing, materials research, neutron science, clean energy, and national security.
Photo by Carlos Jones

5

Oak Ridge National Laboratory

ORNL, the nation's largest and most diverse science and energy laboratory, conducts basic and applied research to deliver transformative scientific and technological solutions to compelling problems in energy and security. ORNL's portfolio of scientific expertise and world-class facilities and equipment enable the development of scientific and technological solutions in the following areas:

- Biology and environment
- Materials
- Clean energy
- National security
- Fusion and fission
- Neutron science
- Isotopes
- Supercomputing

Nine world-class facilities that support ORNL's research and development (R&D) activities are available to users from universities, industry, and other institutions:

- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- Center for Structural Molecular Biology
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership Computing Facility
- Spallation Neutron Source

ORNL is managed by UT-Battelle LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. Other DOE contractors that conducted activities at ORNL in 2022 included UCOR; North Wind Solutions, LLC (NWSol); and Isotek Systems, LLC (Isotek).

During 2022, a phased workplace reentry plan was implemented to return employees who had been teleworking for the past 2 years back to the ORNL campus. In 2020, in response to the coronavirus (COVID-19) pandemic, more than 70 percent of the ORNL workforce transitioned from on-site work to telework status. An internal ORNL COVID-19 Workplace Safety and Reentry Framework established the guiding principles for workplace reentry and on-site operations for ORNL staff and recognizes that ORNL's mission to deliver scientific discoveries and technical breakthroughs in clean energy and global security requires that most staff be on site. This framework follows the latest guidelines from the Centers for Disease Control and Prevention and the Safer Federal Workforce Task Force and is based on the principles outlined in the DOE COVID-19 Workplace Safety and Reentry Framework (DOE 2022b). As the workforce transitioned back to the ORNL campus, UT-Battelle continued to meet commitments to provide a safe and healthy workplace, protect the public and the environment, and meet regulatory requirements and commitments.

5.1. Description of Site, Missions, and Operations

ORNL lies in the southwest corner of ORR (Figure 5.1) and includes facilities in two valleys (Bethel and Melton) and on Chestnut Ridge. ORNL was established in 1943 as part of the secret Manhattan Project to pioneer a method for producing and separating plutonium. During the 1950s and 1960s, and with the creation of DOE in the 1970s, ORNL became an international center for the study of nuclear energy and related research in the physical and life sciences. By the turn of the century, the laboratory supported the nation with a peacetime science and technology mission that was just as important as, but very different from, the work carried out in the days of the Manhattan Project.

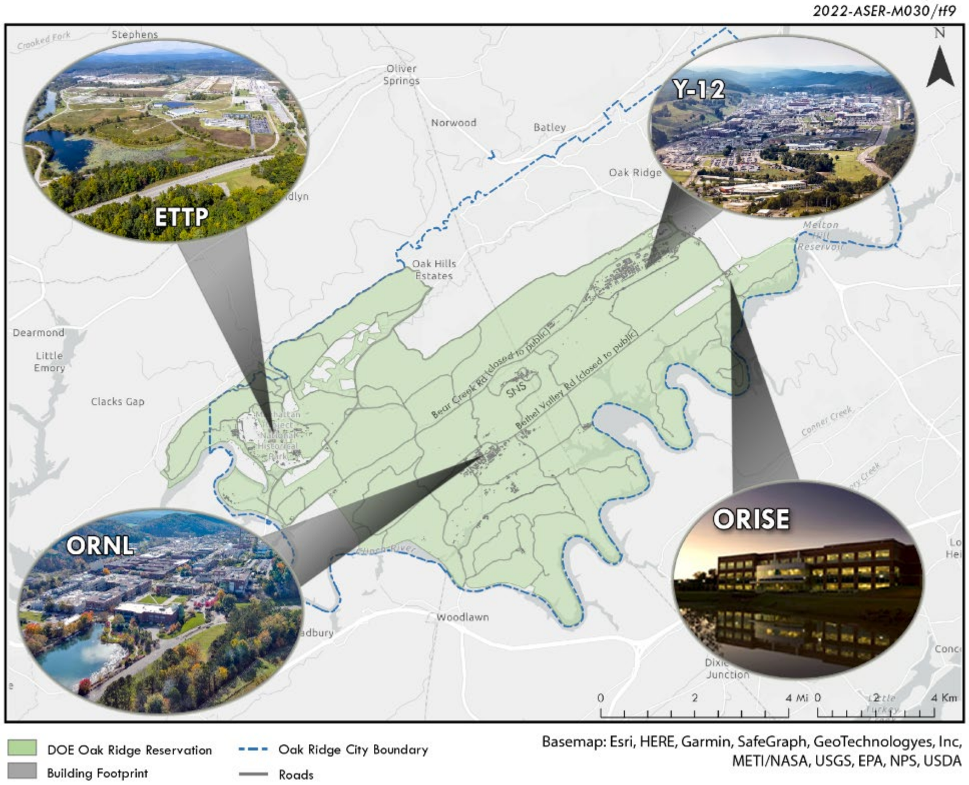
In March 2007, Isotek assumed responsibility for the Building 3019 Complex at ORNL, where the national repository of ^{233}U has been kept since 1962. In 2010, an Analysis of Alternatives was conducted to evaluate methods available for ^{233}U disposition, and in 2011, the recommendations in the *Final Draft ^{233}U Alternatives Analysis Phase I Report* (DOE 2011b) were endorsed. The Phase I recommendations included (1) transfer of Zero-Power Reactor plate canisters to the National Nuclear Security Administration and disposal of Consolidated Edison Uranium Solidification Project material canisters and (2) completion of a Phase II alternatives analysis for processing the remaining 50 percent of the inventory. The transfer of the reactor plate canisters was completed in 2012. Disposal of the Consolidated Edison Uranium Solidification Project material canisters began in 2015 and was completed in 2017.

Responsibility for Building 2026 was transferred from UT-Battelle to Isotek in May 2017. Isotek began processing ^{233}U material inside glove boxes in Building 2026 in the fall of 2019. The glove box processing campaign was completed in August 2021. The remaining inventory requires processing in shielded hot cells because of the high radiation levels of the material. Isotek began processing ^{233}U material in Building 2026 hot cells in October 2022. Hot cell processing is expected to last for the next few years. The processing of the ^{233}U material produces a solidified, low-level radioactive waste (LLW) form that is acceptable for disposal. Additionally, Isotek is extracting ^{229}Th from the material and transferring it to a customer for use as source material to produce vital medical isotopes ideal for targeted alpha therapy, a promising new cancer treatment.

UCOR is the DOE ORR cleanup contractor for the DOE Oak Ridge Office of Environmental Management (OREM). The scope of UCOR activities at ORNL includes long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings. The *2022*

Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup (UCOR 2022) **here** provides detailed information on UCOR activities at ORNL. These activities included demolition of the Bulk Shielding Reactor and preparation for the demolition of several other reactors, continued characterization and deactivation of Isotope Row Facilities (a group of 12 buildings built in the 1950s and early 1960s to process radioisotopes), deactivation of the final hot cell in the former Radioisotope Development Laboratory to prepare for demolition planned for 2023, completion of construction upgrades to Building 2026, and an operational readiness review that will allow for the processing and disposal of the remaining high-dose ^{233}U inventory stored at ORNL.

ORNL 2022-G00265/mhr
2022-ASER-M030/tf9



Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORISE = Oak Ridge Institute for Science and Education
Y-12 = Y-12 National Security Complex

Figure 5.1. Location of ORNL within ORR and its relationship to other local DOE facilities

In October 2022, UCOR assumed responsibility for operations at the Transuranic Waste Processing Center (TWPC), which is located on about 26 acres of land adjacent to the Melton Valley Storage Tanks along State Route 95. NWSol was the prime contractor for TWPC from December 2015 until NWSol's contract with OREM expired on October 27, 2022. TWPC's mission is to receive, process, treat, and repackage transuranic (TRU) wastes for shipment to designated facilities for final disposal. TWPC consists of a waste-processing facility, a personnel building, and numerous support buildings and storage areas. TWPC began processing supernatant liquid from the Melton Valley Storage Tanks in 2002, contact-handled debris waste in December 2005, and remotely handled debris waste in May 2008. Based on the definition of TRU waste, some waste being managed as TRU is later determined to be LLW or mixed LLW. UT-Battelle provides water quality monitoring for operations at the TWPC, and results are included in water monitoring discussions in Section 5.5. Air monitoring data from TWPC are provided to UT-Battelle for inclusion in the ORR National Emission Standards for Hazardous Air Pollutants for Radionuclides (Rad-NESHAPs) annual report and are incorporated into air monitoring discussions in this chapter.

UT-Battelle manages several facilities located off the main ORNL campus for DOE. The Hardin Valley Campus (HVC) is home to the National Transportation Research Center (NTRC) (see website **here**), the Grid Research Integration and Deployment Center (see website **here**), and the Manufacturing Demonstration Facility (see website **here**). The HVC is located on a 23-acre site owned by Pellissippi Investors, LLC and is leased to UT-Battelle and the University of Tennessee. Approximately 152 industry partners work on the HVC to shape US mobility, energy infrastructure, and manufacturing future.

NTRC is DOE's only user facility dedicated to transportation and serves as the gateway to UT-Battelle's comprehensive capabilities for transportation R&D. Research focuses on fuels and lubricants, engines, emissions, electric drive technologies, lightweight and power-train materials, vehicle systems integration, energy storage and fuel cell technologies, vehicle cybersecurity, and intelligent transportation systems.

The Grid Research Integration and Deployment Center (Figure 5.2) combines multiple electrification research activities (e.g., utilities, buildings, vehicles) into one facility. The combination of the following innovative R&D disciplines enables breakthroughs to support a resilient and secure power grid from the first instant of electricity generation to end use:

- Power and energy systems
- Vehicle and buildings science
- Power electronics
- Energy storage
- Sensors and controls
- Data science and modeling
- Cybersecurity

The Manufacturing Demonstration Facility focuses on advanced manufacturing research, including the development of carbon fiber composites and additive manufacturing involving polymers, metal wires, and metal powders. The facility provides lab space for the Institute for Advanced Composites Manufacturing Innovation and hosts an outreach program for local high school students.

The Carbon Fiber Technology Facility (CFTF), a leased 42,000 ft^2 innovative technology facility located in the Horizon Center Business Park, offers a flexible, highly instrumented carbon fiber line for demonstrating the scalability of advanced carbon fiber technology and for producing market-development volumes of prototypical carbon fibers. The CFTF is the world's most capable open-access facility for the scale-up of emerging carbon fiber technology. The cost of carbon fiber material remains relatively high, prohibiting widespread adoption of carbon fiber–containing composite materials in the automotive manufacturing industry, which requires lower commodity pricing. The lower-cost carbon fiber produced at ORNL meets the performance criteria prescribed by some automotive manufacturers for carbon fiber materials for use in high-volume vehicle applications.

UT-Battelle also manages several buildings and trailers located at Y-12 and in the city of Oak Ridge.

Photograph by Carlos Jones. Approved for public release.

Figure 5.2. Power electronics capabilities at the Grid Research Integration and Deployment Center on the ORNL Hardin Valley Campus

5.2. Environmental Management Systems

Demonstration of environmental excellence through high-level policies that clearly state expectations for continual improvement, pollution prevention, and compliance with regulations and other requirements is a priority at ORNL. In accordance with DOE Order 436.1, *Departmental Sustainability* (DOE 2011a), UT-Battelle, NWSol, UCOR, and Isotek have implemented environmental management systems (EMSs) modeled after the International Organization for Standardization (ISO) 14001 standard to measure, manage, and control environmental impacts (ISO 2015). An EMS is a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals.

5.2.1. UT-Battelle Environmental Management System

UT-Battelle's EMS is designed to fully comply with all applicable requirements and to continually improve ORNL's environmental performance. Until August 2018, UT-Battelle was registered to the ISO 14001:2015 standard and had maintained ISO 14001 registration since 2004. In fiscal year (FY) 2018, a management decision was made to transition from registration to a declaration of conformance to ISO 14001:2015, and external registration audits were replaced with annual internal independent ISO 14001 audits.

UT-Battelle's EMS is a fully integrated set of environmental management services for UT-Battelle activities and facilities. Services include pollution prevention, waste management, effluent management, regulatory review, reporting, permitting, and other environmental management programs. Through the UT-Battelle Standards-Based Management System (SBMS), the EMS establishes environmental policies and translates environmental laws, applicable DOE orders, and other requirements into laboratory-wide documents (procedures and guidelines). Through environmental protection officers, environmental compliance representatives, and waste services representatives, the UT-Battelle EMS assists the line organizations in complying with environmental requirements.

5.2.1.1. Integration with the Integrated Safety Management System

The objective of the UT-Battelle Integrated Safety Management System (ISMS) is to systematically integrate environment, safety, and health (ES&H) requirements and controls into all work activities and to ensure protection of workers, the environment, and the public. The UT-Battelle EMS and ISMS are integrated to provide a unified strategy for the management of resources, the control and attenuation of risks, and the establishment and achievement of the organization's ES&H goals. Guided by the ISMS and EMS, UT-Battelle strives for continual improvement through "plan-do-check-act" cycles. Under the ISMS, the term "safety" also encompasses ES&H, including pollution prevention, waste minimization, and resource conservation. Therefore, the guiding principles and core functions in the ISMS apply both to the protection of the environment and to safety. The UT-Battelle EMS is consistent with the ISMS and includes all the elements in the ISO 14001:2015 standard.

5.2.1.2. UT-Battelle Environmental Policy for ORNL

UT-Battelle's environmental policy for ORNL, which can be found on the ORNL website **here**, clearly states expectations and includes commitments to continual improvement, pollution prevention, and compliance with regulations and other requirements.

5.2.1.3. Environmental Management System Planning

The ISO 14001 planning clause requires organizations to identify the environmental aspects and impacts of their operations, products, and services; identify applicable regulations and requirements; establish objectives; implement plans to achieve the objectives; and identify and control risks and opportunities.

UT-Battelle environmental aspects

Environmental aspects are elements of an organization's activities, products, or services that can interact with the environment. Environmental aspects associated with UT-Battelle activities, products, and services have been identified at the line organization level and the laboratory level. Activities that are relative to any of the aspects are carefully controlled to minimize or eliminate impacts to the environment. Nine significant environmental aspects (listed on the ORNL website **here**) have been identified as potentially having significant environmental impacts.

UT-Battelle legal and other requirements

Legal and other requirements that apply to the environmental aspects identified by UT-Battelle include federal, state, and local laws and regulations; environmental permits; DOE orders; UT-Battelle contract clauses; waste acceptance criteria; and voluntary requirements such as ISO 14001:2015. UT-Battelle has established procedures to ensure that all applicable requirements are reviewed and that changes and updates are communicated to staff and are incorporated into work-planning activities. UT-Battelle's environmental compliance status is discussed in Section 5.3.

UT-Battelle objectives

To improve environmental performance, UT-Battelle establishes objectives for monitoring progress for appropriate functions and activities. Laboratory-level environmental objectives are documented in the site sustainability plan (SSP) (ORNL 2022 [**here**]). Line organization objectives are developed annually, entered into a commitment tracking system, and tracked to completion. In all cases, the objectives are consistent with the UT-Battelle environmental policy for ORNL (found on the ORNL website **here**), support the laboratory mission, and, where practical, are measurable.

UT-Battelle programs

UT-Battelle has established an organizational structure to ensure that environmental stewardship practices are integrated into all facets of its missions at ORNL. Programs led by experts in environmental protection and compliance, energy and resource conservation, pollution prevention, and waste management ensure that laboratory activities are conducted in accordance with the environmental policy (see Section 5.2.1.2). Information on UT-Battelle's 2022 compliance status, activities, and accomplishments is presented in Section 5.3.

Environmental protection and waste management staff provide critical support services in the following areas:

- Waste management
- Solid and hazardous waste compliance
- National Environmental Policy Act (NEPA 1969) compliance
- Air quality compliance
- Water quality compliance
- US Department of Agriculture (USDA) compliance
- Environmental sampling and data evaluation
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) interface

Subject matter experts (SMEs) at UT-Battelle provide expertise in waste management, transportation, and disposition support services to research, operations, and support divisions:

- Pollution prevention staff manage recycling programs and work with staff to reduce waste generation and to promote sustainable acquisition.
- Radiological engineering staff provide radiological characterization support to generators and waste service representatives, develop tools to help ensure compliance with facility safety and transportation, and provide packaging support requirements.
- Waste acceptance and disposition staff review and approve waste characterization methods; accept waste from generator areas into Transportation and Waste Management Division storage areas, review waste disposal paperwork to ensure compliance with the disposal facility's waste acceptance criteria, certify waste packages, and coordinate off-site disposition of UT-Battelle's newly generated waste.
- Waste service representatives provide technical support to waste generators to properly manage waste by assisting in identifying, characterizing, packaging, and certifying wastes for disposal.
- The waste-handling team performs waste-packing operations and conducts inspections of waste items, areas, and containers.
- The transportation management team ensures that both the on-site and off-site packaging and transportation activities are performed in a safe, efficient, and compliant manner.
- The hazardous material spill response team is the first line of response to hazardous materials spills at ORNL and controls and contains spills until the situation is stabilized.

5.2.1.4. Site Sustainability

As required by DOE Order 436.1, *Department Sustainability* (DOE 2011a), the SSP, which includes FY 2022 performance data, was completed in December 2022 (ORNL 2022 [**here**]).

To attain the federal sustainability goals outlined in the SSP, sites operated by DOE are expected to contribute toward all targets and to identify strengths that can be adapted as agencywide best practices. To meet the SSP goals at ORNL, UT-Battelle identifies opportunities for continuous improvements in operational and business processes and implements practices to maximize the return on investment in modernizing facilities and equipment. The Sustainable ORNL program (Sustainable ORNL) promotes systemwide best practices, management commitment, and employee engagement that will help lead ORNL into a future of efficient, sustainable operations. The Sustainable ORNL website is available for employee and public view **here**.

The Sustainable ORNL roadmap structure includes 15 vital roadmaps. Figure 5.3 summarizes the current roadmaps and demonstrates that each roadmap contributes to the well-being of the whole. Continuous employee engagement and regular status reports confirm the ideals of the program are being realized.

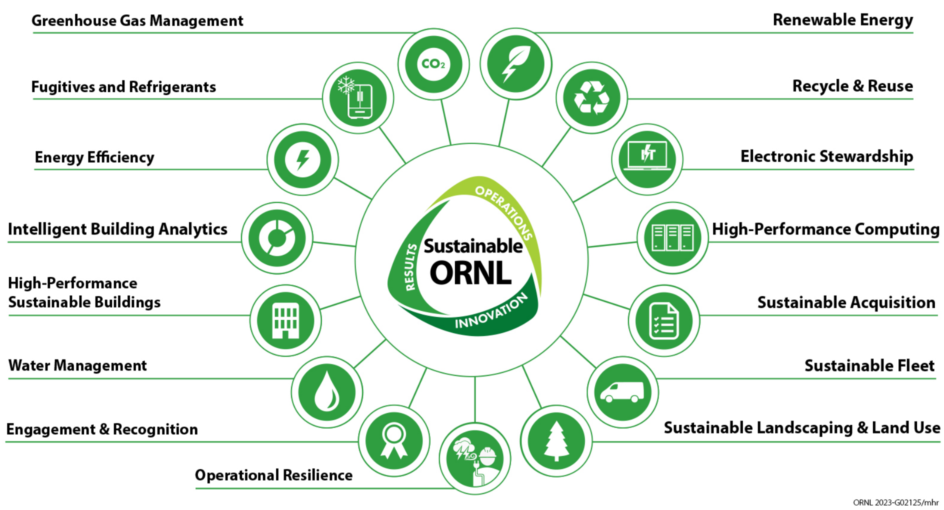


Figure 5.3. Sustainable ORNL focus areas (roadmaps)

The roadmap structure is not static; as the science mission advances and the needs of the organization evolve, the Sustainable ORNL roadmap structure elements are modified to align with developing priorities. In FY 2022, Sustainable ORNL made roadmap changes for FY 2023 implementation to better align ORNL with the new and updated goals and requirements issued in federal and DOE directives.

Changes in federal government and DOE priorities resulted in a year of transition in sustainability goals and priorities as well as increased awareness of the effects that climate change can have on government facilities and operations. In 2021, Executive Order (EO) 14008, *Tackling the Climate Crisis at Home and Abroad* (EO 2021a), established broad strategies calling for federal agencies to take the lead in confronting the climate crisis, engage in the formation of a net-zero economy, and enhance operational resilience at federal facilities. To respond to DOE priorities, ORNL requires a comprehensive cross-cutting process to comply with EO 14008 and enhance climate mitigation efforts. Sustainable ORNL established a new Operational Resiliency Roadmap (Figure 5.3) in FY 2022 to support the DOE *Vulnerability Assessment and Resilience Planning Guidance* (DOE 2022a) issued to implement EO 14008.

Sustainable ORNL also made efforts to better align the roadmap structure with SSP requirements for greenhouse gas reporting. In 2022, two new roadmaps were added: Fugitives and Refrigerants and Electronic Stewardship (Figure 5.3). These additions position Sustainable ORNL to support the critical topics of the SSP and greenhouse gas

(GHG) reporting. The carbon-free electricity and net-zero emissions goals are cross-cutting for all roadmap projects, but the Greenhouse Gas Management and Renewable Energy Roadmaps capture ORNL's holistic approach to achieving these goals.

Net-zero initiatives are not undertaken in isolation; rather, they are implemented in conjunction with other priorities to achieve multiple agency objectives. Throughout the ORNL campus, projects are evaluated on several sustainability priorities, including energy, water, and cost savings from energy conservation measures, net-zero initiatives, and operational resilience. ORNL has an opportunity and a responsibility to lead by example and integrate climate and sustainability into all aspects of operations.

The Exploration for a Carbon-Free Campus initiative began in 2021 under the charge of the Facilities and Operations Directorate. Its goal is to develop a dynamic inventory of research and operational projects that provide opportunities to advance the ORNL campus toward net-zero strategies. The initiative aligns with DOE Office of Science (SC) objectives by amplifying net-zero strategies in business methods and in the budget planning process. Throughout the campus, projects are being evaluated in terms of several sustainability priorities, including reductions in energy and water use and their associated cost savings from energy conservation measures, net-zero initiatives, and operational resilience. ORNL has an opportunity and a responsibility to lead by example and integrate climate and sustainability into all operations.

Each year, Sustainable ORNL makes funding available to support showcase projects that focus on creative measures that can improve ORNL's sustainability. The feasibility and applicability of further implementation are evaluated after the projects are completed. In 2022, the Facilities and Operations Directorate supported three Sustainable ORNL Showcase projects on carbon net-zero and energy improvement research topics:

- "Investigating the Production of Renewable Natural Gas from Anaerobic Digestion of Solid Waste to Decarbonize ORNL Steam Boilers": to demonstrate a circular economy on the ORNL campus, this project proposed using anaerobic digestion of locally sourced waste materials to produce renewable natural gas for steam generation.
- "Towards the Living Laboratory with Buildings as an Energy Hub for Sustainable Campus": this project team, consisting of R&D and Facilities and Operations Directorate staff, proposed to study and showcase advanced control and coordination strategies for buildings to work with other on-site distributed-energy resources in increasing energy efficiency, improving operational resilience, and reducing the carbon footprint.
- "Increasing Condensate Recovery in ORNL Steam Plants to Reduce Primary Fuel Consumption and the Associated Emissions": this project aimed to conduct a systematic diagnostic campaign to identify the reasons for the current low condensate recovery rate.

ORNL's Facilities Management Division is tasked with the management of distinctive research facilities and extraordinary scientific equipment. The commissioning dates of the systems range from the 1940s to 2021. Therefore, many facilities require customized methodologies to enhance sustainability; a boilerplate approach would not be sufficient to operate these facilities efficiently and deliver the desired results. The Facilities Management Division's Energy Efficiency and Sustainability Program is tasked with the daily management of energy- and water-saving projects that are the key to achieving operational savings and implementing sustainable practices throughout the lab.

Responses to changes in priorities and the issuance of new requirements continued throughout 2022. The Energy Act of 2020 (EA 2020) includes requirements for funding and implementing energy conservation measures identified by building energy and water evaluations, and new and revised guidance for sustainability and efficiency goals are anticipated to be the primary focus for Sustainable ORNL for the next few years.

Sustainable ORNL awards

Information about recognition that ORNL has received for sustainability can be found on the Sustainable ORNL website **here**. In 2022, sustainability efforts at ORNL were recognized with the following awards from DOE, *R&D World* (2022 R&D 100 Awards), and the Federal Laboratory Consortium.

- **DOE awards**
  - Glenn Cross, the Central Energy Data System (CEDS) administrator, received the DOE Sustainability Champion Award. Glenn serves in a key leadership role for management of the ORNL CEDS, which supports the submittal of the annual SSP and other DOE Order 436.1 deliverables, all of which are data driven. Glenn was on the lead implementation team for the implementation of CEDS at the ORNL site. He was the CEDS system architect and originator, and he currently serves as the system administrator and manager.
  - Energy Facility Contractors Group Award: Jamie Herold from Natural Resource Management and Amy Albaugh Miller from the Energy Efficiency and Sustainability Program were selected to receive a Teamwork Award for their work on the Sustainable Climate-Ready Sites Task Team for the Energy Facility Contractors Group's Sustainability & Environmental Working Group.
- ***R&D World* R&D 100 Awards** (details **here**)
  - DuAlumin-3D: An Additively Manufactured Dual-Strengthened Aluminum Alloy Designed for Extreme Creep and Fatigue Resistance
  - RapidCure: High-Speed Electron Beam Processing of Battery Electrodes (also received special recognition in the silver level Green Tech category.)
  - SolidPAC: A Comprehensive Solid-State Battery Design Tool
  - Ultraclean Condensing Gas Furnace
- **Federal Laboratory Consortium 2022 National Awards for Excellence in Technology Transfer** (details **here**)
  - ORNL Manufacturing Process Positions Ateios to Debut Ultra-Thin Batteries for Medical Wearables.
  - Creative Licensing Boosts Adoption of ORNL'S AI-Driven Quality Assessment Software for 3D Printing.
  - 3D-Printing Method from ORNL Produces Protective Fuel Pellets for Ultra Safe Nuclear Corporation's (USNC) Ultra-Safe Nuclear Reactor.
- **Federal Laboratory Consortium 2022 National Individual and Team Awards** (details **here**)
  - Campaigning by ORNL and Partners Brings More than $8 Billion to Tennessee for Electric Vehicle Battery Production (State and Local Economic Development Category).

Sustainable ORNL notable achievements

In 2022, the newly released *Vulnerability Assessment and Resilience Planning Guidance Version 1.2* (DOE 2022a) and associated timelines prompted a new and more comprehensive assessment of the vulnerability of operations and facilities to climate change and the development of adaptation plans to increase their resilience.

ORNL's Vulnerability Assessment and Resilience Plan (VARP) reporting team members participated in training and workshops offered by the Sustainability Performance Division and the Federal Energy Management Program. They were trained on how to use the new guidance and collective resources to improve vulnerability planning efforts. The VARP team is also part of a working group with personnel from the other DOE sites on ORR. Because ORNL is in close geographic proximity to other ORR sites, this working group was especially helpful in deliberations concerning the numerous resources suggested by DOE for climate change projections and historical weather event data for the Oak Ridge, Tennessee area. Through collaboration with the ORR working group and use of recommended climate data sources, the following key determinations were made regarding ORNL's climate hazards:

- ORNL is located in a very low-risk area relative to the rest of the United States. Since the beginning of the twentieth century, temperatures in Tennessee have risen by 0.5°F compared with 1.8°F for the entire United States. Furthermore, the lab's geographical position (in narrow valleys between linear and partitioned ridges) offers separation from and natural protection against environmental hazards.
- Historically unprecedented warming is projected during this century. According to higher emissions projections, temperatures may rise by as much as 11°F (Figure 5.4). Heat waves are the only hazard expected to increase in frequency and intensity, leading to more intense droughts.
- Although it is not certain that precipitation events will increase in frequency, they will likely become more intense, which will increase the likelihood of flooding the Oak Ridge area, which is already challenged by abundant precipitation.

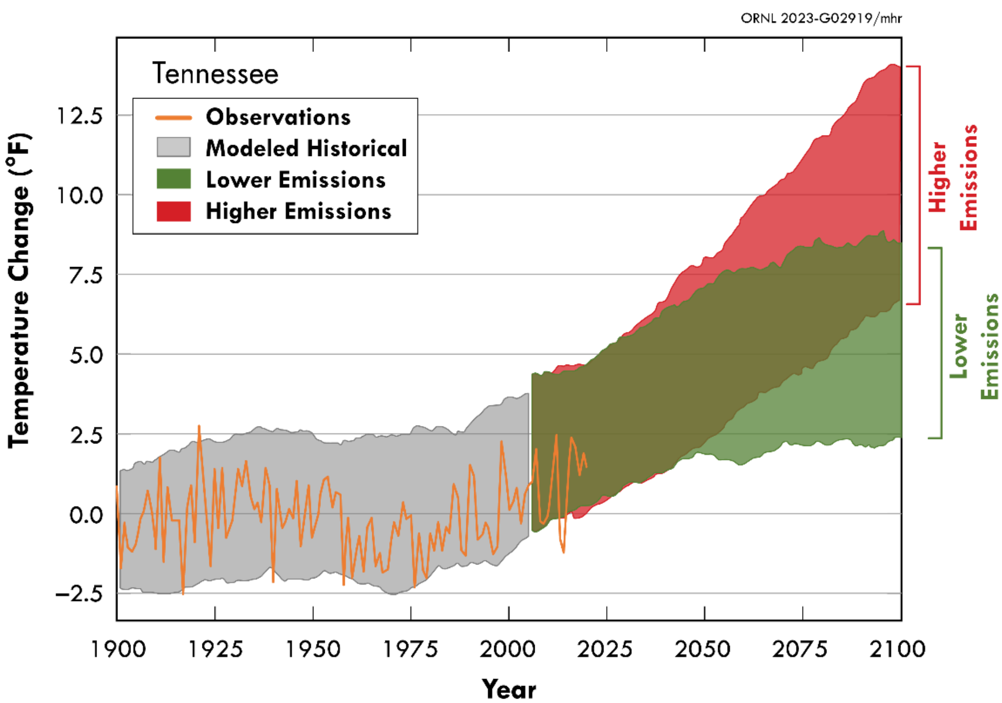


Figure 5.4. Tennessee observed and projected temperature change (Runkle et al. 2022)

In September 2022, the ORNL VARP team submitted the first VARP to the DOE Sustainability Performance Division. Updates to the VARP, including a roadmap to action and a comprehensive list of projects, will be evaluated and modified annually as subject matter knowledge evolves. Along with net-zero initiatives, enhanced operational resilience, and other EO 14008 directives, a comprehensive and defensible analysis of the projects that will enhance the resilience of the facilities and infrastructure that are most critical to ORNL's science mission will be required. Collaboration among multiple ORNL divisions will be necessary to ensure that these assessments are included in the laboratory's comprehensive planning process.

In FY 2022, ORNL added 75 new advanced utility meters (including computational meters and electrical utility distribution meters), migrated seven new data streams from other systems across the lab, and replaced six meters. ORNL meter installations included electrical, steam/hot water, natural gas, chilled water, and potable water. The meters were connected to ORNL's CEDS, which is a network of systems used for data archiving and analysis. CEDS securely collects, archives, and displays advanced utility meter data from the network of utility meters installed throughout the laboratory. CEDS logs multiple parameters from each meter on a standard 15-minute interval. This system also enables meter data trend analysis, report generation, energy awareness dashboard deployment, and data export for use in other analyses.

The Energy Efficiency and Sustainability Program uses fault detection and diagnostics as a process for monitoring operational controls in buildings that use ORNL's building automation system. SkySpark, created by SkyFoundry, is the fault detection and diagnostics software platform that ORNL selected for pilot testing. SkySpark pulls control information from the building automation system and creates customized faults to continuously detect and report operational, equipment, system, energy, and comfort faults that may occur in ORNL buildings. The SkySpark system sends early detection alerts based on data collected in 15 min intervals, identifying possible operational issues in a timely manner. SkySpark supports Project Haystack, an open-source initiative to develop naming conventions and taxonomies for building equipment and operational data. The SkySpark system is highly configurable and allows for easy visibility and downloading of trending control information. By the end of FY 2022, 15 ORNL buildings were added to the system.

Summary of performance data for energy, water, and waste

DOE Order 436.1 directs prime contractors to contribute to departmental sustainability goals and to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs. ORNL collects data and publishes the results in an annual SSP to document compliance with applicable guidance. In FY 2022, the annual SSP guidance and ORNL's submittal were updated to include modifications made as a result of executive orders and applicable federal statutes. Implementation plans for new orders as well as new and revised guidance for sustainability and efficiency goals will be the primary focus for Sustainable ORNL in the next few years. The SSP guidance that outlines all sustainability requirements for reporting by DOE's Sustainability Performance Division can be found **here**. Table 5.1 summarizes ORNL sustainability performance data on federal goals reported to DOE in the ORNL SSP with FY 2022 performance data.

Table 5.1. 2022 ORNL Sustainability goals and performance status

DOE goal	2022 performance status	Planned actions and contribution
Energy management		
Reduce energy use intensity defined as Btu per gross square foot (GSF) in goal-subject buildings.	ORNL's FY 2022 calculated energy use intensity is 234,194 Btu/GSF. This is a cumulative reduction of 35.6% since FY 2003 and a decrease of 2.8% from FY 2021. ORNL continues to improve identification of energy-consuming facilities.	Continued energy use intensity reduction for goal-subject facilities is considered attainable with the best mix of energy conservation measures projects for energy savings and by incorporating net-zero strategies into all levels of lab planning efforts.
Water management		
Reduce potable water use intensity defined as gallons per gross square foot (G/GSF).	Annual water consumption resulted in a potable water use intensity of 137.6 G/GSF in FY 2022, which is an increase of 1.7% from FY 2021, despite	ORNL's potable water use intensity is likely to rise because of increased demands for cooling tower makeup water to support growth of high-performance computing

Table 5.1. 2022 ORNL Sustainability goals and performance status (continued)

DOE goal	2022 performance status	Planned actions and contribution
	overall reduction in water consumption. Therefore, ORNL did not meet its goal of reducing potable water use intensity by 0.5% from previous year. Continued improvements in the identification of water-consuming facilities yielded a 3% reduction in GSF, contributing to the increased water use intensity.	systems. With continued modernization activities that include the elimination of old facilities and the addition of new facilities, ORNL will consider more water-efficient systems and focus on water management best practices to meet future water use intensity reduction goals.
Waste management		
Reduce nonhazardous solid waste sent to treatment and disposal facilities.	In FY 2022, ORNL's diversion rate for municipal solid waste reached 52.8%.	ORNL will continue to identify source reduction opportunities.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities.	In FY 2022, ORNL's construction and demolition diversion rate for waste building materials and deactivation and decommissioning debris was 70.8%. This is a considerable increase from FY 2021.	ORNL will continue to employ terms and conditions within construction contracts to manage construction waste and recycling. Construction and demolition recycle rates will vary as the proper characterization of debris dictates.
Fleet management		
Reduce petroleum consumption.	ORNL continued to optimize utilization, purchase vehicles with improved fuel economy and electric vehicle options when available, and purchase vehicles with anti-idling technology.	ORNL will launch a passenger-carrying vehicle pooling project, encourage use of the ORNL taxi service, and continue replacing existing vehicles with vehicles that have improved fuel economy.
Increase alternative fuel consumption.	82% of all ORNL vehicles are alternative fuel vehicles, with 90% of all replacements over the past 2 fiscal years being alternative fuel or electric vehicles. One hundred percent of light-duty vehicles operate on alternative fuels, exceeding DOE fleet management goals.	ORNL will continue to purchase alternative fuel vehicles and limit access to nonalternative fuel at ORNL gas pumps.
Acquire alternative fuel and electric vehicles.	ORNL is currently meeting the alternative fuel requirement. If available, alternative fuel or electric vehicles that meet mission requirements have been purchased or have been leased during the replacement process.	ORNL will continue replacing vehicles with alternative fuel vehicles or electric vehicles, as available, that meet mission requirements.
Clean and renewable energy		
Increase consumption of clean and renewable electric energy.	Including renewable energy credits ORNL purchased in 2022 to supplement on-site renewable energy generation, renewable energy represented 9.6% of the lab's electrical energy consumption, exceeding the 7.5% statutory requirement.	ORNL will remain compliant by purchasing renewable energy credits because on-site renewable energy projects are expected to remain cost prohibitive. ORNL will continue to explore innovative renewable energy projects. Renewable energy credit purchases will reflect significant mission growth in the near future, and energy attribute certificates will also be considered to enable ORNL to work toward carbon-free electricity requirements.

Table 5.1. 2022 ORNL Sustainability goals and performance status (continued)

DOE goal	2022 performance status	Planned actions and contribution
Increase consumption of clean and renewable nonelectric thermal energy.	N.A. under current statutes	N.A.
Sustainable buildings		
Increase the number of DOE-owned buildings that are compliant with the Guiding Principles (GPs) for Federal Leadership in Sustainable Buildings.	ORNL's sustainable buildings inventory did not increase in FY 2022. With the 2022 extension of the square footage requirement for sustainable buildings to 25,000 ft^2 or more, ORNL has seven GP-certified sustainable buildings. If buildings with 5,000 ft^2 or more are included, ORNL has 21 GP-certified buildings.	ORNL plans to have at least two new construction projects that will be GP-compliant in the next 5 years. ORNL plans to reassess the seven sustainable buildings in the next 3 years, maintaining its inventory of seven GP-certified buildings.
Acquisition and procurement		
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate.	ORNL maintained 100% compliance in FY 2022. All subcontracts contain multistatutory terms and conditions that invoke requirements for sustainable acquisitions as defined in the UT-Battelle prime contract flow-down requirements.	ORNL will continue its mission commitment to include all applicable federal acquisition regulation clauses and provisions in each new contract. ORNL will maintain compliance with DOE Order 436.1 and assist with the supply chain risk assessment moving forward.
Electronic stewardship		
Ensure electronics stewardship from acquisition, operations, to end of life.	ORNL maintained 100% compliance in the acquisition of environmentally certified products and maintained power management on 100% of eligible personal and laptop computers and monitors used by ORNL staff since 2009. Disposition of 100% of end-of-life electronics was preformed through government reuse programs and certified recyclers.	ORNL plans to maintain 100% compliance with all electronics stewardship goals and categories. There are no foreseen obstacles to achieving the goal.
Increase energy and water efficiency in high-performance computing and data centers.	In FY 2022, the average comprehensive power use effectiveness for ORNL was 1.10.	ORNL will continue to optimize the control system for the Frontier supercomputer and to develop the Trim cooling distribution unit concept, which will convert loads that are currently chilled water–cooled to be medium temperature water–cooled.
Operational resilience		
Implement climate adaptation and resilience measures.	In response to EO 14008 and DOE directives, ORNL submitted the Vulnerability Assessment and Resiliency Plan in September 2022 along with a portfolio of actionable resiliency solutions.	Updates on the implementation status of ORNL's solutions will be reported annually to the Sustainability Performance Division starting in the fall of 2023.

Table 5.1. 2022 ORNL Sustainability goals and performance status (continued)

DOE goal	2022 performance status	Planned actions and contribution
Multiple categories		
Reduce Scope 1 and 2 greenhouse gas (GHG) emissions.	The FY 2022 Scope 1 and 2 GHG inventory is 212,929 $MTCO_2e$ (net after renewable energy credits), an annual reduction of approximately 6.2%. Currently, purchased electricity (Scope 2) makes up 71% of ORNL GHG. Regional EPA Emissions and Generation Resource Integrated Database improvements bolstered Scope 2 reductions.	Mission growth will limit the ability to reduce emissions in the next 5 years. However, forward-looking DOE priorities such as those combined for net-zero carbon initiatives will reverse the trend of higher emissions.
Reduce Scope 3 GHG emissions.	Current Scope 3 GHG inventory is 23,527 $MTCO_2e$, a 39.5% increase from FY 2021. Scope 3 activities at ORNL include distribution losses from purchased electricity and increased employee commuting and business travel.	Employee commuting and business travel categories are returning to prepandemic levels, which will likely reverse the progress in Scope 3 reductions observed in FY 2020 and FY 2021.

Acronyms:
DOE = US Department of Energy
EO = executive order
EPA = US Environmental Protection Agency
FY = fiscal year
GHG = greenhouse gas
GP = Guiding Principle
ORNL = Oak Ridge National Laboratory

The sources of GHG emissions at ORNL and the inventory for FY 2022 are detailed in Figure 5.5. After 2 years of reduced emissions because of COVID-19 protocols, GHG emissions are expected to increase in the next 2 years. The science mission at ORNL is growing, and because federal accounting guidance allows no GHG emissions exceptions or exclusions regardless of mission, emissions are expected to increase in the near term. The implementation of EO 14008, EO 14057 (EO 2021b), and other federal programs and initiatives is expected to significantly reduce GHG emissions by 2030.

The most significant contributor to ORNL GHG emissions is the production and delivery of electrical power, which accounted for 71 percent of net emissions in FY 2022. As ORNL power plants implement net-zero strategies, the plants will use more efficient and cleaner energy sources for electricity production, reducing GHG emissions. In January 2022, EPA released a new set of electricity grid factors, which are available **here**.

Over the past 15 years, GHG emission factors from electricity have improved slowly but steadily, and the rate of progress is expected to accelerate as net-zero strategies are deployed nationwide by the producers of carbon-free electricity. In the coming year, ORNL will explore the possibility of reporting carbon sequestration that occurs on ORR’s 25,000 acres of unimproved land, 40 percent (10,000 acres) of which has historically been managed by ORNL.

Figure 5.5. Summary of ORNL's greenhouse gas inventory in FY 2022

Pollution prevention

Source reduction efforts at ORNL include increasing the use of acceptable nontoxic or less toxic alternative chemicals and processes while minimizing the acquisition of hazardous chemicals and materials via material substitution, operational assessments, and inventory management. In cases where the complete elimination of a particular hazardous material is not possible, a combination of actions is pursued, including controls to limit use, procurement alternatives, and recycling processes to mitigate the environmental impact. UT-Battelle implemented a total of 26 ongoing and new pollution prevention projects during 2022. These projects and ongoing reuse and recycle efforts eliminated more than 3.6 million kg of waste. Researchers at ORNL implement traditional recycling options when feasible and investigate new options when a need is identified. For instance, ORNL recycles its plastic waste off site when that option is available; however, ORNL researchers and commercial partners also recognize the need to close the loop on plastic recycling. The DOE Manufacturing Demonstration Facility at ORNL works with industry to replace material disposability with renewability by conducting research on closing the loop on the modern material supply chain. Through research, some conducted at ORNL, today's advanced manufacturing composite waste becomes tomorrow's valuable raw materials. Researchers are researching and deploying new processes that convert feedstocks used in advanced manufacturing into reusable materials. These efforts, including controlled pyrolysis research (Figure 5.6), continue to close the recycling loop for plastics. More information can be found **here**.

Efforts to further reduce and divert the amount of material going to the landfill also include the development of contract language requiring construction contractors to recycle as much construction debris as possible. Within ORNL, the extensive use of training, awareness, presentations, and outreach encourage source reduction and recycling by all associates.

Figure 5.6. Controlled pyrolysis: creating a robust, scalable composite recycling technology source

Environmental Justice

Environmental justice (EJ) is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA 2023). EJ is achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.

EJ principles are integrated into all ORNL programs and activities to comply with the following executive orders:

- EO 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (EO 1994)
- EO 14008, *Tackling the Climate Crisis at Home and Abroad* (EO 2021a)
- EO 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability* (EO 2021b)

In keeping with a presidential memorandum accompanying EO 12898, National Environmental Policy Act (NEPA) evaluations for proposed actions at ORNL include an analysis of environmental effects, including human health–related, economic, and social effects on minority and low-income communities. In 2022, a NEPA environmental assessment, which included evaluating EJ impacts, was completed for the construction and operation of the Stable Isotope Production and Research Center, a planned ~60,000 ft^2 facility that will be located at ORNL. This facility will expand current stable isotope production capabilities and reduce dependencies on foreign suppliers. The assessment identified no EJ concerns. All construction and operation activities associated with the Stable Isotope Production and Research Center will occur at ORNL and will not adversely affect communities near ORR.

ORNL's Environmental Protection Services Division conducts environmental monitoring and sampling for the ORR-wide environmental surveillance program discussed in Chapter 6. The objectives of this program are to (1) characterize environmental conditions in areas outside facility boundaries on ORR and in areas adjacent to or near ORR and (2) ensure that doses to members of the public from radionuclides and chemicals released from ORR are not above established limits. Elements of the ORR-wide surveillance program include monitoring ambient air, external gamma exposure, water, fish, and food crops in several communities near ORR, including a historically minority community that borders ORR.

One of the most serious EJ concerns is climate change, which often has disproportionate adverse social, economic, and health effects on marginalized and underserved communities. ORNL uses its world-leading capabilities in supercomputing and large-scale experiments to advance understanding of climate change. ORNL's Climate Change Science Institute was formed in 2009 to integrate climate science activities across ORNL and to evaluate the interactions of climate change with human and natural systems. This research helps to develop adaptation and mitigation solutions at the intersection of climate, clean energy, national security, and EJ.

In 2022, an "EJ lens" that can identify urban neighborhoods that are most vulnerable to climate change down to the block and building level was developed through research at the Climate Change Science Institute. Demographic data from US census databases were applied to climate models that simulate weather patterns over time to generate a high-resolution analysis of the different impacts of climate events across socioeconomic groups down to the street level. This method, which was developed and tested using data from the Atlanta metropolitan area to characterize neighborhoods and to evaluate the potential impacts across different demographically defined groups, could help ensure that mitigation and resilience programs reach the people who need them the most.

ORNL's Building Envelope and Materials Research Group uses scientific expertise in heat, air, and moisture transport to develop and evaluate new building envelope materials and assemblies that reduce energy use. In 2022, as part of DOE's Advanced Building Construction Initiative, ORNL began working with the Knoxville Community Development Corporation to retrofit the exteriors of roughly a dozen single-family public housing units to reduce energy costs. The exteriors of the homes will be retrofitted with a high-tech 3D shell developed at ORNL. The projected 75 percent reductions home energy use resulting from this project will benefit lower-income families in these public housing units.

Native Americans are particularly vulnerable to environmental threats because of the crucial role that nature plays in their culture and their reliance on natural resources. To help ensure that plant species with cultural significance to the Eastern Band of Cherokee Indians and across the region are protected and preserved, ORNL participates in the Southeastern Appalachian Man and the Biosphere (SAMAB) Cooperative, a collaboration of land management agencies promoting sustainability. Core to SAMAB are five areas recognized internationally for their significance to the natural world: Great Smoky Mountains National Park, Mount Mitchell State Park, Grandfather Mountain, Coweeta Hydrologic Lab, and the ORNL Natural Environmental Research Park (NERP). The NERP, a major resource for conducting ecological studies, is a 20,000-acre research facility that lies on ORR at the intersection of Anderson and Roane counties. More than 1,100 plant species are found on the NERP, some of which hold rich cultural importance. This prompted ORNL's participation in the Culturally Significant Plant Species Initiative, a collaboration between the Eastern Band of Cherokee Indians and SAMAB focused on the sustainability, conservation, and management of plants with cultural significance to the Cherokee through education and increased access.

Other ORNL programs that invest in and engage with historically underserved communities while also contributing to a greener and more inclusive economy include the following:

- Collaborations and partnerships with tribal communities and universities, minority-serving institutions, and historically black colleges and universities to enhance the accessibility of ORNL respources to underrepresented entities
- Recruiting programs to attract staff from minority-serving institutions
- A comprehensive Diversity, Equity, Inclusion, and Accessibility Plan that includes recruiting, onboarding, and career development strategies to close gaps in representation
- Community engagement and corporate giving programs to support local communities, including minority and underserved populations
- ORNL Small Business Programs Office initiatives to significantly increase opportunities for small, disadvantaged

businesses to provide the goods and services that are used at ORNL

5.2.1.5. Storm Water Management and the Energy Independence and Security Act of 2007

Section 438 of the Energy Independence and Security Act of 2007 (EISA) stipulates the following:

> The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow (EISA 2007).

For the purposes of this provision, *development or redevelopment* is defined as follows:

> any action that results in the alteration of the landscape during construction of buildings or other infrastructure such as parking lots, roads, etc. (e.g., grading, removal of vegetation, soil compaction) such that the changes affect runoff volumes, rates, temperature, and duration of flow. Examples of projects that would fall under "redevelopment"include structures or other infrastructure that are being reconstructed or replaced and the landscape is altered. Typical patching or resurfacing of parking lots or other travel areas would not fall under this requirement (EISA 2007).

Because of the soil types (low permeability) and karst geology, conditions exist at ORNL that would allow for claiming technical infeasibility, as described in technical guidance from EPA (EPA 2009). Clay soils have low infiltrative capacities, and the introduction of more water to the subsurface in a karst geology can accelerate the formation of sinkholes. As a result of these two geological conditions at ORNL, the use of subsurface infiltration to address EISA-438 is being pursued on a limited basis. Instead, mitigation strategies are being pursued (e.g., installation of water quality systems and devices to improve water quality and strategies that would allow for additional evapotranspiration for streams and their associated buffer zones).

Implementing this revised approach to EISA-438 compliance, as opposed to claiming technical infeasibility, demonstrates ORNL's commitment to environmental stewardship. If projects take place in existing contaminated areas or where an area approach is not feasible, technical infeasibility is claimed to prevent potential movement of contamination within soil or groundwater.

When possible, this environmental stewardship approach is implemented on an area basis at ORNL. Addressing EISA-438 on an area basis, instead of a project-by-project basis, allows for the following:

- Storm water runoff from adjacent areas can be diverted around developed areas to keep water quality high.
- Water quality structures and devices can be installed to handle runoff from developed areas, therefore reducing the number of water quality structures and devices to be installed and maintained.
- Individual projects are not burdened with the costs associated with addressing EISA-438 requirements.

In 2022, no water quality improvements were completed for EISA-438.

5.2.1.6. Emergency Preparedness and Response

The UT-Battelle Emergency Management Program supplies the resources and capabilities to provide emergency preparedness and emergency response services. The on-site emergency management organization provides emergency call answering and dispatch, emergency medical care and transport, firefighting capability, technical rescue services, and hazardous materials release mitigation. Emergency management personnel perform hazard surveys and hazard assessments to identify potential emergency situations. Procedures and plans have been developed to prepare for and respond to a wide variety of potential emergency situations. Training is provided to ensure appropriate response and performance during emergency events. Frequent exercises and drills are scheduled to ensure the effective execution of the procedures and plans. Emergency responders to expanding and complex incidents are supported by an emergency operations center consisting of laboratory leaders and SMEs. An environmental SME is a member of the emergency response organization. The environmental SME participates in real events, drills, and exercises to ensure that environmental requirements are met and that environmental impacts are mitigated.

5.2.1.7. Environmental Management System Performance Evaluation

ISO 14001 includes requirements to monitor, measure, analyze, and regularly evaluate the performance of the EMS. EMS performance evaluations ensure that goals and objectives are being met and that opportunities to continually improve are identified.

Monitoring and measurement

UT-Battelle has developed monitoring and measurement processes for each operation or activity that can have a significant adverse effect on the environment. SBMS includes requirements for management system owners to establish performance objectives and indicators, conduct performance assessments to collect data and monitor progress, and evaluate the data to identify strengths and weaknesses in performance and areas for improvement.

UT-Battelle Environmental Management System assessments

UT-Battelle uses several methods to evaluate compliance with legal and other environmental requirements. Most compliance evaluation activities are implemented through the EMS or participation in line-organization assessment activities. If a nonconformance was identified, the ORNL issues management process requires that any regulatory or management system nonconformance be reviewed for cause and that corrective and/or preventive actions be developed. These actions would then be implemented and tracked to completion.

Environmental assessments that cover legal and other requirements are performed periodically. Additionally, management system owners are required to assess management system performance and to address issues identified from customer feedback, staff suggestions, and other assessment activities.

UT-Battelle also uses the results from numerous external compliance inspections conducted by regulators to verify compliance with requirements. In addition to regulatory compliance assessments, an internal EMS assessment is performed annually to ensure that the UT-Battelle EMS continues to conform to ISO requirements. An independent internal audit conducted in 2022 verified that the EMS conforms to ISO 14001:2015. In addition to verifying conformance, these management system assessments also identify continual improvement opportunities.

5.2.2. Environmental Management System for the Transuranic Waste Processing Center

The National Sanitation Foundation International Strategic Registrations Ltd. registered the EMS for TWPC to the ISO 14001:2015 standard (ISO 2015) in May 2020. The EMS is integrated with ISMS to provide a unified strategy for managing resources, controlling and reducing risks, and establishing and achieving the organization's ES&H goals. The EMS and ISMS are incorporated into the *Integrated Safety Management System Description* (BJC 2009), and a plan-do-check-act cycle is used to continually improve both. The National Sanitation Foundation, International Strategic Registrations Ltd. conducted a recertification audit in May 2022. No nonconformances or issues were identified, and several significant practices were noted.

The EMS for TWPC incorporates applicable environmental laws; DOE orders and directives; and other federal, state, and local laws in accordance with documentation that describes how the various requirements are incorporated into subject area documents (procedures and guidelines). The EMS assists line organizations at TWPC in identifying and addressing environmental issues.

Environmental aspects are elements of an organization’s activities, products, or services that can interact with the environment. Environmental aspects associated with TWPC activities, products, and services have been identified at both the project and activity levels, and waste management activities, air emissions, storm water, pollution prevention, and energy have been identified as potentially having significant environmental impacts. Activities that are related to any of those environmental aspects are carefully controlled to minimize or eliminate impacts to the environment. Objectives and performance indicators have been established and implemented for the targets associated with the identified significant impacts.

The pollution prevention programs at TWPC involve waste reduction efforts and implementation of sustainable practices that reduce the environmental impacts of the activities conducted at TWPC. The TWPC EMS establishes annual goals and targets to reduce the impact of TWPC’s environmental aspects.

TWPC has a well-established recycling program, and new material recycling streams and opportunities to expand the types of materials included in the program continue to be identified. Currently, recycle streams at TWPC range from office materials such as paper, aluminum cans, plastic drinking bottles, foam beverage cups, alkaline batteries, and toner cartridges to operations-related materials such as cardboard, lamps, circuit boards, used oil, and batteries. The single-stream recycling program established at TWPC allows the mixing of multiple types of recyclables and thus increases the amount of recyclable items and improves compliance.

Environmentally preferable purchasing is a phrase used to describe an organization’s policy to reduce packaging and to purchase products made with recycled or bio-based materials and other environmentally friendly products. Green procurement requirements are incorporated into TWPC procurement procedures to ensure environmentally preferable products are purchased for TWPC.

Several methods to evaluate compliance with legal and other requirements are used at TWPC. Most of these compliance evaluation activities are implemented by internal and external environmental and management assessment activities and by routine reporting and reviews. The results from numerous external compliance inspections conducted by regulators and contractors are used to verify compliance with requirements. The UCOR EMS will be expanded to include operations at TWPC in 2023 following the prime contractor change in late 2022.

5.2.3. Environmental Management System for Isotek

Isotek has developed and implemented an EMS for the U-233 Disposition Project that reflects the elements and framework found in the ISO 14001:2004 standard (ISO 2004) and satisfies the applicable requirements of DOE Order 450.1A, *Environmental Protection Program* (DOE 2008). The scope of the Isotek EMS is to achieve and demonstrate environmental excellence by identifying, assessing, and controlling the impact of Isotek activities and facilities on the environment. The EMS is designed to ensure compliance with environmental laws, regulations, and other applicable requirements and to improve effectiveness and efficiency, reduce costs, and earn and retain regulator and community trust. The Isotek EMS and ISMS are fully integrated.

Project procedures provide a systematic approach to integrating environmental considerations into all aspects of Isotek’s activities at ORNL. The Isotek EMS includes a procedure for identifying environmental aspects associated with the U-233 Disposition Project and for determining whether those aspects can have significant environmental impacts. Isotek has identified radiological air emissions as the only environmental aspect of its operations that has potentially significant environmental impacts and has developed an environmental management plan with measurable objectives and targets to address that aspect. Isotek reviews environmental aspects, potential impacts, objectives, targets, and its environmental management plan at least annually and updates them as necessary.

The U-233 Disposition Project has a well-established recycling program that is implemented at all Isotek-managed facilities and includes Buildings 3017, 3019 Complex, 2026, and 3137. Materials Isotek currently recycles include paper, cardboard, aluminum cans, plastic bottles, inkjet and toner cartridges, lamps, batteries, scrap metal, circuit boards, aerosol cans, and used oil.

To evaluate compliance with legal and other requirements, Isotek conducts an EMS audit every 3 years, annual management assessments, and periodic surveillances. Compliance with requirements is also evaluated through inspections performed by regulatory agencies. The results of the compliance evaluations are used to continually improve the EMS.

5.3. Compliance Programs and Status

During 2022, UT-Battelle, UCOR, NWSol, and Isotek operations were conducted to comply with contractual and regulatory environmental requirements. (UCOR replaced NWSol as the operator or responsible contractor on all permits associated with TWPC on October 27, 2022.) Table 5.2 summarizes environmental audits conducted at ORNL in 2022. The following discussions summarize the major environmental programs and activities carried out at ORNL during 2022 and provide an overview of the compliance status for the year. Summary information on 2022 noncompliances at ORNL is also available under Federal Services Registry ID number 110002040201 on EPA's Enforcement and Compliance History Online website **here**.

5.3.1. Environmental Permits

Table 5.3 lists the environmental permits that were in effect in 2022 at ORNL.

Table 5.2. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORNL, 2022

Date	Reviewer	Subject	Issues
March 9–11	TDEC	Hazardous Waste Compliance Evaluation Inspection (including UT-Battelle, Transuranic Waste Processing Center, and UCOR)	0
March 23	TDEC	Underground Storage Tank Inspection	0
March 31	City of Oak Ridge	CFTF Wastewater Inspection	0
April 26	TDEC	Hardin Valley Campus Hazardous Waste Compliance Evaluation Inspection	0
June 9	KCDAQM	Hardin Valley Campus Clean Air Act Inspection	0
July 21	City of Oak Ridge	CFTF Wastewater Inspection	0
July 28	TDEC	CFTF Clean Air Act Inspection	0
December 14	TDEC	Annual Clean Air Act Inspection for ORNL	0

Acronyms:
TDEC = Tennessee Department of Environment and Conservation
KCDAQM = Knox County Department of Air Quality Management
CFTF = Carbon Fiber Technology Facility

Table 5.3. Environmental permits in effect at ORNL in 2022

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit, ORNL	571359	DOE	UT-B	UT-B
CAA	Operating Permit, NTRC	22-0941	DOE	UT-B	UT-B
CAA	Operating Permit, TRU	071009P	DOE	UCOR	UCOR
CAA	Construction Permit, 3525 Area Off Gas System	971543P	DOE	UT-B	UT-B
CAA	Operating Permit, TRU emergency generators	071010P	DOE	UCOR	UCOR
CAA	Title V Major Source Operating Permit, ORNL	578132	DOE	UCOR	UCOR
CAA	CFTF CAA Operating Permit (Conditional Major)	474951	DOE	UT-B	UT-B
CAA	Construction Permit, NTRC	C-21-0941-02-01	DOE	UT-B	UT-B
CAA	CAA Title V Operating Permit for Isotek operations at ORNL	576448	DOE	Isotek	Isotek
CAA	Construction Permit, CFTF	980167	DOE	UT-B	UT-B
CAA	Construction Permit, SNS 8915 Upgrade	980182	DOE	UT-B	UT-B
CWA	ORNL NPDES Permit (ORNL sitewide wastewater discharge permit)	TN0002941	DOE	DOE	UT-B, UCOR, NWSol[a], Isotek
CWA	Industrial and Commercial User Wastewater Discharge Permit (CFTF)	1-12	UT-B	UT-B	UT-B
CWA	General NPDES Permit for Storm Water Discharges Associated with Craft Resources Support Facility Construction Activities	TNR136355	DOE	UT-B	UT-B
CWA	General NPDES Permit for Storm Water for ORNL Experimental Gas Cooled Reactor Parking Lot	TNR136470	DOE	UT-B	UT-B
CWA	Tennessee Operating Permit, Holding Tank/Haul System for Domestic Wastewater	SOP-07014	UCOR	UCOR	UCOR
CWA	Tennessee Operating Permit (sewage)	SOP-02056	DOE	NWSol[a]	NWSol[a]

Table 5.3. Environmental permits in effect at ORNL in 2022 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CWA	Notice of Coverage Under the General NPDES Permit for Storm Water for 7000 Area Infrastructure Modernization[b]	TNR136181	DOE	UT-B	UT-B
CWA[a]	Notice of Coverage Under the General NPDES Permit for Storm Water for TRC Project	TNR136285	DOE	UT-B	UT-B
RCRA	Hazardous Waste Transporter Permit	TN1890090003	DOE	UT-B	UT-B, UCOR
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	DOE	DOE/all	DOE/all
RCRA	Hazardous Waste Storage and Treatment Permit	TNHW-145	DOE	DOE/ UCOR/ NWSol[a]	UCOR/NWSol[a]
RCRA	Hazardous and Mixed Waste Storage Permit	TNHW-178	DOE	DOE/UT-B	UT-B
PCB	PCB Risk Based Agreement between UT-B and EPA	TN1890090003	DOE	UT-B	UT-B
CWA	ARAP—Construction of a New Outfall Consisting of a Headwall and Riprap Apron	NR2203.208	DOE	UT-B	UT-B
CWA	ARAP—Installation of a New Effluent Flow Monitoring Station with a Parshall Flume and New Outfall Line	NR2203.188	DOE	UT-B	UTB

[a] UCOR replaced NWSol as the operator or responsible contractor on all permits associated with the TWPC on October 27, 2022.
[b] Permit terminated during 2022.

Acronyms:
ARAP = Aquatic Resources Alteration Permit
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
DOE = US Department of Energy
EPA = US Environmental Protection Agency
Isotek = Isotek Systems, LLC
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
NWSol = North Wind Solutions, LLC
SNS = Spallation Neutron Source
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TRC = Translational Research Capability
TRU = transuranic
UCOR = United Cleanup Oak Ridge, LLC
UT-B = UT-Battelle LLC

Table 5.4. National Environmental Policy Act activities, 2022

Types of NEPA documentation	Number of instances
UT-Battelle LLC	
Environmental Assessments	1
Approved under general actions or generic CX determinations[a]	85
Project-specific CX determinations[b]	0
North Wind Solutions, LLC and UCOR[c]	
Approved under general actions[a] or generic CX determinations	0

[a] Projects that were reviewed and documented through the site NEPA compliance coordinator
[b] Projects that were reviewed and approved through the DOE Site Office and the NEPA compliance officer
[c] UCOR assumed responsibility for TWPC on October 27, 2022.
Acronyms:
CX = categorical exclusion
DOE = US Department of Energy
NEPA = National Environmental Policy Act

5.3.2. National Environmental Policy Act/National Historic Preservation Act

The NEPA process is used to to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. UT-Battelle, NWSol, and Isotek maintain compliance with NEPA using site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to establish NEPA as a key consideration in the formative stages of project planning. Table 5.4 summarizes NEPA activities conducted at ORNL during 2022.

NEPA requires environmental assessments to evaluate the environmental impacts of major federal actions and to identify reasonable alternatives (including the proposed action). In 2022, an environmental assessment (DOE/EA-2136) was conducted for the construction and operation of the Stable Isotope Production and Research Center. No significant environmental concerns were identified by the assessment and a Finding of No Significant Impact was issued by DOE, allowing the action to proceed.

During 2022, UT-Battelle and NWSol continued to operate under site-level procedures that provide requirements for project reviews and NEPA compliance. (Operations at TWPC transitioned from NWSol to UCOR on October 27, 2022.) The procedures call for a review of each proposed project, activity, or facility to determine the potential for impacts to the environment. To streamline the NEPA review and documentation process, DOE has approved generic categorical exclusion determinations that cover proposed bench-scale and pilot-scale research activities and generic categorical exclusions that cover proposed nonresearch activities (e.g., maintenance activities, facilities upgrades, personnel safety enhancements). A categorical exclusion is one of a category of actions defined in 40 CFR 1508.4 that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required.

UT-Battelle uses SBMS as the delivery system for guidance and requirements to manage and control work at ORNL. NEPA is an integral part of SBMS, and a UT-Battelle NEPA coordinator works with principal investigators, environmental compliance representatives, and environmental protection officers within each UT-Battelle division to determine appropriate NEPA decisions.

Compliance with the National Historic Preservation Act (NHPA 1966) is achieved and maintained at ORNL in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR cultural resource management plan (Souza et al. 2001).

5.3.3. Clean Air Act Compliance Status

The Clean Air Act (CAA 1970), passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation established comprehensive federal and state regulations to limit air emissions. It includes four major regulatory programs: the national ambient air quality standards, state implementation plans, new source performance standards, and Rad-NESHAPs.

Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by EPA and the Tennessee Department of Environment and Conservation (TDEC) Division of Air Pollution Control. The most recent sitewide UT-Battelle Title V Major Source Operating Permit was issued in January 2022. The Title V Major Source Operating Permit for the 3039 stack, operated by UCOR, was issued in January 2022. To demonstrate compliance with the Title V major source operating permits, more than 1,500 data points are collected and reported every year. In addition, nitrogen oxides, a family of poisonous, highly reactive gases defined collectively as a criteria pollutant by EPA (EPA 2016), are monitored continuously at one location. Samples are collected continuously from 8 major radionuclide sources and periodically from 14 minor radionuclide sources. There are numerous other demonstrations of compliance with generally applicable air quality protection requirements (e.g., asbestos, stratospheric ozone).

NTRC and CFTF are two off-site CAA-regulated facilities maintained and operated by UT-Battelle. An operating permit, issued by Knox County for two emergency generators located at NTRC, was issued in December 2022. The CFTF operates under a conditional major operating permit issued to UT-Battelle by TDEC in January 2022.

In summary, there were no UT-Battelle, Isotek, UCOR, or NWSol (transitioned to UCOR on October 27, 2022) CAA violations or exceedances in 2022. Section 5.4. provides detailed information on 2022 activities conducted by UT-Battelle in support of the CAA.

5.3.4. Clean Water Act Compliance Status

The objective of the Clean Water Act (CWA 1972) is to restore, maintain, and protect the integrity of the nation's waters. The CWA is the basis for comprehensive federal and state programs to protect the nation's waters from pollutants. (See Appendix C for water quality reference standards.) One of the strategies developed to achieve the goals of the CWA was the EPA's establishment of limits on specific pollutants allowed to be discharged to US waters by municipal sewage treatment plants (STPs) and industrial facilities. EPA established the National Pollutant Discharge Elimination System (NPDES) permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the State of Tennessee.

In 2022, compliance with the ORNL NPDES permit was calculated based on the total 1,736 required laboratory analyses and field measurements. ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 100 percent in 2022 (see Table 5.5).

Table 5.5. National Pollutant Discharge Elimination System compliance at ORNL, January through December 2022

Effluent parameters[a]	Number of numeric noncompliances	Number of compliance measurements[b]	Percentage of compliance[c]
X01 (Sewage Treatment Plant)			
IC_{25} Static renewal 7-day chronic *Ceriodaphnia dubia* (%)[d]	0	1	100
IC_{25} Static renewal 7-day chronic *Pimephales promelas* (%)[d]	0	1	100
Ammonia, as N (summer)	0	26	100
Ammonia, as N (winter)	0	26	100
Carbonaceous biological oxygen demand	0	52	100
Dissolved oxygen	0	52	100
Escherichia coliform (col/100 mL)	0	52	100
Peracetic acid	0	0	100
pH (standard units)	0	52	100
Total suspended solids	0	52	100
X12 (Process Waste Treatment Complex)			
IC_{25} Static renewal 7-day chronic *Ceriodaphnia dubia* (%)[d]	0	1	100
IC_{25} Static renewal 7-day chronic *Pimephales promelas* (%)[d]	0	1	100
Oil and grease	0	4	100
pH (standard units)	0	52	100
Temperature (°C)	0	52	100
X16 through X27 (12 instream monitoring locations)			
Total residual oxidant	0	288	100
X28 and X29 (two additional instream monitoring locations)			
Peracetic acid	0	0	100
Hydrogen peroxide	0	0	100

[a] *Only permit parameters with a numerical limit are listed.*
[b] *Total number of readings taken in the year by approved method for the given parameter.*
[c] *Percentage compliance = 100 − [(number of noncompliances/number of samples) × 100].*
[d] *The inhibition concentration (IC_{25}) is the concentration (as a percentage of full-strength wastewater) that reduces survival or reproduction of the test species by 25 percent when compared to a control treatment.*

In October 2022, water from a potable water line break in the 7000 Area was released into White Oak Creek (WOC) and caused aquatic species mortality (total of 141 fish, 11 salamanders, and 13 aquatic worms). This incident was reported as a noncompliance with narrative criteria in the permit.

ORNL received a renewed NPDES permit in May 2019. Several conditions in the permit were appealed and were addressed in a reissued permit in December 2022.

5.3.5. Safe Drinking Water Act Compliance Status

ORNL's water distribution system is designated as a "nontransient, noncommunity" public water system by the TDEC Division of Water Supply. TDEC's water supply rules—Chapter 0400-45-01, "Public Water Systems" (TDEC 2020)—set limits for biological contaminants and for chemical activities and chemical contaminants. TDEC requires sampling for the following constituents to demonstrate compliance with state and federal regulations:

- Residual chlorine
- Bacteria (total coliform)
- Disinfectant by-product (trihalomethanes and haloacetic acids)
- Lead and copper (required once every 3 years)

The fifth Unregulated Contaminant Monitoring Rule (UCMR 5) was published on December 27, 2021, and requires sample collection for 30 chemical contaminants between 2023 and 2025. Laboratory analyses will be perfomed using using analytical methods developed by EPA and consensus organizations. Sample collection at ORNL for UCMR 5 will begin in 2023 and will continue through 2026.

The City of Oak Ridge supplies potable water to the ORNL water distribution system and meets all regulatory requirements for drinking water. The water treatment plant, located on ORR north of the Y-12 Complex, is owned and operated by the City of Oak Ridge.

In 2022, sampling results for ORNL's water system residual chlorine levels, bacterial constituents, and disinfectant by-products were all within acceptable limits. Sampling for lead and copper is not required until 2024.

5.3.6. Resource Conservation and Recovery Act Compliance Status

The Hazardous Waste Program under the Resource Conservation and Recovery Act (RCRA 1976) establishes a system for regulating hazardous wastes from the initial point of generation through final disposal. In Tennessee, TDEC has been delegated authority by EPA to implement the Hazardous Waste Program; EPA retains an oversight role. In 2022, DOE and its contractors at ORNL were jointly regulated as a "large-quantity generator of hazardous waste" under EPA ID TN1890090003 because, collectively, they generated more than 1,000 kg of hazardous/mixed wastes in at least one calendar month during 2022.

Mixed wastes are both hazardous (under RCRA regulations) and radioactive. Hazardous/mixed wastes are accumulated in satellite accumulation areas or in less-than-90-day accumulation areas and are stored and/or treated in RCRA-permitted units. In addition, hazardous/mixed wastes are shipped off site for treatment and disposal. The RCRA units operate under three permits at ORNL, as shown in Table 5.6. In 2022, UT-Battelle and UCOR were permitted to transport hazardous wastes under the EPA ID number issued for ORNL activities. TNHW-164 is a set of conditions pertaining to the current status of all solid waste management units and areas of concern at ETTP, ORNL, and the Y-12 Complex. The corrective action conditions require that the solid waste management units and areas of concern be investigated and, as necessary, remediated.

Reporting is required for hazardous waste activities on 12 active waste streams at ORNL, some of which involve mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2022 was 363,892 kg, of which 114,417 kg was mixed wastewater.

ORNL generators treated 14,924 kg of hazardous waste by elementary neutralization. The quantity of hazardous/mixed waste treated in permitted treatment facilities at ORNL in 2022 was 115,084 kg. This includes waste treated by macroencapsulation, size reduction, and stabilization/solidification, as well as wastewater treatment at the Process Waste Treatment Complex (PWTC). The amount of hazardous/mixed waste shipped off site to commercial treatment, storage, and disposal facilities was 162,055 kg in 2022.

Table 5.6. ORNL Resource Conservation and Recovery Act operating permits, 2022

Permit number	Storage and treatment/description
	Oak Ridge National Laboratory
TNHW-178	Building 7651 Mixed Waste Container Storage Unit Building 7652 Hazardous Waste Container Storage & Treatment Unit Building 7653 Chemical Waste Container Storage Unit Building 7654 Mixed Waste Container Storage & Treatment Unit
TNHW-145	Building 7572 Contact-Handled Transuranic Waste Storage Facility Building 7574 Transuranic Storage Facility Building 7855 Remote-Handled Transuranic Retrievable Storage Facility Building 7860A Remote-Handled Transuranic Retrievable Storage Facility Building 7879 Transuranic/Low Level Waste Storage Facility Building 7883 Remote-Handled Transuranic Storage Bunker Building 7831F Flammable Storage Unit[a] Transuranic Waste Processing Center (TWPC)-1 Contact-Handled Storage Area TWPC-2 Waste Processing Building Second Floor TWPC-3 Drum Aging Criteria Area TWPC-4 Waste Processing Building First Floor TWPC-5 Container Storage Area TWPC-6 Contact-Handled Marshaling Building TWPC-7 Drum-Venting Building TWPC-8 Multipurpose Building T-1 Macroencapsulation Treatment[a] T-2 Solidification/Stabilization Treatment[a] T-3 Amalgamation Treatment[a] T-4 Groundwater Absorption Treatment[a] T-5 Size Reduction[a] T-6 Groundwater Filtration Treatment[a] T-7 Neutralization[a] T-8 Oxidation/Deactivation[a] T-9 Puncturing Potentially Pressurized Containers[a]
	Oak Ridge Reservation
TNHW-164	Hazardous Waste Corrective Action Document

[a] *Treatment methodologies within Transuranic Waste Processing Center facilities.*

In March 2022, the TDEC Division of Solid Waste Management conducted a Hazardous Waste Compliance Evaluation inspection of the following:

- ORNL generator areas
- Used oil collection areas
- Universal waste collection areas
- RCRA-permitted treatment, storage, and disposal facilities
- Hazardous waste training records
- Site-specific contingency plans
- Hazardous Waste Reduction Plan

- Active Mutual Aid and Memorandums of Agreement with local authorities
- Waste determinations
- RCRA records

TDEC also reviewed the Hazardous Waste Transporter Permit, hazardous waste manifests, and US Department of Transportation training records. No violations were observed.

DOE and UT-Battelle operations at the HVC and CFTF were categorized as *very small-quantity generators* in 2022, meaning that less than 100 kg of hazardous waste was generated per month. Hazardous waste generator regulations allow very small-quantity generators to conduct one planned or unplanned episodic event in a year. An *episodic event* is defined as an activity that does not normally occur during a generator's operations and that causes that generator to exceed the threshold for its normal generator category for that month. On September 18 through October 8, 2022, a planned episodic event was conducted at the HVC, generating approximately 823 kg of flammable liquids, corrosives, and organic peroxides left over from an R&D project. TDEC was notified of the planned event on August 16, 2022.

In 2022, no hazardous/mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle from the Jones Island Road 0800 Area, Property Sales, or the DOE Office of Scientific and Technical Information.

5.3.7. ORNL RCRA-CERCLA Coordination

The *Federal Facility Agreement for Oak Ridge Reservation* (DOE 1992) is intended to coordinate the corrective action processes of RCRA required under the Hazardous and Solid Waste Amendments permit with CERCLA response actions. Annual updates for 2021 for ORNL's solid waste management units and areas of concern were consolidated with updates for ETTP, the Y-12 Complex, and ORR and were reported to TDEC, DOE, and the EPA Region 4 in January 2022.

Periodic updates onproposed construction and demolition activities of facilities at ORNL have been provided to managers and project personnel from the TDEC Remediation Division and EPA Region 4. A CERCLA screening process is used to identify proposed construction and demolition projects and facilities that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not adversely affect future CERCLA environmental remediation actions or the effectiveness of previously completed CERCLA environmental remediation actions.

5.3.7.1. RCRA Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280). EPA has granted TDEC the authority to regulate USTs containing petroleum under TDEC Rule 400-18-01; however, EPA still regulates hazardous-substance USTs.

ORNL has two USTs registered with TDEC under Facility ID 0-730089. These USTs are in service (for petroleum storage) and meet the current UST standards. TDEC did not conduct any compliance inspections in 2022.

5.3.8. CERCLA Compliance Status

CERCLA, also known as Superfund, was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA 1986). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health or the environment to warrant cleanup under CERCLA.

In 1989, ORR was placed on the National Priorities List. In 1992, the ORR Federal Facility Agreement became effective among EPA, TDEC, and DOE and established the framework and schedule for developing, implementing, and monitoring remedial actions (RAs) on ORR. UCOR operates the on-site CERCLA Environmental Management

Waste Management Facility (EMWMF) for DOE. Located in Bear Creek Valley, the EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR, including ORNL. The EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes and combinations of these wastes in accordance with specific waste acceptance criteria under an agreement with state and federal regulators.

5.3.9. Toxic Substances Control Act Compliance Status

PCB uses and waste at ORNL are regulated under the Toxic Substances Control Act (TSCA 1976). PCB waste generation, transportation, and storage at ORNL are reported under EPA ID TN1890090003. In 2022, ORNL contractors operated eight PCB waste storage areas. When longer-term storage was necessary, PCB/radioactive wastes were stored in RCRA-permitted storage buildings at ORNL. One of the PCB waste storage areas was operated at a UT-Battelle facility in the Y-12 Complex. The continued use of authorized PCBs in electrical systems and equipment (e.g., transformers, capacitors, rectifiers) is regulated at ORNL. Most of the equipment at ORNL that required regulation under the Toxic Substances Control Act has been dispositioned. However, some of the ORNL facilities at the Y-12 Complex continue to use (or store for future reuse) PCB equipment.

Because of the age of many of the ORNL facilities and the continued presence of PCBs in gaskets, grease, building construction, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE and ORNL contractors negotiated a compliance agreement with EPA (see Chapter 2, Table 2.1, under “Toxic Substances Control Act”) to address the compliance issues related to these unauthorized uses and to allow for continued use pending decontamination or disposal. As a result of that agreement, DOE continues to notify EPA when additional unauthorized uses of PCBs, such as in paint, adhesives, electrical wiring, or floor tile, are identified at ORNL. No new unauthorized uses of PCBs were identified during 2022.

5.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA 1986) and Title III of SARA require that facilities report inventories and releases of certain chemicals that exceed specific release thresholds. The inventory report is submitted to the Emergency Response Information System (E-Plan), which is an electronic database managed by the University of Texas at Dallas and funded by the US Department of Homeland Security. The State of Tennessee Emergency Response Commission has access to ORNL EPCRA data via the E-Plan system.

Table 5.7 describes the main elements of EPCRA. UT-Battelle complied with these requirements in 2022 through the submittal of reports under EPCRA Sections 302, 303, 311, 312, and 313. The reports contain information on all DOE prime contractors and their subcontractors who reported activities at the ORNL site.

In 2022, ORNL had no releases of extremely hazardous substances as defined by EPCRA. Releases of toxic chemicals that were greater than the reportable threshold quantities designated in Section 313 are discussed in Section 5.3.9.2.

Table 5.7. Main elements of the Emergency Planning and Community Right-to-Know Act

Title	Description
Sections 302 and 303, Planning Notification	Requires that local planning committee and state emergency response commission be notified of EPCRA-related planning
Section 304, Extremely Hazardous Substance Release Notification	Addresses reporting to state and local authorities of off-site releases
Sections 311–312, Safety Data Sheet/Chemical Inventory	Requires that either safety data sheets or lists of hazardous chemicals for which they are required be provided to state and local authorities for emergency planning. Requires that an inventory of hazardous chemicals maintained in quantities over thresholds be reported annually to EPA
Section 313, Toxic Chemical Release Reporting	Requires that releases of toxic chemicals be reported annually to EPA

Acronyms:
EPA = US Environmental Protection Agency
EPCRA = Emergency Planning and Community Right-to-Know Act

5.3.10.1. Safety Data Sheet/Chemical Inventory (Section 312)

Inventories, locations, and associated hazards of hazardous chemicals and/or extremely hazardous substances were submitted in an annual report to the E-Plan as required by the State of Tennessee. In 2022, there were 17 hazardous or extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2022 submittals. Under the terms of their leases, lessees must evaluate their own inventories of hazardous and extremely hazardous chemicals and must submit information as required by the regulations.

5.3.10.2. Toxic Chemical Release Reporting (EPCRA Section 313)

DOE submits annual toxic release inventory reports to EPA and the Tennessee Emergency Management Agency on or before July 1 of each year. The reports cover the previous calendar year and track the management of certain chemicals that are released to the environment and/or managed through recycling, energy recovery, and treatment. (A release of a chemical means that it is emitted to the air or water or that it is placed in some type of land disposal.) Operations involving certain chemicals were compared with regulatory reporting thresholds to determine which chemicals exceeded individual thresholds on amounts manufactured, amounts processed, or amounts otherwise used. Releases and other waste management activities were determined for each chemical that exceeded one or more threshold.

In 2022, ORNL exceeded the reporting threshold and reported on the manufacture of nitrate compounds. Nitrate compounds were coincidentally manufactured as by-products of on-site sewage treatment.

5.3.11. US Department of Agriculture/Tennessee Department of Agriculture

USDA, through Animal and Plant Health Inspection Services, issues permits for the import, transit, and controlled release of regulated animals, animal products, veterinary biologics, plants, plant products, pests, organisms, soil, and genetically engineered organisms. The Tennessee Department of Agriculture issues agreements and jointly regulates domestic soil with USDA. In 2022, UT-Battelle personnel had 32 permits and agreements for the receipt, movement, or controlled release of regulated articles.

5.3.12. Wetlands

Wetland delineations are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetland protection requirements. In

2022, four wetlands were delineated within the potential disturbance area for a future project along Melton Valley Drive. Currently, the preliminary project designs only impact one of these wetlands. Wetland boundaries were flagged and surveyed, and official US Army Corps of Engineers delineation forms were completed. Data from these forms were compiled into sensitive resource survey and compliance documents. Assessing the potential for jurisdictional wetlands during site selection and early project planning stages can reduce adverse impacts to wetlands, design changes, and mitigation costs. For example, wetlands delineations conducted in 2021 for a project along White Oak Avenue were used to avoid wetland impacts in the final project design in 2022.

5.3.13. Radiological Clearance of Property at ORNL

DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011d), established standards and requirements for operations of DOE and its contractors with respect to protection of members of the public and the environment against undue risk from radiation. In addition to discharges to the environment, the release of property containing residual radioactive material is a potential contributor to the dose received by the public, and DOE Order 458.1 established requirements for clearance of property from DOE control and for public notification of clearance of property.

5.3.13.1. Graded Approach to Evaluate Material and Equipment for Release

At ORNL, UT-Battelle uses a graded approach for release of material and equipment for unrestricted public use. Material that may be released to the public has been categorized so that in some cases an administrative release can be accomplished without a radiological survey. Such material originates from nonradiological areas and includes items such as the following:

- Documents, mail, diskettes, compact disks, and other office media
- Nonradioactive items or materials received that are immediately (within the same shift) determined to have been delivered in error or damaged
- Personal items or materials
- Paper, plastic products, aluminum beverage cans, toner cartridges, and other items released for recycling
- Office trash
- Housekeeping materials and associated waste
- Breakroom, cafeteria, and medical wastes
- Compressed gas cylinders and fire extinguishers
- Medical and bioassay samples
- Other items with an approved release plan

Items that are not in the listed categories and that originate from nonradiological areas within ORNL's controlled areas are surveyed before release to the public, or a process knowledge evaluation is conducted to ensure that the material has not been exposed to radioactive material or beams of radiation capable of creating radioactive material. In some cases, both a radiological survey and a process knowledge evaluation are performed (e.g., a radiological survey is conducted on the outside of the item, and a process knowledge form is signed by the custodian for inaccessible surfaces). A similar approach is used for material released to state-permitted landfills on ORR. The only exception is for items that could be internally contaminated; those items are also sampled by laboratory analysis to ensure that landfill permit criteria are met.

When the process knowledge approach is used, the item's custodian is required to sign a statement that specifies that the history of the item or material is known and that the material is known to be free of contamination. This process knowledge certification is more stringent than what is required by DOE Order 458.1 (DOE 2011d) in that ORNL requires an individual to take personal responsibility and accountability for knowing the complete history of an item before it can be cleared using process knowledge alone. DOE Order 458.1 allows use of procedures for evaluating operational records and operating history to make process knowledge release decisions, but UT-Battelle has chosen to continue to require personal certification of the status of an item. This requirement ensures that each individual certifying the item is aware of the significance of this decision and encourages the individual to obtain a survey of the item if he or she is not confident that the item can be certified as being free of contamination.

A survey and release plan may be developed to direct the radiological survey process for large recycling programs or for clearance of bulk items with low contamination potential. For such projects, survey and release plans are developed based on guidance from the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000) or the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (MARSAME) (NRC 2009). MARSSIM and MARSAME allow for statistically based survey protocols that typically require survey measurements for a representative portion of the items being released. The survey protocols are documented in separate survey and release plans, and the measurements from such surveys are documented in radiological release survey reports.

In accordance with DOE Order 458.1, Section k.(6)(f)2 b, "Pre-Approved Authorized Limits," UT-Battelle continues to use the preapproved authorized limits for surface contamination originally established in Table IV-1 of DOE Order 5400.5 (cancelled in 2011) and the November 17, 1995, Pelletier memorandum (Pelletier 1995) for TRU alpha contamination. UT-Battelle also continues to follow the requirements of the scrap metal suspension. No scrap metal directly released from radiological areas is being recycled. In 2022, UT-Battelle cleared more than 17,307 items through the excess items and property sales processes. A summary of items requested for release through these processes is shown in Table 5.8.

Table 5.8. Excess items requested for release or recycling, 2022

Item	Process knowledge	Radiologically surveyed
Release request totals for 2022		
Totals	16,006	1,301
Recycling request totals for 2022		
Cardboard (lb)	299,742	
Scrap metal (nonradiological areas) (tons)	511.08	

5.3.13.2. Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples

The Spallation Neutron Source (SNS) and High Flux Isotope Reactor (HFIR) facilities provide unique neutron scattering experiment capabilities that allow researchers to explore the properties of various materials by exposing samples to well-characterized neutron beams. Because materials exposed to neutrons can become radioactive, a process has been developed to evaluate and clear samples for release to off-site facilities. DOE regulations and orders governing radiological release of material do not specifically cover items that may have radioactivity distributed throughout the volume of the material. To address sample clearance, activity-based limits were established using the authorized limits process defined in DOE Order 458.1 (DOE 2011d) and associated guidance. The sample clearance limits are based on an assessment of potential doses against a threshold of 1 mrem/year to an individual and evaluation of other potentially applicable requirements (e.g., Nuclear Regulatory Commission licensing regulations). Implementation of the clearance limits involves using unique instrument screening and methods to predict sample activity to provide an efficient and defensible process to release neutron scattering experiment samples to researchers without further DOE control.

In 2022, ORNL cleared a total of 61 samples from neutron scattering experiments using the sample authorized limits process. Of those, 10 samples were from SNS and 51 were from HFIR.

5.4. Air Quality Program

Permits issued by the State of Tennessee convey the clean air requirements that are applicable to ORNL. These permits and the results of 2022 air monitoring activities are summarized in the following sections.

5.4.1. Construction and Operating Permits

New projects are governed by construction permits until the projects are converted to operating status. The sitewide Title V Major Source Operating Permits include requirements that are generally applicable to large operations such as national laboratories (e.g., asbestos and stratospheric ozone) as well as specific requirements directly applicable to individual air emission sources. Source-specific requirements include Rad-NESHAPs (see Section 5.4.3), requirements applicable to sources of radiological air pollutants, and requirements applicable to sources of other hazardous (nonradiological) air pollutants. In August 2017, the State of Tennessee issued Title V Major Source Operating Permit 571359 to DOE and UT-Battelle for operations at ORNL. DOE and UT-Battelle also maintained a valid minor source operating permit with the Knox County Department of Air Quality Management Division for the NTRC facilities, which are in Knox County.

The CFTF was constructed at an off-site location in the Horizon Center Business Park in Oak Ridge, Tennessee. UT-Battelle applied for and received two construction permits for construction of the CFTF (Permit No. 965013P in 2012 and Permit No. 967180P in 2014). The initial start-up of the CFTF occurred in March 2013. The most recent Conditional Major Source Operating Permit for the facility was issued in January 2022 (Permit No. 474951).

DOE/UCOR has two non-Title V Major Source Operating Permits for one emission source and two emergency generators at TWPC (Permit Nos. 071009P and 071010P). During 2022, no permit limits were exceeded. Isotek has a Title V Major Source Operating Permit (576448) for the Radiochemical Development Facility (Building 3019 Complex). During 2022, no permit limits were exceeded. UCOR was issued a Title V Major Source Operating Permit (569768) on September 18, 2015, for the Building 3039 Process Off-Gas and Hot Cell Ventilation System. Construction Permit 974744 was issued on November 19, 2018, to implement several proposed modifications to the Title V Operating Permit, and Significant Modification #1 to the Title V Operating Permit was issued on April 5, 2019, incorporating those modifications. The current operating permit (578132) was issued January 4, 2022. During 2022, no permit limits were exceeded.

5.4.2. National Emission Standards for Hazardous Air Pollutants—Asbestos

Numerous facilities, structures, facility components, and pieces of equipment at ORNL contain asbestos-containing material. UT-Battelle's Asbestos Management Program manages the compliance of work activities involving the removal and disposal of asbestos-containing material. This program includes notifications to TDEC for all demolition activities and required renovation activities, approval of asbestos work authorization requests, implementation of engineering controls and work practices, inspections, air monitoring, and waste tracking of asbestos-contaminated waste material. During 2022, no deviations or releases of reportable quantities of asbestos-containing material occurred.

In 2022, four Notification of Asbestos Demolition or Renovation Applications were completed:

- The Building 7067 suite demolition project consisted of asbestos removal and demolition work activities for Buildings 7067, 7615, 7077C, 7867, and 7849. No regulated asbestos-containing material (RACM) was present for this project; however, 768 ft^2 of Category II nonfriable asbestos-containing materials was removed. The application (ORNL-2022-001) was submitted with a start date of January 26, 2022, and was completed by February 16, 2022.

- The Building 8940 demolition project consisted of demolition work activities. This project did not involve asbestos removal activities. The application (ORNL-2022-002) was submitted with a start date of June 20, 2022, and was completed by June 30, 2022.
- The demolition of trailers 7981B, 7981C, and 7605A project consisted of demolition and asbestos disposal work activities. No RACM was present for this project; however, 2 ft^2 of Category II nonfriable suspect asbestos-containing materials was segregated during demolition and disposed of as nonfriable asbestos waste. The application (ORNL-2022-003) was submitted with a start date of August 15, 2022, and was completed by September 16, 2022.
- The Freels Bend suite demolition project consisted of asbestos removal and demolition work activities associated with XF1304, XG1410, XG1415, XG1416, and 7964C facilities. No RACM was present; however, 18 ft^2 and 60 ln ft of Category II nonfriable asbestos-containing materials were present and removed. XG1410 and XG1415 were facility components with no RACM above threshold limits. The application (ORNL-2022-004) was submitted with a start date of September 7, 2022, and was completed by September 30, 2022.

5.4.3. Radiological Airborne Effluent Monitoring

Radioactive airborne discharges at ORNL are subject to Rad-NESHAPs and consist primarily of ventilation air from radioactively contaminated or potentially contaminated areas, vents from tanks and processes, and ventilation for hot cell operations and reactor facilities. The airborne emissions are treated and then filtered with high-efficiency particulate air filters and/or charcoal filters before discharge. Radiological airborne emissions from ORNL consist of solid particulates, tritium (^3H), adsorbable gases (e.g., iodine), and nonadsorbable gases (e.g., noble gases).

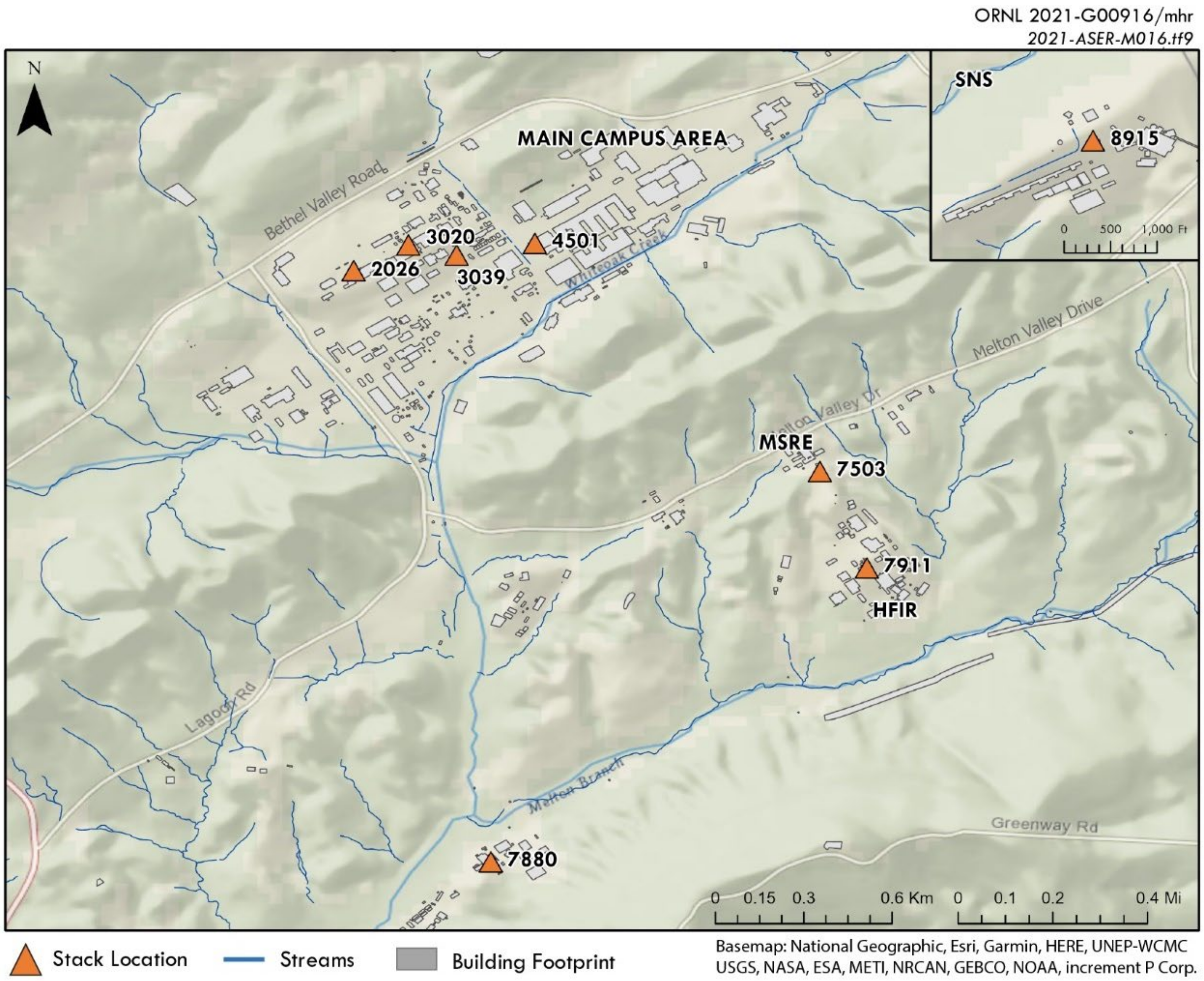
The major radiological emission point sources for ORNL consist of the following eight stacks. Seven are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.7):

- 2026 Radioactive Materials Analytical Laboratory
- 3020 Radiochemical Development Facility
- 3039 central off-gas and scrubber system, which includes the 3500 cell ventilation system, isotope area cell ventilation system, 3025/3026 cell ventilation system, 3042 ventilation system, and 3092 central off-gas system
- 4501 Radiochemistry Laboratory Area Off-Gas System
- 7503 Molten Salt Reactor Experiment Facility
- 7880 TWPC
- 7911 Melton Valley complex, which includes HFIR and the Radiochemical Engineering Development Center
- 8915 SNS Central Exhaust Facility stack

In 2022, there were 15 minor point/group sources, and emission calculations/estimates were made for each of them.

5.4.3.1. Sample Collection and Analytical Procedure

Three of the major point sources (stacks 3020, 3039, and 7503) are equipped with in-stack source-sampling systems that comply with criteria in the American National Standards Institute (ANSI) standard ANSI N 13.1-1969R (ANSI 1969).



Acronyms:
HFIR = High Flux Isotope Reactor *MSRE = Molten Salt Reactor Experiment* *SNS = Spallation Neutron Source*

Figure 5.7. Locations of major radiological emission points at ORNL, 2022

Each sampling system generally consist of comprises a multipoint in-stack sampling probe, a sample transport line, a particulate filter, activated charcoal cartridges (or canister), a silica gel cartridge (if required), flow measurement and totalizing instruments, a sampling pump, and a return line to the stack. The 2026 (Radioactive Materials Analytical Laboratory), 4501 (Radiochemistry Laboratory), 7911 (Melton Valley complex), and 7880 (TWPC) stacks are equipped with in-stack source-sampling systems that comply with criteria in the ANSI–Health Physics Society standard ANSI/HPS N13.1-1999 (ANSI 1999).

The 2026, 4501, and 7911 sampling systems have the same components as the ANSI 1969 sampling systems used for the four major point sources but use stainless-steel-shrouded probes instead of multipoint in-stack sampling probes. The 7911 sampling system also includes a high-purity germanium detector with an analog-to-digital converter and ORTEC GammaVision software, which allows for continuous isotopic identification and quantification of radioactive noble gases (e.g., ^{41}Ar) in the effluent stream. The 7880 sampling system consists of a stainless steel–shrouded probe, an in-line filter cartridge holder placed at the probe to minimize line losses, a particulate filter, a sample transport line, a rotary vane vacuum pump, and a return line to the stack. The sample probes from both the ANSI 1969 and

ANSI 1999 stack-sampling systems are removed, inspected, and cleaned annually. The SNS Central Exhaust Facility (8915) stack is equipped with an in-stack radiation detector that complies with criteria in ANSI/HPS N13.1-1999 (ANSI 1999). The detector monitors radioactive gases flowing through the exhaust stack and provides a continual readout of activity detected by a scintillator probe. The detector is calibrated to correlate with isotopic emissions. Velocity profiles are performed quarterly at major sources (except for the 3039 stack) and at some minor sources; the criteria in EPA Method 2 (40 CFR 60, Appendix A-1, Method 2) are followed.

The profiles provide accurate stack flow data for subsequent emission rate calculations. An annual leak check program is carried out to verify the integrity of the sample transport system. Results obtained from the the effluent flow rate totalizer and from EPA Method 2 are compared annually for the 7880 stack. The response of the stack effluent flow rate monitoring system is checked quarterly with the manufacturer's instrument test procedures. The stack sampler rotameter is calibrated at least quarterly in comparison with a secondary (transfer) standard. Only a certified secondary standard is used for all rotameter tests.

Starting in 2017, the 3039 emissions were calculated using a fixed stack flow rate. A fixed stack flow rate was used because the stack velocity at the sampling level is at or below the sensitivity of standard methods for measuring the velocity, and therefore stack flow rates can no longer be determined. Low effluent velocity measurements are due to stack flow reductions resulting from the removal of facilities exhausting through the stack. The EPA Region 4 office approved a request to use an alternative fixed stack flow for emission calculations for the 3039 stack in a letter dated April 27, 2017 (V. Anne Heard, Acting Regional Administrator, United States Environmental Protection Agency Region 4 to Raymond J. Skwarek, Environmental Safety, Health and Quality Assurance Manager, UCOR, April 27, 2017). The 3039 stack velocity was successfully measured with new equipment in November 2019 and in July 2020. Both results were below the fixed stack flow rate; the stack velocity result obtained in 2020 was used for emission calculation purposes in 2022.

In addition to the major sources, ORNL has several minor sources that have the potential to emit radionuclides to the atmosphere. A minor source is defined as any ventilation system or component such as a vent, laboratory hood, room exhaust, or stack that does not meet the approved regulatory criteria for a major source but that is in or vents from a radiological control area as defined by Radiological Support Services of the UT-Battelle Nuclear and Radiological Protection Division. Various methods are used to determine the emissions from the minor sources. Methods used for calculations of minor source emissions comply with EPA criteria. The minor sources are evaluated on a 1- to 5-year basis. Major and minor emissions are compiled annually to determine the overall ORNL source term and associated dose.

The charcoal cartridges and canisters, particulate filters, and silica gel traps are collected weekly to biweekly. The use of charcoal cartridges (or canisters) is a standard method for capturing and quantifying radioactive iodine in airborne emissions. Gamma spectrometric analysis of the charcoal samples quantifies the adsorbable gases. Analyses are performed weekly to biweekly. Particulate filters are held for 8 days before a weekly gross alpha and gross beta analysis to minimize the contribution from short-lived isotopes such as ^{220}Rn and its daughter products. At stack 7911, a weekly gamma scan is conducted to better detect short-lived gamma isotopes. The filters are composited quarterly or semiannually and are analyzed for alpha-, beta-, and gamma-emitting isotopes. At stack 7880, the filters are collected monthly and analyzed for alpha-, beta-, and gamma-emitting isotopes. The sampling system on stack 7880 requires no other type of radionuclide collection media. Monthly sampling provides a better opportunity for quantification of the low-concentration isotopes. Silica gel traps are used to capture water vapor that may contain ^{3}H. Analysis is performed weekly to biweekly. At the end of the year, the sample probes for all the stacks are rinsed, except for the 8915 and 7880 probes, and the rinsate is collected and submitted for isotopic analysis identical to that performed on the particulate filters. A probe-cleaning program has been determined unnecessary for 8915 because the sample probe is a scintillator probe used to detect radiation and not to extract a sample of stack exhaust emissions. Contaminant deposits are not expected to collect on the scintillator probe. A probe-cleaning program for 7880 has established that rinse analysis historically showed no detectable contamination. Therefore, the frequency of probe rinse collection and analysis is not more often than every 3 years unless particulate emissions increase, detectable radionuclides in the sample media increase, or process modifications occur.

The data from the charcoal cartridges or canisters, silica gel, probe wash, and filter composites are compiled to give the annual emissions for each major source and some minor sources.

5.4.3.2. Results

Annual radioactive airborne emissions for ORNL in 2022 are presented in Appendix G.

Historical trends for ^{3}H and ^{131}I are presented in Figures 5.8 and 5.9. For 2022, ^{3}H emissions totaled about 1,241 Ci (Figure 5.8), comparable to what was seen in 2021; ^{131}I emissions totaled 0.07 Ci (Figure 5.9), comparable to what was seen in 2021. For 2022, of the 358 radionuclides (excluding radionuclides with multiple solubility type) released from ORNL operations and evaluated, the isotopes that contributed 10 percent or more to the off-site dose from ORNL included ^{212}Pb, which contributed about 42 percent; ^{11}C, which contributed about 21 percent; and ^{138}Cs, which also contributed about 21 percent to the total ORNL dose.

Emissions of ^{212}Pb result from research activities and from the radiation decay of legacy material stored on-site and areas containing ^{228}Th, ^{232}Th, and ^{232}U. Emissions of ^{212}Pb were from the following stacks: 2026, 3020, 3039, 4501, 7503, 7856, 7911, and the 4000 area laboratory hoods. Emmissions of ^{11}C originate from SNS operations and are emitted from stack 8915. Emissions of ^{138}Cs result from Radiochemical Engineering Development Center research activities and HFIR operations. For 2022, ^{212}Pb emissions totaled 8.34 Ci, ^{138}Cs emissions totaled 1,110 Ci, and ^{41}Ar emissions totaled 498 Ci (Figure 5.10).

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2022 was 0.2 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 41 percent of the ORR dose. This dose is well below the Rad-NESHAPs standard of 10 mrem and is equal to approximately 0.07 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. (See Section 7.1.2 for an explanation of how the airborne radionuclide dose was determined.)

5.4.4. Stratospheric Ozone Protection and Hydrofluorocarbon Phasedown

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances during maintenance activities performed on refrigeration equipment. In 2017, EPA enacted major revisions to the stratospheric ozone rules to include the regulation of substitutes for ozone-depleting substances as part of 40 CFR 82 Subpart F. The revisions became effective January 1, 2018, for the disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. Necessary changes to the Stratospheric Ozone Protection compliance program were implemented to comply with the requirements of the new rule. Service requirements for refrigeration systems (including motor vehicle air conditioners), technician certification requirements, record keeping requirements, and labeling requirements were implemented in accordance with 40 CFR 82 Subpart F. On October 1, 2021, EPA began implementing the hydrofluorocarbons phasedown requirements of the American Innovation and Manufacturing (AIM) Act of 2020, which seeks to reduce hydrofluorocarbon consumption and production to 15 percent of a 2011–2013 baseline by 2036. (*Final Rule—Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act* [EPA 2022a] is available **here**.) Sitewide use of hydrofluorocarbons is being evaluated to understand future effects of AIM Act phasedowns.

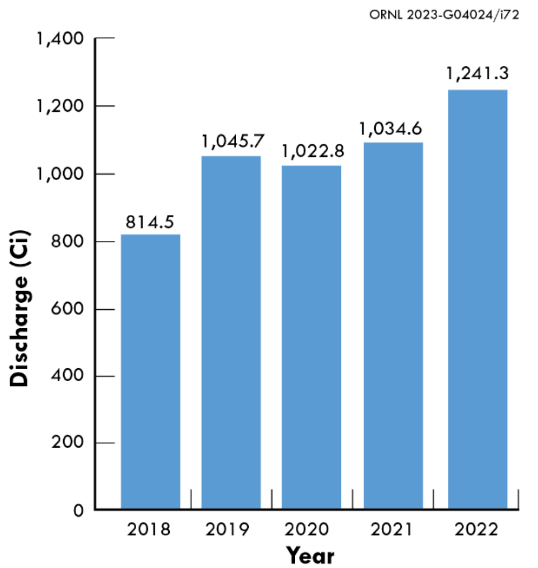


Figure 5.8. Total curies of ^{3}H discharged from ORNL to the atmosphere, 2018–2022

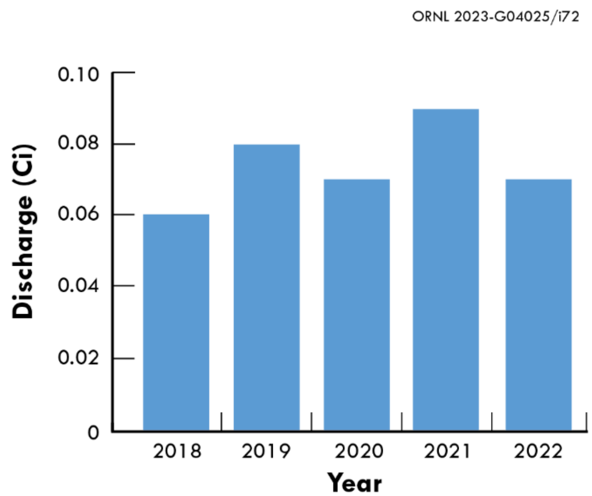


Figure 5.9. Total curies of ^{131}I discharged from ORNL to the atmosphere, 2018–2022

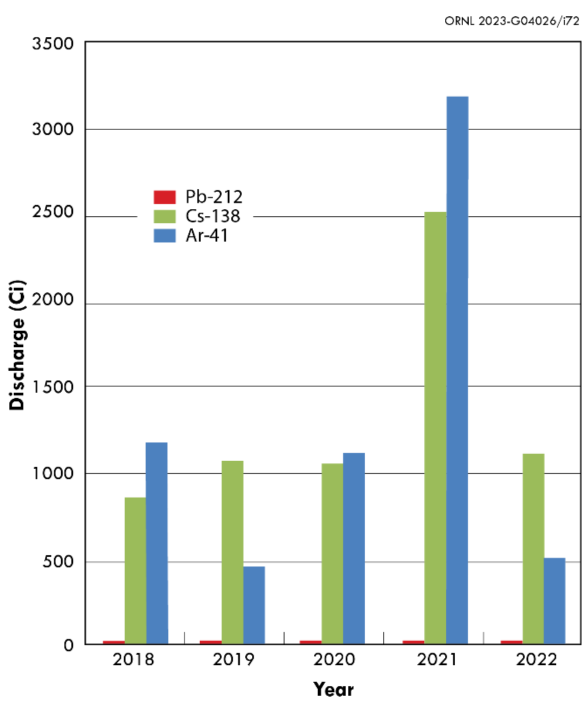


Figure 5.10. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from ORNL to the atmosphere, 2018–2022

5.4.5. Ambient Air

Station 7 in the ORNL 7000 maintenance area is the site-specific ambient air monitoring location. During 2022, the sampling system at Station 7 was used to quantify levels of ^{3}H; uranium; and gross alpha-, beta-, and gamma-emitting radionuclides. A low-volume air sampler was used for particulate collection. The 47 mm glass fiber filters were collected biweekly and were composited annually for laboratory analysis. A silica gel column was used for collection of ^{3}H as tritiated water. The silica gel was collected biweekly or weekly, depending on ambient humidity, and was composited quarterly for ^{3}H analysis. Station 7 sampling data (Table 5.9) were compared with the derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2021a). During 2022, average radionuclide concentrations at Station 7 were less than 1 percent of the applicable DCSs in all cases.

Table 5.9. Radionuclide concentrations measured at ORNL air monitoring Station 7, 2022

Parameter	Concentration (pCi/mL)[a]
Alpha	3.3×10^{-9}
^{7}Be	2.8×10^{-8}
Beta	1.9×10^{-8}
^{40}K	0
^{3}H	4.6×10^{-6}
^{234}U	3.2×10^{-11}
^{235}U	0
^{238}U	2.9×10^{-11}

[a] *1 pCi = 3.7×10^{-2} Bq.*

5.5. ORNL Water Quality Program

NPDES Permit TN0002941—issued to DOE for the ORNL site, reissued by the State of Tennessee in 2019, and modified in 2022—includes requirements for discharging wastewaters from the two ORNL on-site wastewater treatment facilities and from more than 150 category outfalls (outfalls with nonprocess wastewaters such as cooling water, condensate, groundwater, and storm water), and for developing and implementing a water quality protection plan (WQPP). The permit calls for a WQPP to "efficiently utilize the facility's financial resources to measure its environmental impacts." Rather than prescribing rigid monitoring schedules, the ORNL WQPP is flexible and focuses on significant findings. It is implemented using an adaptive management approach, whereby results of investigations are routinely evaluated and strategies for achieving goals are modified based on those evaluations. The goals of the WQPP are to meet the requirements of the NPDES permit, improve the quality of aquatic resources on the ORNL site, prevent further impacts to aquatic resources from current activities, identify the stressors that contribute to impairment of aquatic resources, use available resources efficiently, and communicate outcomes with decision-makers and stakeholders.

The ORNL WQPP was developed by DOE and was approved by TDEC in 2008, and the WQPP monitoring was initiated in 2009. Revisions to the WQPP are submitted to TDEC for review and comment. The WQPP incorporated several control plans that were required under the previous NPDES permit, including a biological monitoring and abatement plan, a chlorine control strategy, a storm water pollution prevention plan, a non–storm water best management practices plan, and an NPDES radiological monitoring plan.

To prioritize the stressors and contaminant sources that may be of greatest concern to water quality and to define conceptual models to guide any special investigations, the WQPP strategy was defined using EPA's *Stressor Identification Guidance Document* (EPA 2000a). The process involves three major steps for identifying the cause of any impairment:

1. List candidate causes of impairment (based on historical data and a working conceptual model).
2. Analyze the evidence (using both case study and outside data).
3. Characterize the causes.

Special investigations were designed to identify specific source areas and to revise the conceptual model of the major causes of contamination in the WOC watershed.

Monitoring and investigation data collected under the ORNL WQPP are analyzed, interpreted, reported, and compared with past results at least annually. The significant findings are reported in the *Annual Site Environmental Report*, and a more comprehensive report of findings is submitted to TDEC on an annual basis. This information is used to assess the status of ORNL's receiving-stream watersheds and the impact of ongoing efforts to protect and restore those watersheds and will guide efforts to improve the water quality in the watershed.

5.5.1. Treatment Facility Discharges

The ORNL STP and the ORNL PWTC appropriately treat the various R&D, operational, and domestic wastewaters generated by site staff and activities. Both are permitted to discharge treated wastewater and are monitored under NPDES Permit TN0002941, issued by TDEC to DOE for the ORNL site. The ORNL NPDES permit requirements include monitoring the two ORNL wastewater treatment facility effluents for conventional, water quality–based, and radiological constituents and for effluent toxicity, with numeric parameter-specific compliance limits established by TDEC as determined to be necessary. The results of field measurements and laboratory analyses to assess compliance for the parameters required by the NPDES permit and rates of compliance with numeric limits established in the permit are provided in Section 5.3.3. (Table 5.5). Compliance with permit limits for ORNL wastewater treatment facilities was 100 percent in 2022.

Toxicity testing provides an assessment of any potential harmful effects from the total combined constituents in discharges from ORNL wastewater treatment facilities. The NPDES permit has required testing of effluents from the STP for toxicity to aquatic species since 1986, and effluents from PWTC have been tested since it went into operation in 1990. Test species have been *Ceriodaphnia dubia*, an aquatic invertebrate, and fathead minnow (*Pimephales promelas*) larvae. Tests have been conducted using EPA chronic or acute test protocols at frequencies ranging from one to four times per year. The STP and PWTC have shown isolated indications of effluent toxicity, but confirmatory tests conducted as required by the permit have shown that either the result of the routine test was an anomaly or that the condition of toxicity that existed at the time of the routine test was temporary and of short duration.

Toxicity test requirements under the current NPDES permit include annual testing for chronic toxicity from the ORNL STP and PWTC. Both test species are tested on a series of four aliquots of effluent, collected at 6 h intervals over a 24 h period. An “inhibition concentration” of 25 percent was used in the testing.

5.5.2. Residual Bromine and Chlorine Monitoring

ORNL receives potable water from the City of Oak Ridge Department of Public Works, which uses chlorine as a final disinfectant. On the ORNL site, potable water is used for drinking, sanitary, and housekeeping purposes as well as for research processes and in cooling systems. After the water is used, residual chlorine remains and can be toxic to fish and other aquatic life if discharged to surface water. Residual chlorine in wastewater routed to the STP is generally consumed in reactions with other substances within the collection and treatment system, and any residual chlorine in wastewater routed to the PWTC is removed by final activated carbon filtration. Air-conditioning systems that used once-through cooling water and discharged to storm outfalls have been replaced (except for one) with air-cooled systems that discharge only condensate to the ground or a storm drain. Newer buildings and complexes have been constructed to use cooling towers for air-conditioning and dehumidifying and to remove heat from instrumentation and computer systems. Two main campus outfalls (211 and 210) still receive research-generated, once-through cooling water, but flows have been reduced by water-recycling efforts.

Leaks or discharge from any of these systems to storm drains are dechlorinated and monitored via the WQPP Chlorine Control Strategy. DOE’s NPDES permit for ORNL establishes an action level of 1.2 g/day for total residual oxidant (TRO) loading at all outfalls. If that level is exceeded, ORNL is required to investigate and remove TRO sources to reduce chlorine/bromine loading to less than 1.2 g/day.

In 2022, TRO was monitored twice a month at outfalls that receive cooling tower discharges and once-through cooling water. Less frequent monitoring was conducted at other outfalls (semimonthly, monthly, quarterly, or semiannually if flow was present). A total of 357 TRO measurements were taken at 21 outfall locations, in addition to 288 semimonthly instream measurements. TRO was detected at or above the end-of-pipe action level on 19 occasions during 2022 but was never detected at any of the 12 instream monitoring points (Table 5.10).

Table 5.10. Overview of 2022 chlorine control strategy

Total residual oxidant sampling events	644
Below detection (<0.05 mg/L)	570
Instream total residual oxidant exceedances	0
Outfall detections	23
Outfall action level detections (>1.2 g/day)	19
Number of outfalls with action level detections	7

5.5.2.1. Monitoring Results and Corrective Actions

Activities in response to TRO monitoring included emergency repairs, source investigation and elimination, and dechlorination system adjustments. Outfalls 211 and 210 are the only outfalls that still receive once-through cooling water discharges. Outfall 211 receives cooling water from multiple small sources. Two dechlorinator boxes are mounted in a weir located at the point where the outfall discharges to WOC. Each box is designed to treat chlorinated discharges at flow rates up to 50 gpm. Flows ranged from 30 to 65 gpm above the dechlorinator; TRO levels above the dechlorinator ranged from 0.3 to 1.5 mg/L. No TRO exceedances occurred downstream of the outfall 211 dechlorinators in 2022. A liquid sodium bisulfite dechlorinator, located inside Building 4508, is used to treat discharges from outfall 210. The dechlorinator treats cooling water from instrumentation that cannot use the recycled cooling water system. In 2022, TRO was dectected at the outfall on several occasions because of a liquid feed pump failure. This source was dechlorinated with tablets until the pump could be repaired.

Outfall 231 receives cooling tower blowdown from the Oak Ridge Leadership Computing Facility towers. In previous years, TRO exceedances have occurred at outfall 231 from irrigation water line leaks and other sources unrelated to cooling tower discharges. In 2022, TRO was detected again from an unknown source, at a flowrate lower than normal cooling tower discharge. Dechlorination tablets will continue to be placed at the outfall while source investigation continues. In August 2022, a system failure at the cooling towers resulted in blowdown with residual oxidant discharging to outfall 231. Staff were promptly notified, and the source was repaired. Environmental compliance and aquatic ecology staff inspected the outfall and creek for impacts from the discharge. No significant aquatic life impacts were observed. This outfall will continue to be monitored under the Chlorine Control Strategy.

A summary of 2022 TRO monitoring detections greater than 1.2 g/day are listed in Table 5.11, along with any additional investigation actions or repairs.

Table 5.11. Total residual oxidant mitigation summary: emergency repairs, 2022

Outfall	Date	TRO (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream water kilometer	Instream monitoring point	Notes
210	3/3/2022	0.6	3	9.81	WOC	WCK 4.1	X18	Once-through cooling dechlorination pump failure. Source dechlorinated with tablets until pump could be replaced.
210	3/22/2022	0.4	15	32.71	WOC	WCK 4.1	X18	
210	4/25/2022	0.4	2	4.36	WOC	WCK 4.1	X18	
210	5/20/2022	0.3	2	3.27	WOC	WCK 4.1	X18	
210	5/31/2022	0.6	2	6.54	WOC	WCK 4.1	X18	
210	6/17/2022	0.4	1	2.18	WOC	WCK 4.1	X18	
210	6/21/2022	0.3	1	1.64	WOC	WCK 4.1	X18	
210	8/26/2022	2	8	87.22	WOC	WCK 4.1	X18	
210	10/28/2022	0.4	8	17.44	WOC	WCK 4.1	X18	
231	5/20/2022	0.4	8	17.44	WOC	WCK 4.4	X25	Dechlorination tabs placed in bucket at outfall. Source unknown.
231	7/25/2022	0.3	40	65.41	WOC	WCK 4.4	X25	
231	8/26/2022	3	65	1062.94	WOC	WCK 4.4	X25	Cooling tower dechlorination system failure. No stream or fish impacts observed.
231	8/29/2022	0.7	40	152.63	WOC	WCK 4.4	X25	
231	12/13/2022	0.1	25	13.63	WOC	WCK 4.4	X25	
267	12/19/2022	0.2	20	21.80	Fifth Creek	FFK 0.1	X20	Construction activities in the drainage area, but no source identified.
281	7/25/2022	0.2	60	65.41	MB	MEK 0.6	X27	Cooling tower dechlorination functioning properly; may be another source contributing.
282	9/29/2022	0.1	8	4.36	MB Tributary	MEK 0.6	X13	Possible potable water line leak
314	12/19/2022	0.2	25	27.25	WOC	WCK 4.4	X26	Foundation sump pumping what was thought to be just groundwater. Sample showed TRO in sump water. Hose moved to grass, and tablets placed around storm drains.
585	8/29/2022	0.4	1	2.18	MB Tributary	MEK 0.6	X27	Reverse osmosis reject water is the only known source. Monitoring and investigation will continue.

Acronyms:
FFK = Fifth Creek kilometer
MB = Melton Branch
MEK = Melton Branch kilometer
TRO = total residual oxidant
WCK = White Oak Creek kilometer
WOC = White Oak Creek

5.5.2.2. Cooling Tower Discharge Outfalls

Chlorine- and bromine-based chemicals are added to supply water to control bacterial growth. Residuals of chlorine and bromine remain in the water in cooling towers if they do not evaporate or are not consumed by bacterial growth. As the cooling towers lose water by evaporation, higher conductivity caused by an increase in the concentration of minerals triggers a blowdown, resulting in a discharge that may contain chlorine and bromine residuals. The discharge must be treated to reduce residual oxidants to less than 0.05 mg/L TRO. A combination of sodium sulfite tablet feeders and/or additions of liquid sodium bisulfite solution have historically been used to neutralize TRO in cooling tower discharges at ORNL.

In some cases, pretreatment enhances the effectiveness of the primary dechlorination tablet feeders. Potassium sulfite is used as a pretreatment in one location and is proposed for use at new cooling towers. Inspections of tablet feeders are conducted multiple times a week to ensure that sodium sulfite tablets are refilled, in good condition, and that any fouled tablets are removed for disposal.

Outfall 014 discharges only cooling tower blowdown from towers 4510 and 4521. To better identify the sources of TRO detections, these towers are now monitored separately, prior to their confluence at outfall 014. In 2021, liquid potassium sulfite pretreatment was added to both tower discharges to improve dechlorination. There have been no action level detections since pretreatment installation.

Outfall 227 receives large blowdown flows from multiple cooling towers in Buildings 5600 and 5511. There were no TRO exceedances in 2022. Primary dechlorination occurs in Building 5600, and a secondary dechlorination box located at WOC is used as a backup. Combined use of two dechlorination boxes enables approximately 4 mg/L TRO to be removed before cooling tower discharges enter the creek. To better understand dechlorination needs, TRO is monitored above and below secondary dechlorination. Without secondary treatment, TRO discharges could have exceeded 1.2 g/day at the outfall on three instances in 2022.

Outfall 363 also receives discharges from multiple cooling towers. Data show that residual oxidants remain in discharges after primary dechlorination at the tower or building sources. Since 2017, sodium sulfite tablet bags have been placed below the outfall 363 pipe as secondary dechlorination. Monitoring efforts upstream and downstream of secondary treatment in 2022 identified six instances when primary dechlorination would have been insufficient.

SNS cooling tower discharges are monitored to verify that dechlorination is adequate prior to merging with a larger wet-weather channel above the west SNS storm water retention basin and outfall 435. Outfall 435, which discharges to WOC several hundred feet downstream, is not monitored for TRO because it would not be expected after dechlorination at the towers and dilution from the retention pond. Monitoring efforts resulted in 11 detections in the SNS discharge upstream of the retention basin.

5.5.3. Radiological Monitoring

At ORNL, monitoring of liquid effluents and selected instream locations for radioactivity is conducted under the WQPP. Table 5.12(a) details the analyses performed on samples collected from January through June 2022 at two treatment facility outfalls, three instream monitoring locations, and 20 category outfalls (outfalls that are categorized into groups with similar effluent characteristics for the purposes of setting monitoring and reporting requirements in the site NPDES permit). An assessment of historical data using 2021 DCS values resulted in the establishment of new frequencies for radiological monitoring which were effective in July-December 2022 and in discontinuing monitoring at category outfalls 204, 205, 241, and 265. Table 5.12(b) details the analyses performed on samples collected from July through December 2022. Dry-weather discharges from category outfalls are primarily cooling water, groundwater, and condensate. Low levels of radioactivity can be discharged from category outfalls in areas where groundwater contamination exists and where contaminated groundwater enters category outfall collection systems by direct infiltration and from building sumps, facility sumps, and building footer drains. In 2022, dry-weather grab samples were collected at 18 of the 20 category outfalls targeted for sampling. Eight category outfalls were not sampled because no discharge was present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2022 were the STP outfall (outfall X01) and the PWTC outfall (outfall X12). The three instream locations that were monitored were X13 on Melton Branch, X14 on WOC, and X15 at White Oak Dam (WOD) (Figure 5.11). At each treatment facility outfall and instream monitoring location, monthly flow-proportional composite samples were collected using dedicated automatic water samplers.

A DCS for each radioisotope is used to evaluate discharges of radioactivity from DOE facilities (DOE 2021a). DCSs were developed for evaluating effluent discharges and are not intended to be applied to instream values, but the comparisons can provide a useful frame of reference. Four percent of the DCS is used as a comparison point. Although comparisons are made, neither ORNL effluents nor ambient surface waters are direct sources of drinking water. The annual average concentration of at least one radionuclide exceeded 4 percent of the relevant DCS concentration in dry-weather discharges from outfalls 081, 085, 207, 302, 304, and X12 (Figure 5.12). In 2022, no dry-weather discharges from sampled outfalls had an annual mean radioactivity concentration greater than 100 percent of a DCS.

The total annual discharges (or amounts) of radioactivity measured in stream water at WOD, the final monitoring point on WOC before the stream flow leaves ORNL, were calculated from concentration and flow. Results of those calculations for each of the past 5 years are shown in Figures 5.13 through 5.17. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Figure 5.18. Discharges of radioactivity at WOD in 2022 were similar to discharges during other recent years, particularly when differences in annual flow volume are taken into account, and continue to be generally lower than in the years preceding completion of the waste area caps in Melton Valley (substantially complete by 2006).

Radiological monitoring at category outfalls in 2022 also included monitoring during storm runoff conditions. Eight storm water outfalls were monitored. Storm water samples were analyzed for gross alpha, gross beta, ^{137}Cs, $^{89/90}$Sr, and ^{3}H activities. A gamma scan analysis was also performed. The monitoring plan calls for additional analyses to be added when sufficient gross alpha or beta activity is present in a sample to indicate that levels of radioactivity may exceed DCS levels and if the radionuclides contributing to the gross activities are not identified by routine analyses. In 2022, no samples from the outfalls sampled required additional analyses.

Concentrations of radioactivity in storm water discharges were compared with DCSs if a DCS existed for that parameter (no DCSs exist for gross alpha or gross beta activities) and if a concentration was greater than or equal to the minimum detectable activity for the measurement. In 2022, the radionuclide $^{89/90}$Sr exceeded 4 percent of the relevant DCS concentration in wet-weather discharges from outfalls 207, 301 and 304 (Figure 5.12).

Table 5.12(a). Radiological monitoring conducted under the ORNL Water Quality Protection Plan, January–June 2022

Location	Frequency	Gross alpha/beta	Gamma scan	^{3}H	^{14}C	$^{89/90}$Sr	Isotopic uranium	Isotopic plutonium	^{241}Am	$^{243/244}$Cm
Outfall 001	Annual	X								
Outfall 080[a]	Monthly									
Outfall 081	Annual	X								
Outfall 085[a]	Quarterly									
Outfall 203	Annual	X	X			X				
Outfall 204[a]	Semiannual									
Outfall 205[a]	Annual									
Outfall 207	Quarterly	X								
Outfall 211	Annual	X								
Outfall 234[a]	Annual									
Outfall 241[a]	Quarterly									
Outfall 265[a]	Annual									
Outfall 281	Quarterly	X		X						
Outfall 282	Quarterly	X								
Outfall 302	Monthly	X	X	X		X	X[b]	X[b]	X[b]	X[b]
Outfall 304	Monthly	X	X	X		X	X[b]	X[b]	X[b]	X[b]
Outfall 365	Semiannual	X								
Outfall 368[a]	Annual									
Outfall 383	Annual	X		X						
Outfall 484	Annual	X								
STP (X01)	Monthly	X	X	X	X	X				
PWTC (X12)	Monthly	X	X	X		X	X			
Melton Branch (X13)	Monthly	X	X	X		X				
WOC (X14)	Monthly	X	X	X		X				
WOD (X15)	Monthly	X	X	X		X				

[a] The outfall was included in the monitoring plan, but samples were not collected because no discharge was present during sampling attempts.

[b] The Water Quality Protection Plan does not require this parameter for this location, and therefore it may have been monitored on a frequency less than indicated in the table. Additional analyses are sometimes performed on samples, the most common reason being that gross alpha and gross beta activities exceeded a screening criterion (as described in the February 2020 update to the Water Quality Protection Plan).

Acronyms:

STP = Sewage Treatment Plant
PWTC = Process Waste Treatment Complex
WOC = White Oak Creek
WOD = White Oak Dam

Table 5.12(b). Radiological monitoring conducted under the ORNL Water Quality Protection Plan, July–December 2022

Location	Frequency	Gross alpha/beta	Gamma scan	^{3}H	^{14}C	$^{89/90}Sr$	Isotopic uranium	Isotopic plutonium	^{241}Am	$^{243/244}Cm$
Outfall 001[a]	Annual									
Outfall 080[a]	Annual									
Outfall 081	Annual	X		X						
Outfall 085	Monthly	X	X			X				
Outfall 203[a]	Annual									
Outfall 207	Monthly	X	X			X				
Outfall 211	Annual	X	X			X				
Outfall 234[a]	Annual									
Outfall 281[a]	Annual									
Outfall 282[a]	Annual									
Outfall 302	Monthly	X	X	X		X	X[b]	X[b]	X[b]	X[b]
Outfall 304	Monthly	X	X	X		X	X[b]	X[b]	X[b]	X[b]
Outfall 365[a]	Annual									
Outfall 368[a]	Annual									
Outfall 383[a]	Annual									
Outfall 484[a]	Annual									
STP (X01)	Monthly	X	X	X	X	X				
PWTC (X12)	Monthly	X	X	X		X	X			
Melton Branch (X13)	Monthly	X	X	X		X				
WOC (X14)	Monthly	X	X	X		X				
WOD (X15)	Monthly	X	X	X		X				

[a] The outfall was included in the monitoring plan, but samples were not collected because no discharge was present during sampling attempts.

[b] The Water Quality Protection Plan does not require this parameter for this location, and therefore it may have been monitored on a frequency less than indicated in the table. Additional analyses are sometimes performed on samples, the most common reason being that gross alpha and gross beta activities exceeded a screening criterion (as described in the February 2020 update to the Water Quality Protection Plan).

Acronyms:

STP = Sewage Treatment Plant
PWTC = Process Waste Treatment Complex
WOC = White Oak Creek
WOD = White Oak Dam

ORNL 2021-G00642/mhr
March 2021-EPSDM005.tf9

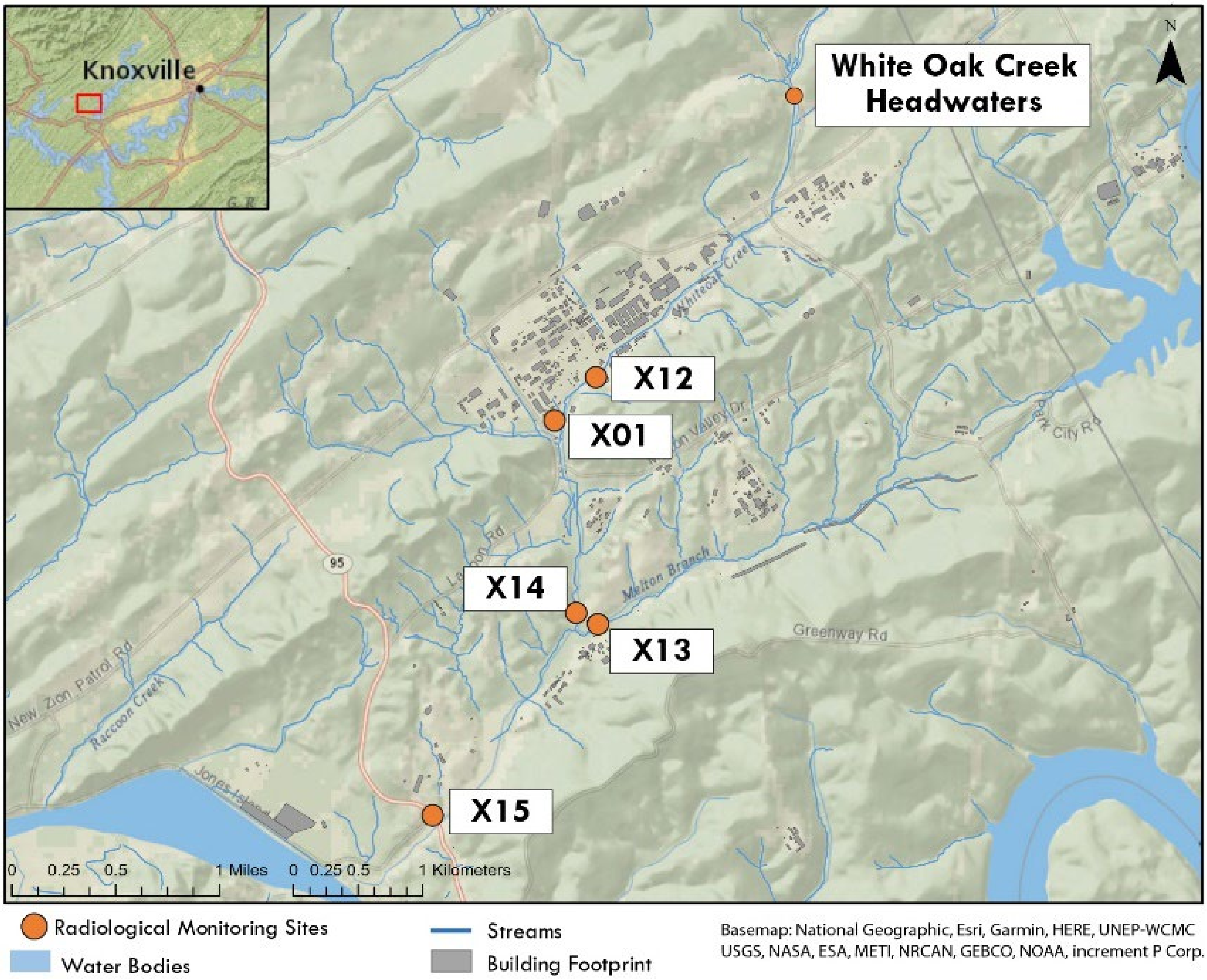


Figure 5.11. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at ORNL

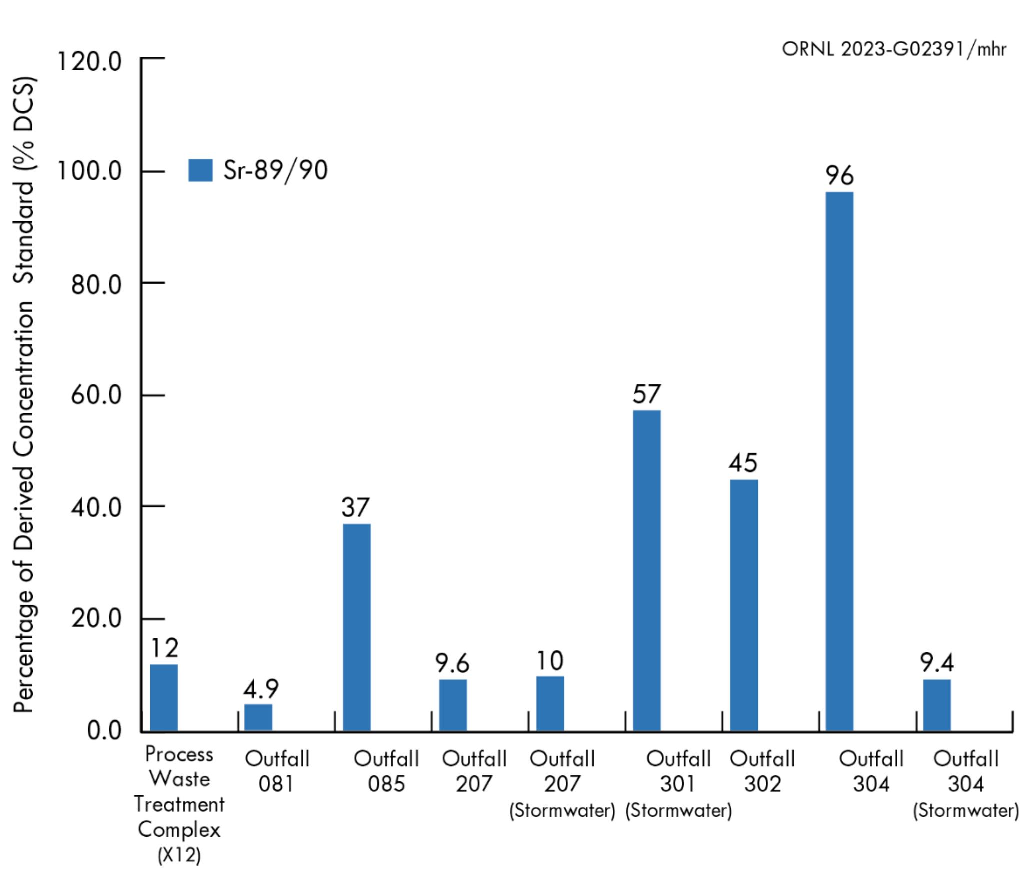


Figure 5.12. Outfalls and instream locations, including storm water outfalls at ORNL with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2022

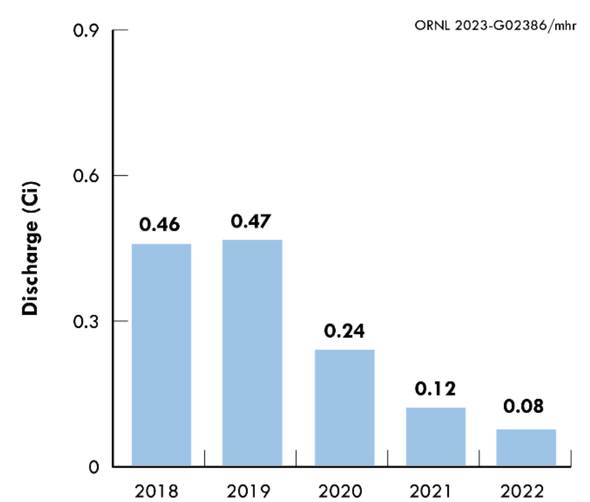


Figure 5.13. Cesium-137 discharges at White Oak Dam, 2018–2022

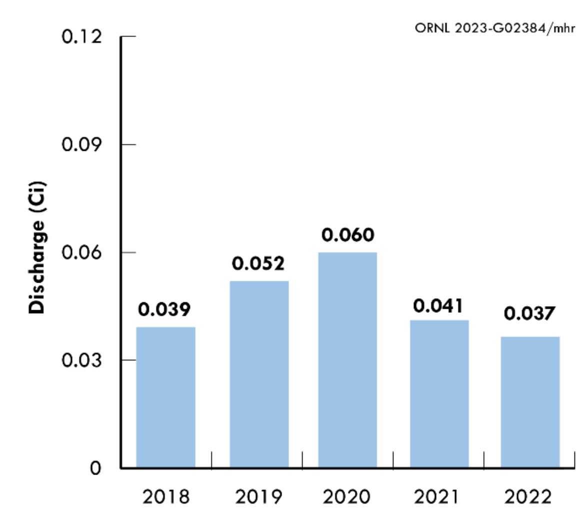


Figure 5.14. Gross alpha discharges at White Oak Dam, 2018–2022

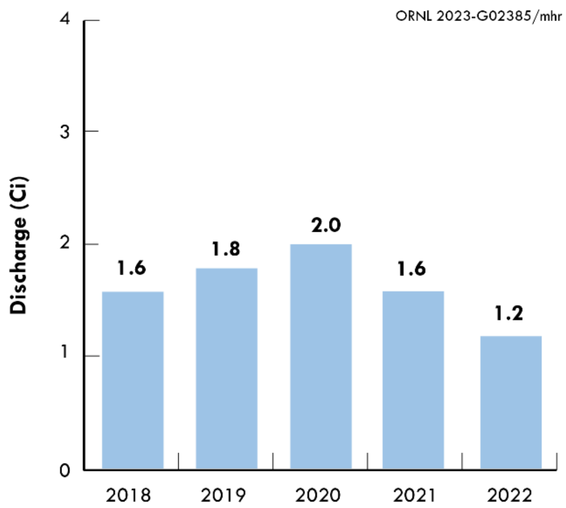


Figure 5.15. Gross beta discharges at White Oak Dam, 2018–2022

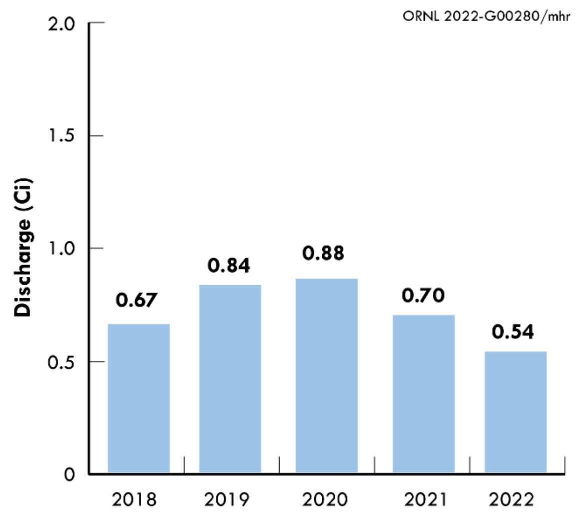


Figure 5.16. Total radioactive strontium discharges at White Oak Dam, 2018–2022

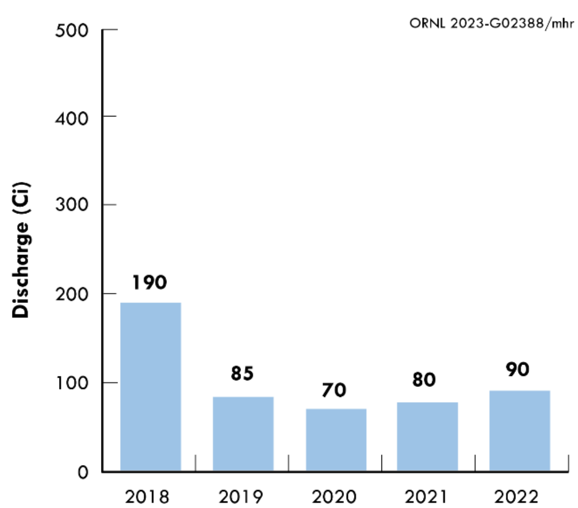


Figure 5.17. Tritium discharges at White Oak Dam, 2018–2022

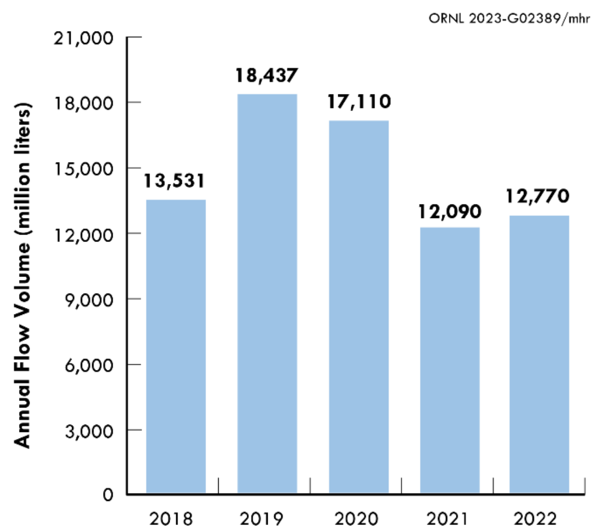


Figure 5.18. Annual flow volume at White Oak Dam 2018–2022

5.5.4. Mercury in the White Oak Creek Watershed

During the mid-1950s, mercury (Hg) was used for pilot-scale isotope separation work in Buildings 4501, 4505, and 3592 and in spent-fuel reprocessing in Building 3503. By 1963, this work was transferred to Y-12.

Buildings 4501 and 4505 are active research facilities located east of Fifth Creek and north of WOC. In 1996, the Building 4501 foundation sump was found to contain legacy Hg because of its volatility and from its use and spills in the 1950s. The foundation sump discharged to storm outfall 211 (Figure 5.19) on WOC; a smaller foundation sump in the building discharged to outfall 263 on

Fifth Creek. By 2011, an Hg pretreatment system had been installed on the larger sump. Discharge from the foundation sumps in Buildings 4501 and 4500N and from the smaller sump in Building 4501 had also been rerouted along with the smaller sump and a 4500N foundation sump to the PWTC. Outfall 211 and outfall 363 storm piping still receives other sources of storm water, cooling water, and steam condensate discharges. Because of the persistence of elemental Hg, its volatility, and the complexity of its interactions in piping and soil, Hg continues to be monitored and assessed at these storm outfalls.

Buildings 3592 and 3503 were demolished under the CERCLA remedial process in 2011 and 2012, respectively; their footprints and associated storm water drains remain in the outfall 207 storm water drainage system.

Mercury associated with process infrastructure has also been found in other areas, such as north of the Fifth Street and Central Avenue intersection and in the outfall 304 drainage area. Storm water exchange with process leaks or overflows has occurred under certain situations.

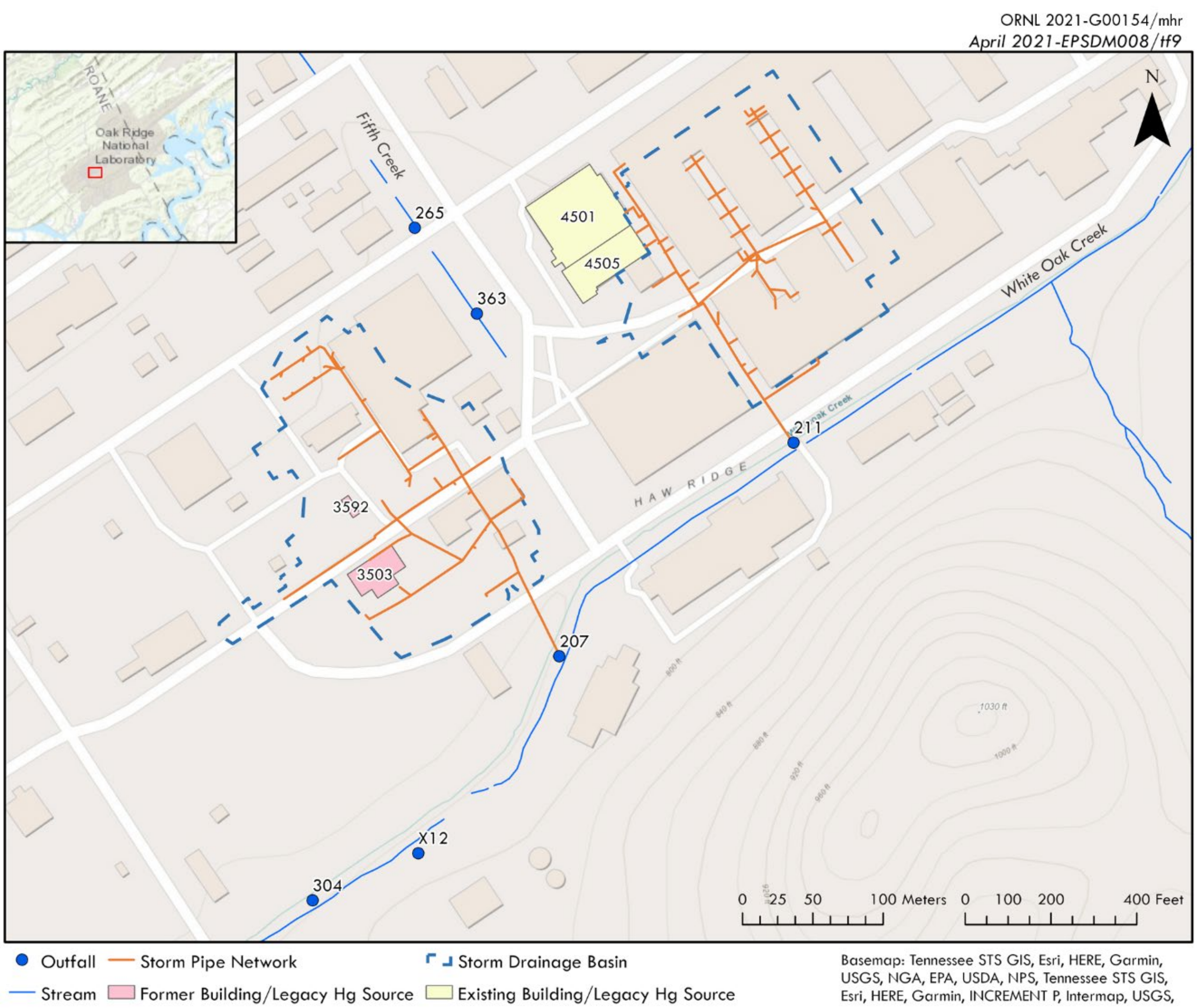


Figure 5.19. Outfalls 211 and 207 and associated storm drain connections that are potential mercury sources

5.5.4.1. Mercury in Ambient Water

Aqueous Hg monitoring in WOC was initiated in 1997 and continued in 2022 with quarterly sampling at four instream sites: White Oak Creek kilometer (WCK) 1.5, WCK 3.4, WCK 4.1, and WCK 6.8 (Figure 5.20). Samples were collected to be representative of seasonal base flow conditions (dry weather, clear flow). Historical sampling results show that Hg concentrations are typically higher under those conditions.

In 2022, the average concentration of Hg in WOC upstream from ORNL (WCK 6.8) was less than 3 ng/L, with the highest value there being 6.4 ng/L. Waterborne Hg concentrations in WOC downstream of ORNL (Figure 5.21) had been above Tennessee water quality criteria (WQC) from 1997 to 2007, but declined abruptly in 2008 following corrective actions. Concentrations remained low through 2022 as a result of actions to lessen Hg discharges to WOC at outfall 211 (sump reroutes to PWTC) and to reduce Hg discharges from PWTC. In general, ambient concentrations have remained low since 2008, with a few exceptions. In 2022, Hg concentrations were well below WQC at all the instream sites that were monitored. The average aqueous Hg concentration at WOD (WCK 1.5) was 16.33 ng/L compared with 25.73 ng/L in 2021, except for an abnormally high outlier value (810 ng/L) in a composite sample retrieved on November 9, 2022, which is currently under investigation. The sample was normal in appearance when it was retrieved from the composite sampling system. No maintenance or construction activities were occuring in the vicinity of WOD around November 9, and no unusual circumstances were noted during sample collection or analysis. A possible explanation is that sediment from the lake bottom just upstream of WOD was disturbed and mobilized by the natural activities of fish such as carp or animals that inhabit this area such as beavers and muskrats. Mercury-bearing particulate could have been entrained in the 24 h composite sample with the unusually high Hg concentration.

ORNL 2021-G00155/mhr
2021-EPSDM007.tf9

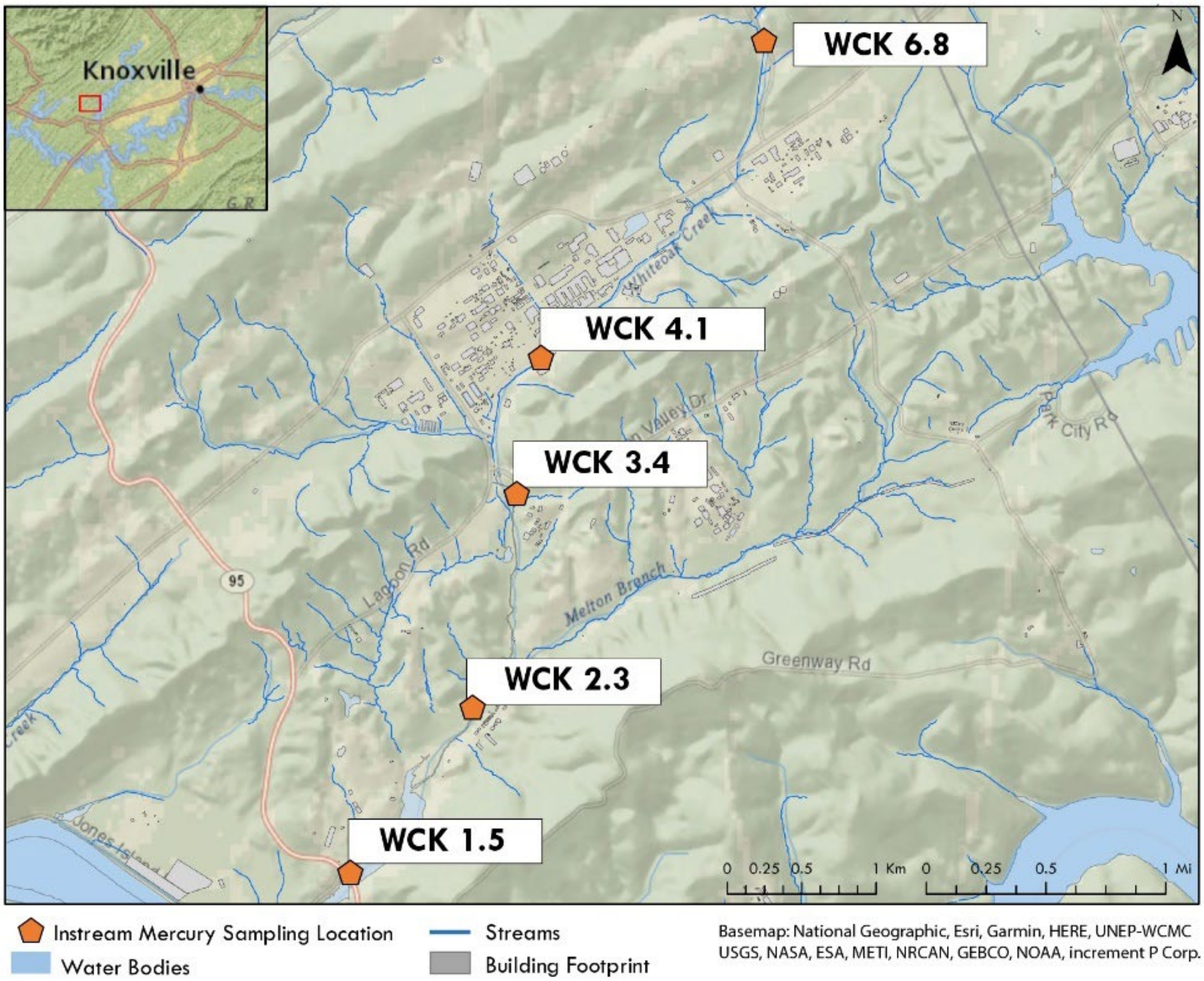
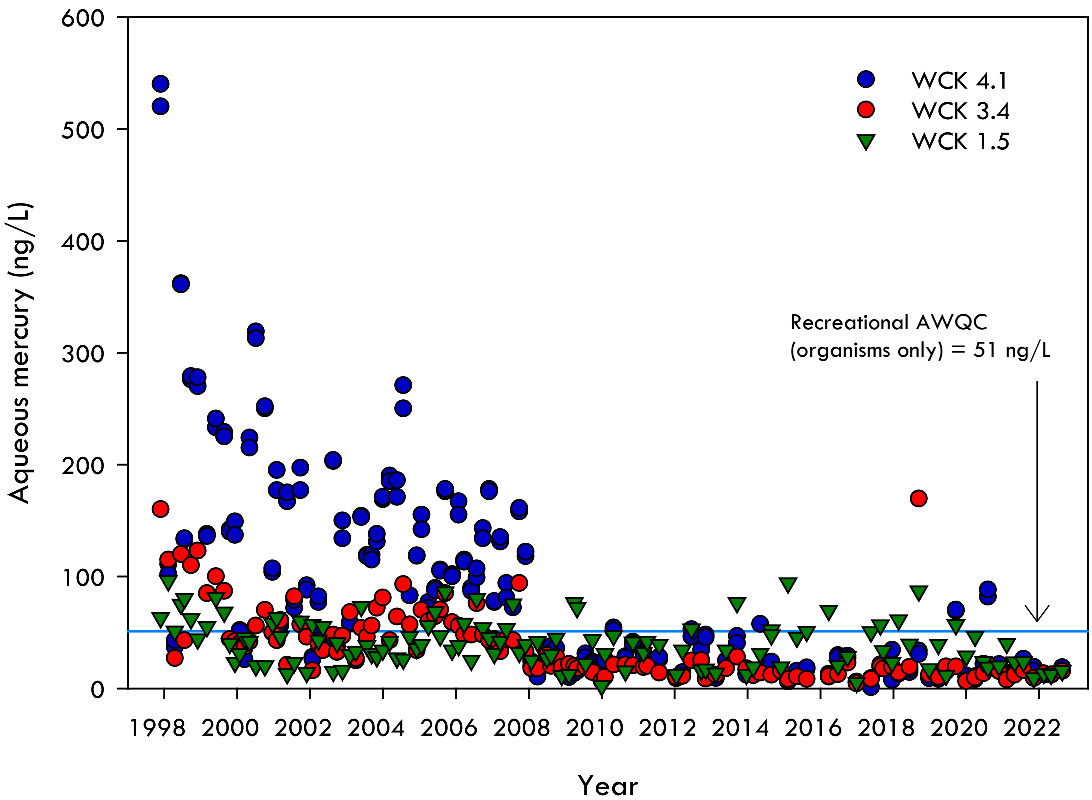


Figure 5.20. Instream mercury monitoring and data locations, 2022



Note: *The blue line at 51 ng/L shows the Recreational Water Quality Criteria for Water and Organisms.*
Acronym: *WCK = White Oak Creek kilometer, AWQC = ambient water quality criterion*

Figure 5.21. Aqueous mercury concentrations of grab samples at sites in White Oak Creek downstream from ORNL, 1998–2022

5.5.4.2. Water Quality Protection Plan Mercury Investigation

Outfalls X01 (STP) and X12 (PWTC) are monitored for Hg quarterly. Twenty-four–hour composite samples are taken, and discharge flows are measured and recorded. Figure 5.22 shows total Hg concentrations in STP discharges to outfall X01 from 2010 to 2022. In 2022, Hg concentrations in outfall X01 effluent averaged 5.4 ng/L. Figure 5.23 shows trends in X12 total Hg concentrations and fluxes for 2009 through 2022. (Worst-case loads are calculated in milligrams per day based on concentration and flow using 24 h discharge rates.) In 2022, the average X12 effluent Hg concentration was 32 ng/L.

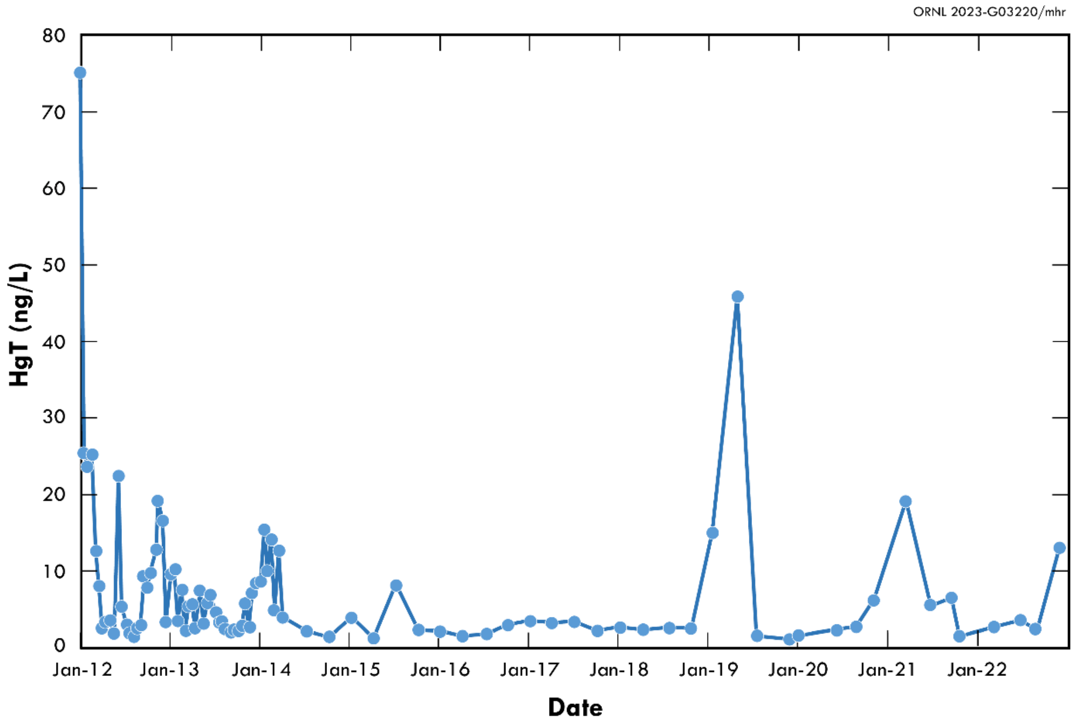
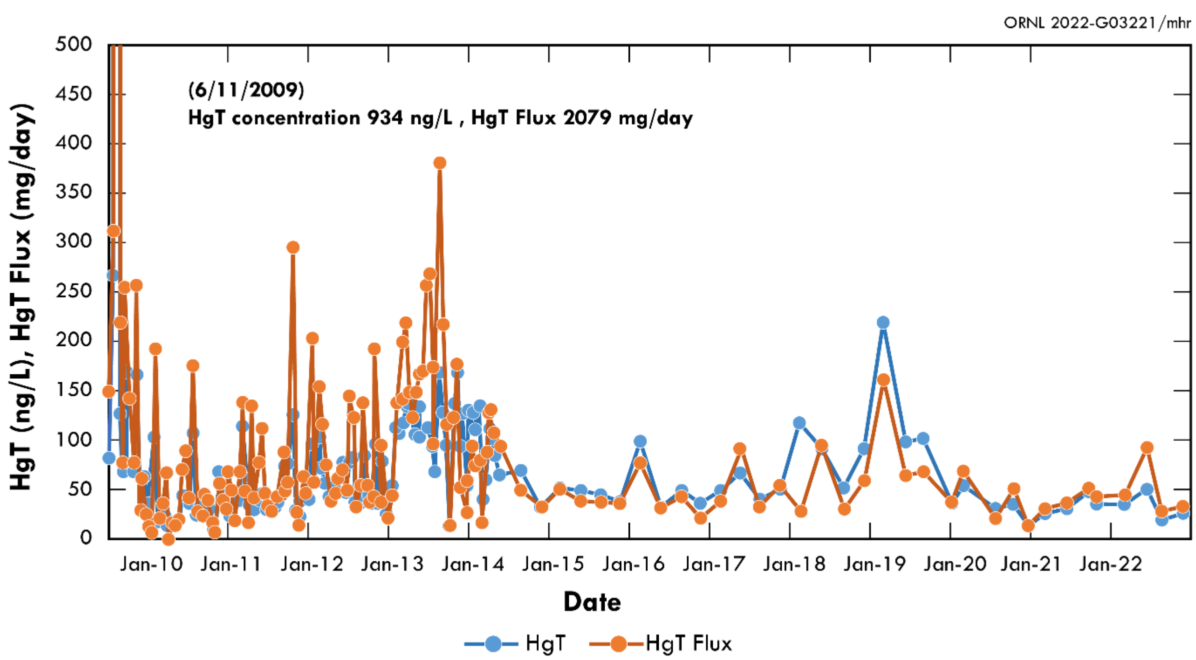


Figure 5.22. Total mercury concentration in discharges to outfall X01 from the Sewage Treatment Plant, 2010–2022



Acronym: *PWTC = Process Waste Treatment Complex*

Figure 5.23. Total mercury concentrations and fluxes in Process Waste Treatment Complex discharges to outfall X12, 2009–2022

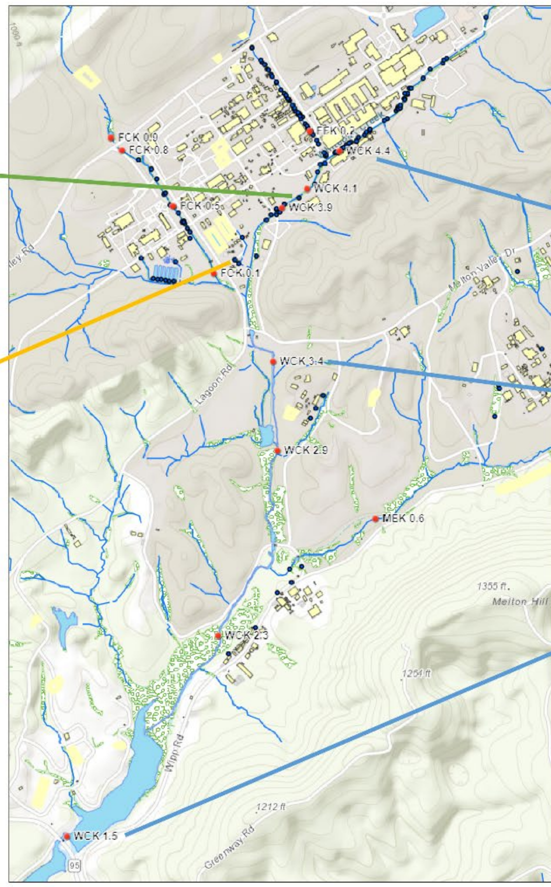
Dry-weather sampling at outfalls X01 and X12 was coordinated with 24 h Hg sampling at three instream locations (Figure 5.24). Instream locations were WCK 4.4, which is upstream of the two treatment plant outfalls; WCK 3.4 at the 7500 Bridge monitoring station, downstream of the ORNL main campus and both wastewater treatment plant outfalls; and X15 at WOD. Flow measurements were not available to calculate fluxes at the upstream point (WCK 4.4) but were available for treatment plant discharges and for the two locations downstream of the treatment plants (see Figure 5.25). As shown in Figure 5.25, Hg flux at WOD (X15), the discharge outlet from White Oak Lake, is typically several times greater than the Hg flux at the treatment plant outfalls X01 and X12 or the flux at WCK 3.4 in WOC downstream of the ORNL main campus.

ORNL 2023-G03219_VerA/mhr

Treatment Plant 24 h composites HgT

Outfall X12 (PWTC)	
Date	HgT (ng/L)
03/08/22	34
06/13/22	50
08/30/22	19
11/09/22	25

Outfall X01 (STP)	
Date	HgT (ng/L)
03/08/22	2.8
06/13/22	3.6
08/30/22	2.2
11/09/22	13.0



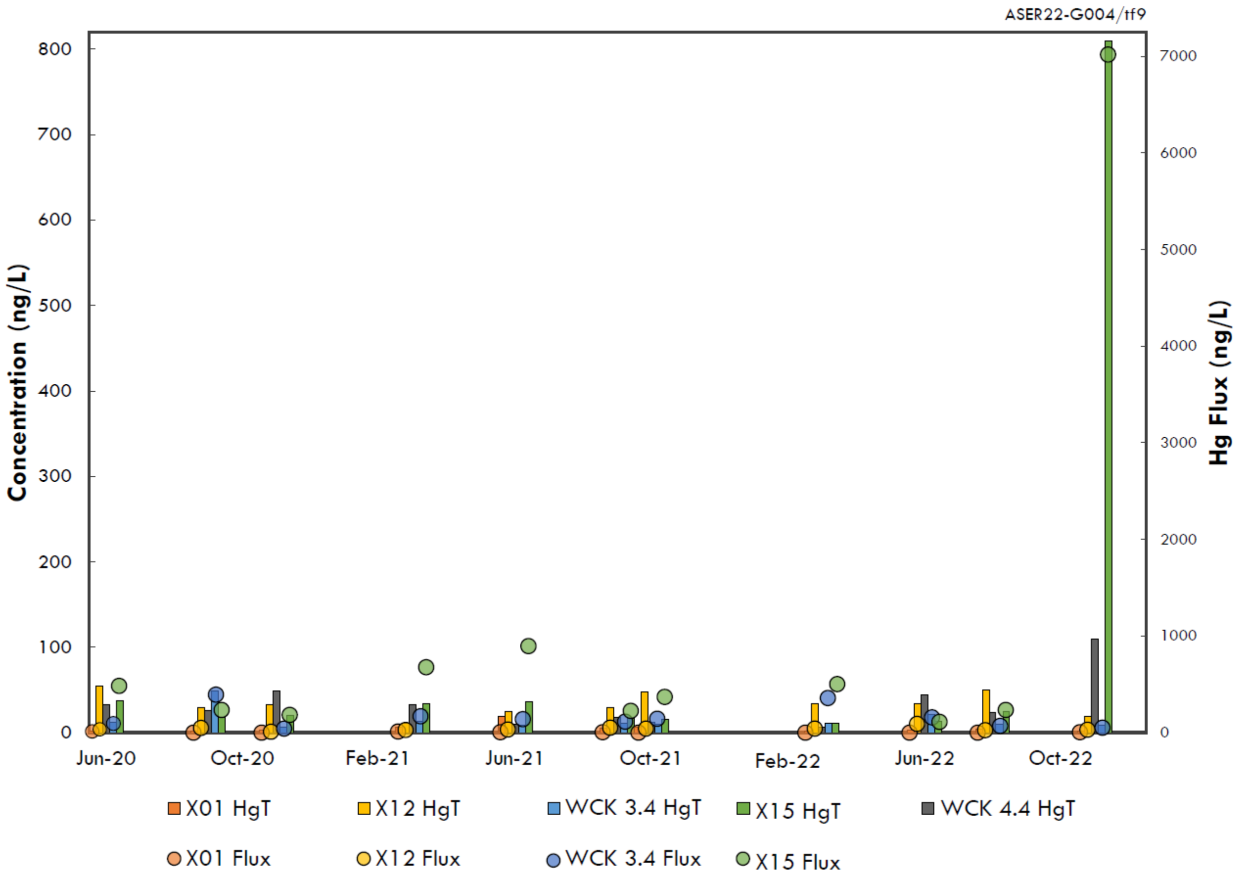
Instream 24 h composites HgT (51 ng/L WQC)

WCK 4.4	
Date	HgT (ng/L)
03/08/22	6.1
06/13/22	44.0
08/30/22	24.0
11/09/22	110.0

WCK 3.4 (7500 Bridge)	
Date	HgT (ng/L)
03/08/22	11.0
06/13/22	21.0
08/30/22	9.7
11/09/22	8.9

WCK 1.5 (White Oak Dam)	
Date	HgT (ng/L)
03/08/22	11
06/13/22	13
08/30/22	25
11/09/22	810

Figure 5.24. Locations and data for instream sampling sites coordinated with treatment plant sampling, 2022



Acronym: *WCK = White Oak Creek kilometer*

Figure 5.25. Mercury concentrations and fluxes at Sewage Treatment Plant and Process Waste Treatment Complex and dry-weather instream values in White Oak Lake at WCK 4.4 (no flux available), 3.4, and X15 (White Oak Dam), 2020–2022

5.5.4.3. Legacy Outfall Source Investigation

Legacy outfalls are investigated as part of the WQPP to better delineate Hg sources and to prioritize future abatement actions. In recent years, WQPP monitoring has focused on outfalls 207 and 211, which generally show the highest Hg concentrations. Discharged water volumes (and therefore fluxes) from outfall 211 are higher than discharges from outfall 207. In 2022, Hg sampling was also performed at outfalls 265 and 363, which both discharge to Fifth Creek. In the past, there have been discharges of Hg at levels of interest at these two outfalls; therefore, Hg monitoring continued at these locations in 2022. The volumes of outfall 211 dry-weather discharges dropped after 2012, when water conservation efforts were made to recirculate once-through cooling water. Figure 5.26 shows Hg concentrations and fluxes in dry-weather discharges to outfall 211; Hg concentrations dropped to around 55 ng/L in 2022, whereas dry-weather flows averaged about 60 gal/min. During storms, a downward trend in flux may be the result of previous sediment removal from the outfall 211 weir box (Figure 5.27). Actions are being considered to remove additional accumulated sediments from the outfall 211 weir box in 2023 and to evaluate changes in Hg flux from the ORNL site to the WOC watershed. However, if steady declines in flux are observed, sediment in the vicinity of outfall 211 may be left undisturbed.

Since 2015, dry-weather flow rates at outfall 207 have been 1 gpm or less, with fluxes of less than 1 mg/day total Hg. In 2022, dry-weather flows at outfall 207 averaged 4.5 gpm, with Hg concentrations of 6 ng/L and fluxes averaging 0.148 mg/day total Hg. Flow rates for storm water discharged through outfall 207 (Figure 5.28) have historically ranged from 5 gpm to more than 100 gpm and averaged 35 gpm in 2022; higher fluxes occurred during storms. The average wet-weather Hg flux from outfall 207 in 2022 was 36 mg/day. The higher Hg fluxes at Outfall 207 in 2022 may have been due to ongoing construction and excavation activities in the outfall 207 drainage area that may have temporarily mobilized legacy Hg contamination in soils and underground storm drain collection piping.

Outfall 363 receives cooling tower blowdown, and monitoring is performed twice monthly. No dry-weather flows were detected in 2022, and wet-weather flow averaged 40 gpm. In 2022, the average dry-weather Hg flux from outfall 363 was 1.1 mg/day, and the average wet-weather flux was 5.4 mg/day. No dry-weather flow was detected during 2022 monitoring of outfall 265; in wet weather, the average Hg flux from outfall 265 was 0.98 mg/day.

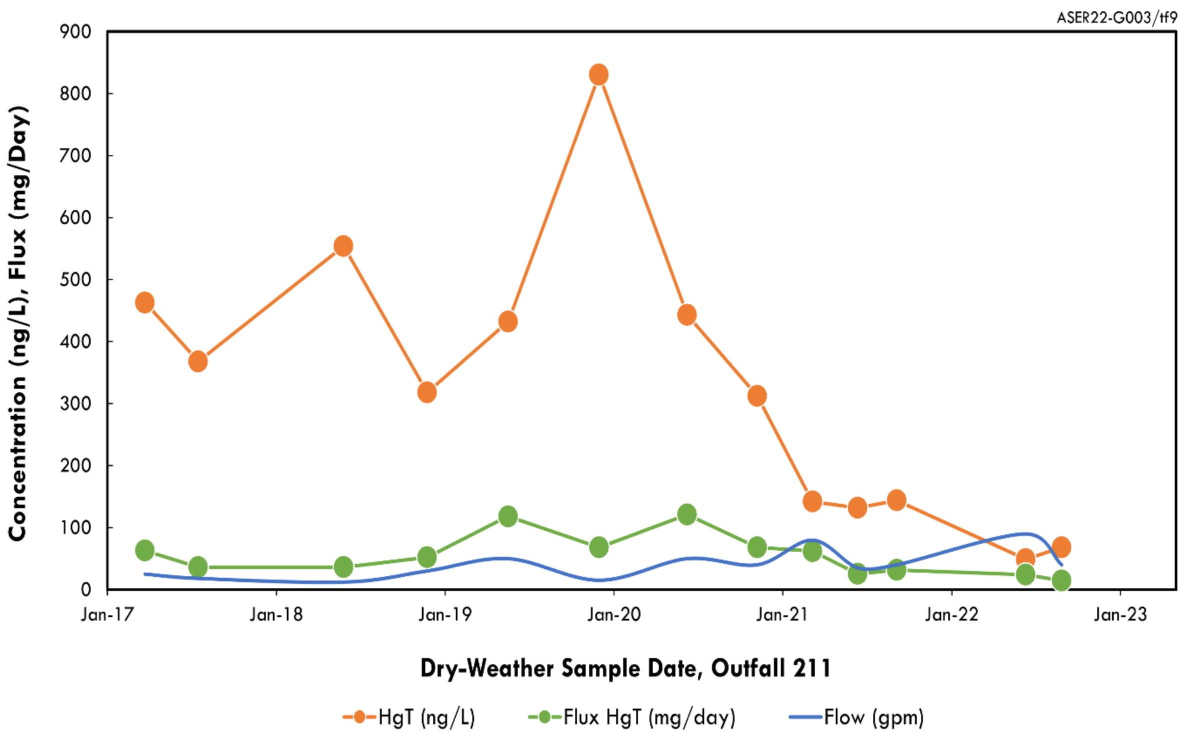


Figure 5.26. Outfall 211 dry-weather flow, concentration, and flux, 2017–2022

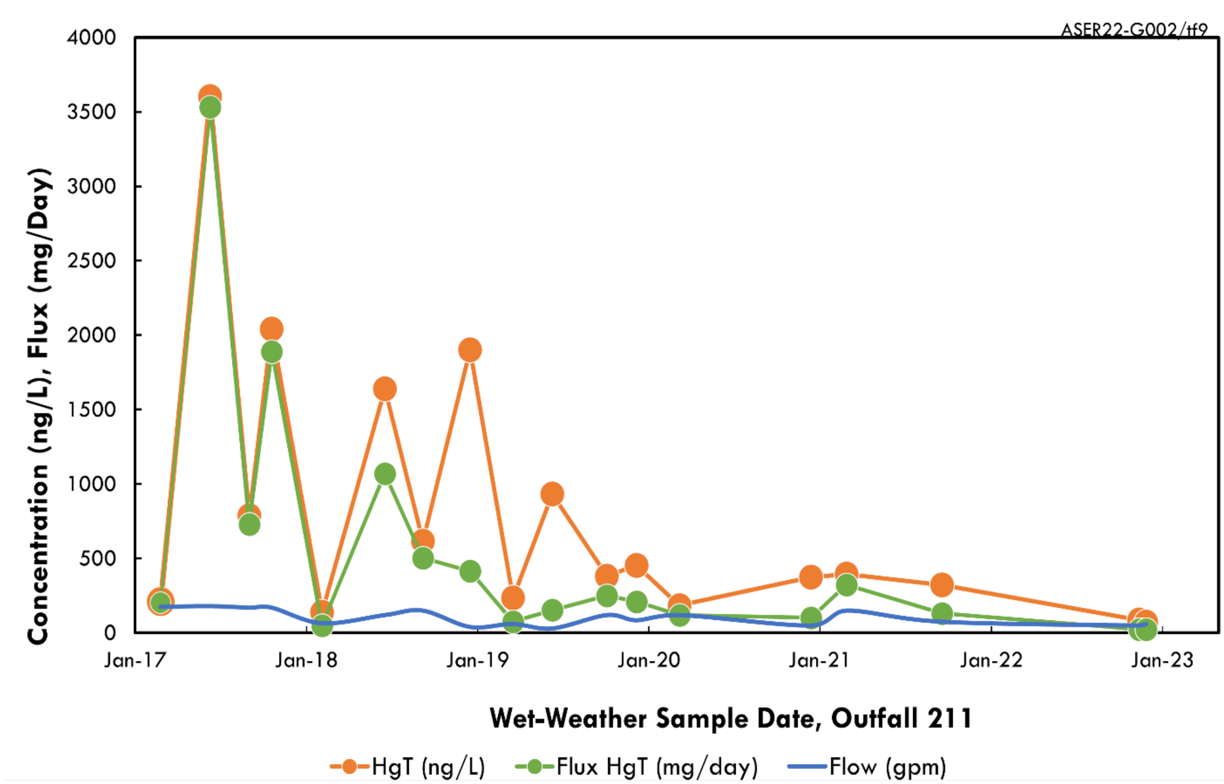


Figure 5.27. Outfall 211 storm flow, total mercury concentration and flux, 2017–2022

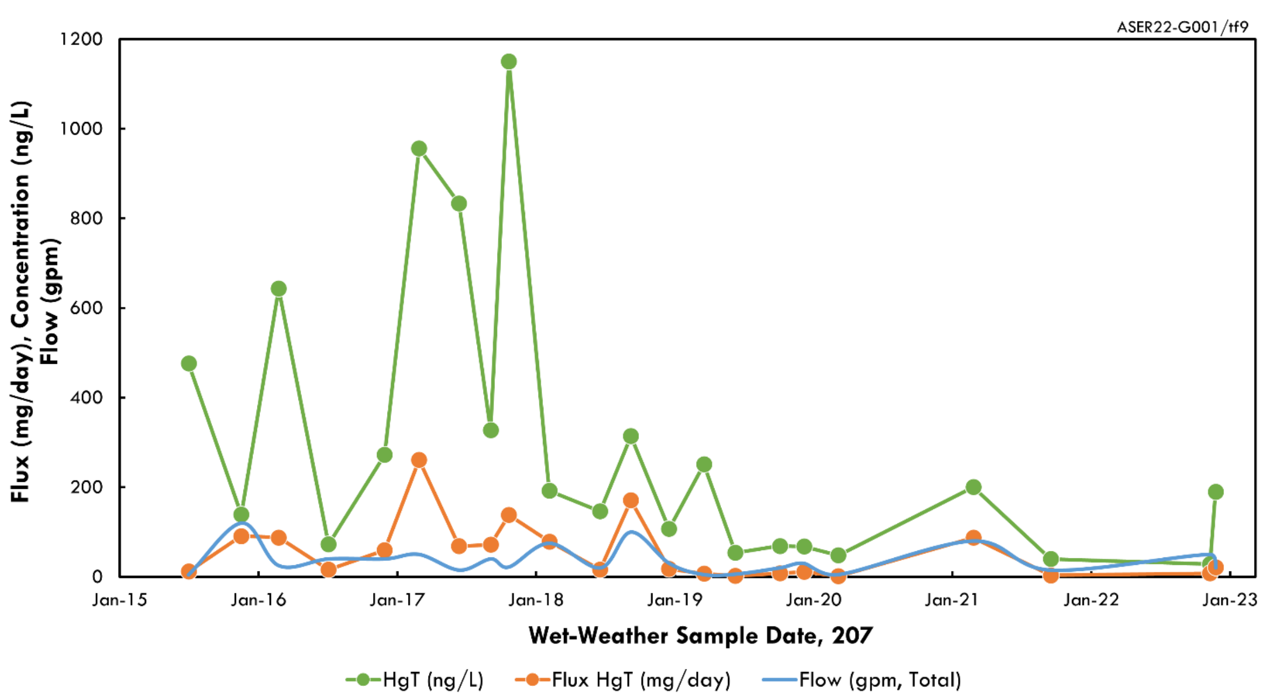


Figure 5.28. Outfall 207 storm flow, total mercury concentration, and total mercury flux, 2015–2022

5.5.4.4. Baseline Preconstruction Investigation of 207 and 304 Storm Catch Basins

Redevelopment is underway for a central portion of the ORNL main plant area, west of Building 3500. The soil at the southeast corner of the construction site contains legacy Hg contamination. Construction of a planned new building, subsequent discharges from its cooling towers, or storm water runoff through old storm piping might increase Hg discharges through outfalls 207 and 304. Therefore, sampling and preconstruction investigation of storm water catch basins in the outfall 207 and 304 drainage areas were conducted in 2020. During design of the new building, the cooling tower discharge and approximately half to three-quarters of the roof drainage were to be routed to outfall 264 on Fifth Creek. The remaining roof and storm water discharges were to be routed to outfall 207. As construction plans changed, attempts were made to sample baseline discharges from outfall 264; however, no water was flowing through outfall 264 during any of the attempted sampling events. Efforts to collect samples will continue.

The storm drain systems at outfalls 304 and 207 are original and currently have no cooling water discharge inputs. However, standing water (i.e., accumulated discharges from a groundwater sump, steam condensate discharges, and unknown leakage) was found and sampled in the storm water system during dry weather in both 207 and 304 collection systems before the start of construction. In 2022, dry- and wet-weather concentrations of Hg were 6 and 190 ng/L, respectively, in outfall 207 and 4.9 and 10 ng/L, respectively, for outfall 304. Outfall 304 flow rates were 0.1 gpm in dry weather and 12.5 gpm in wet weather. Consequently, outfall 304 Hg fluxes were less than 1 mg/day, orders of magnitude less than for outfall 207 in 2022.

5.5.5. Storm Water Surveillances and Construction Activities

Storm water drainage areas at ORNL are inspected twice per year as directed in the WQPP. Land use within drainage areas is typical of office, industrial, and research settings with surface features that include laboratories, support facilities, paved areas, and grassy lawns. Outdoor material is located temporarily in many places at ORNL, but most activity involving the movement and storage of outdoor material occurs in the 7000 area, which is located on the east end of the ORNL site and is where most of the craft and maintenance shops are located. Smaller outdoor storage areas are located throughout the ORNL site in and around loading docks and material delivery areas at laboratory and office buildings. Types of materials stored outside, as noted in field inspections, include finished metal items (pipes and parts); equipment awaiting use, disposal, or repair; aging (rusting) infrastructure; and construction equipment and material. Sites that are covered by a Tennessee construction general permit are considered to have significant potential for runoff impacts. However, inspections and controls required by an approved storm water pollution prevention plan have proven effective at minimizing short- and long-term impacts to nearby streams and waterways from construction sites.

Some construction activities are performed on third party–funded construction projects on ORR under agreements with federal agencies other than DOE and with local and state agencies. Mechanisms are in place for ensuring effective storm water controls at the third-party sites, one of which includes staff from UT-Battelle acting as points of contact for communication interface on environmental conditions, erosion and sedimentation controls, spill and emergency responses, and other key issues.

5.5.6. Biological Monitoring

Biological monitoring programs conducted at ORNL in 2022 included bioaccumulation studies in the WOC watershed; benthic macroinvertebrate monitoring in WOC, First Creek, and Fifth Creek; and fish community monitoring in WOC and its major tributaries. The following sections summarize the biological monitoring programs at ORNL and the results for 2022.

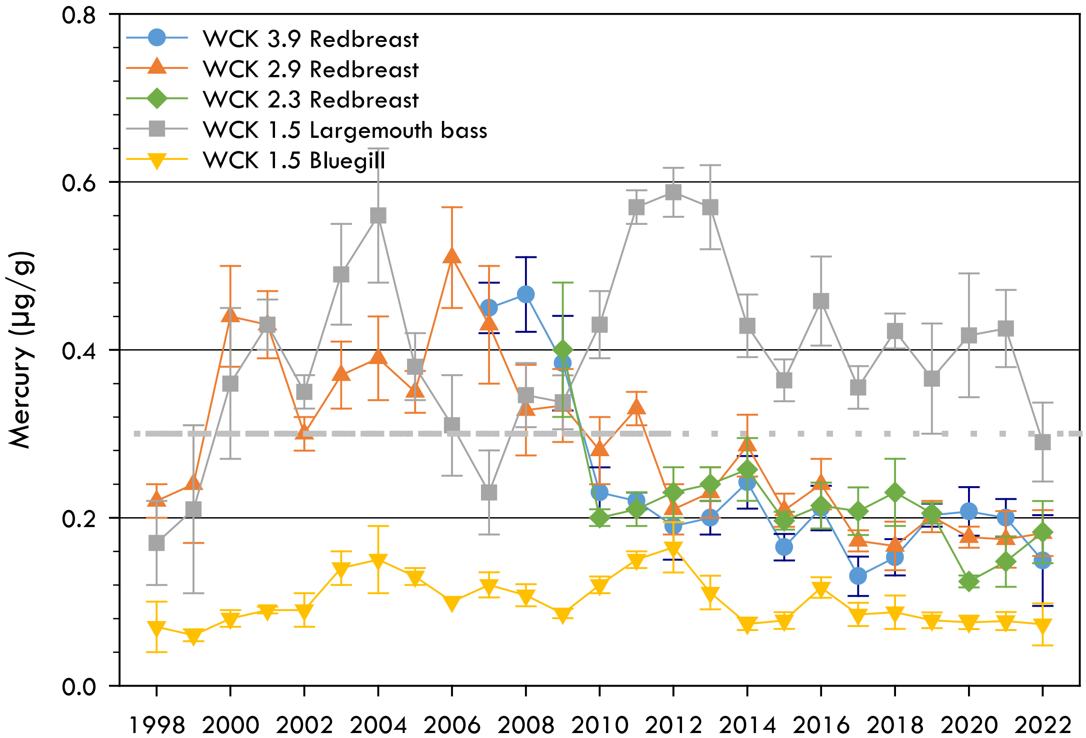
5.5.6.1. Bioaccumulation Studies

Bioaccumulation tasks for the biological monitoring and abatement plan addresses two NPDES permit requirements at ORNL: (1) evaluate whether Hg at the site is contributing to streams at a level that will adversely affect fish and other aquatic life or that will violate the recreational criteria and (2) monitor the status of PCB contamination in fish tissue in the WOC watershed. Concentrations of Hg in fish in the WOC watershed are monitored annually and are evaluated relative to the EPA ambient water quality criterion (AWQC) of 0.3 µg/g in fish fillets, a concentration considered protective of human health and the environment. Concentrations of PCBs in fish fillets are also monitored annually and are evaluated relative to the TDEC fish advisory limit of 1 µg/g.

Bioaccumulation in fish

Mercury concentrations in fish have been below human health risk thresholds (e.g., EPA-recommended fish-based AWQCs [0.3 µg/g for Hg]) in the stream portions of WOC, but concentrations in fish collected in White Oak Lake continue to exceed this threshold (Figure 5.29). Actions taken in 2007 to treat an Hg-contaminated sump significantly decreased Hg concentrations in fish throughout WOC. The decreases were most apparent at upstream locations closest to the sump water reroute. Although the overall trends in the uppermost locations sampled in the creek suggest that Hg concentrations in fish tissue are decreasing overall, some interannual variability exists. In 2022, Hg concentrations in fillets of all species collected from all monitored sites were comparable to 2021 concentrations, except at WCK 1.5, where concentrations in largemouth bass decreased significantly in 2022. Concentrations in all sunfish samples remained below the AWQC for Hg in fish, and in 2022 concentrations in largemouth bass collected from WCK 1.5 concentrations were also below this AWQC for the first time in over a decade.

In 2022, PCB concentrations (defined as the sum of Aroclors 1248, 1254, and 1260) in fish collected throughout the WOC watershed were below human health risk thresholds (the TDEC fish advisory limit of 1 µg/g for PCBs). PCB concentrations in fish collected in the stream portions have remained below this threshold for years, and concentrations in fish collected in White Oak Lake, especially largemouth bass, have been decreasing in recent years such that they were below the threshold in 2022 (Figure 5.30).

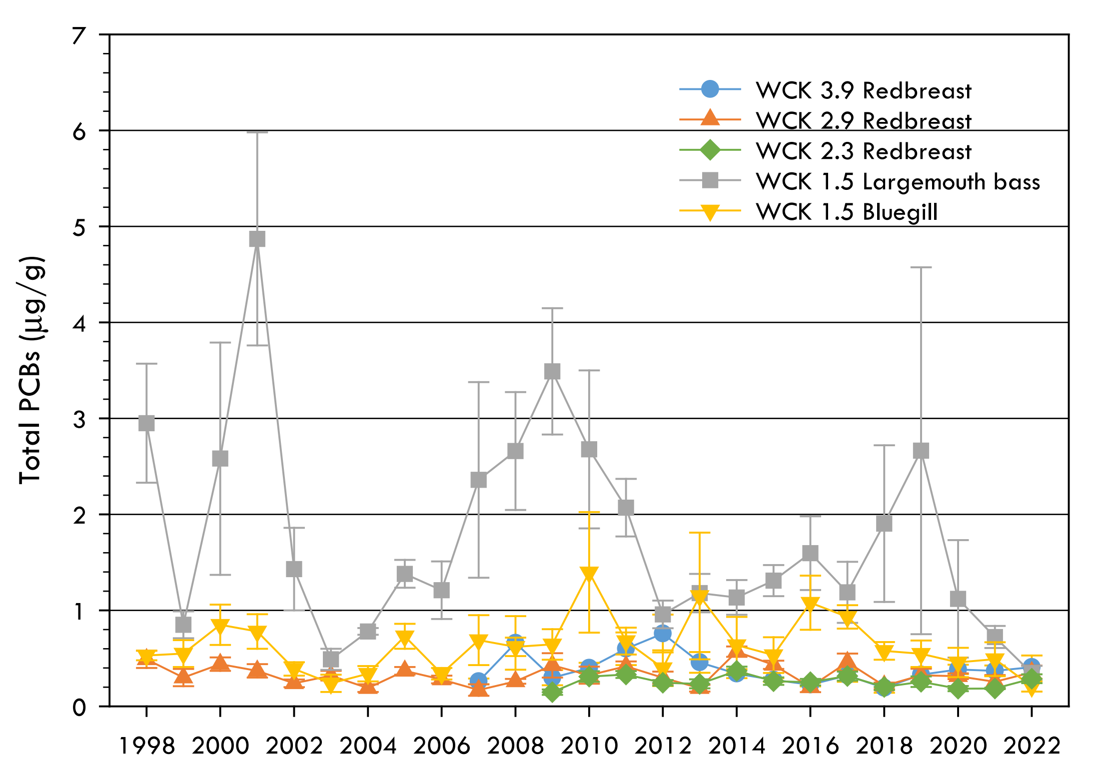


Notes:

1. *Mean concentrations of mercury (± standard error, N = 6) in tissue taken from sampled fish.*
2. *The dashed grey line at 0.3 µg/g indicates the US Environmental Protection Agency ambient water quality criterion for mercury in fish tissue.*

Acronym: *WCK = White Oak Creek kilometer*

Figure 5.29. Mean mercury concentrations in muscle tissue of sunfish and bass sampled from the White Oak Creek watershed, 1998–2022



Note: *Mean total PCB concentrations (± standard error, N = 6) found in fish fillets.*
Acronyms: *PCB = polychlorinated biphenyl   WCK = White Oak Creek kilometer*

Figure 5.30. Mean total PCB concentrations in fish sampled from the White Oak Creek watershed, 1998–2022

5.5.6.2. Benthic Macroinvertebrate Communities

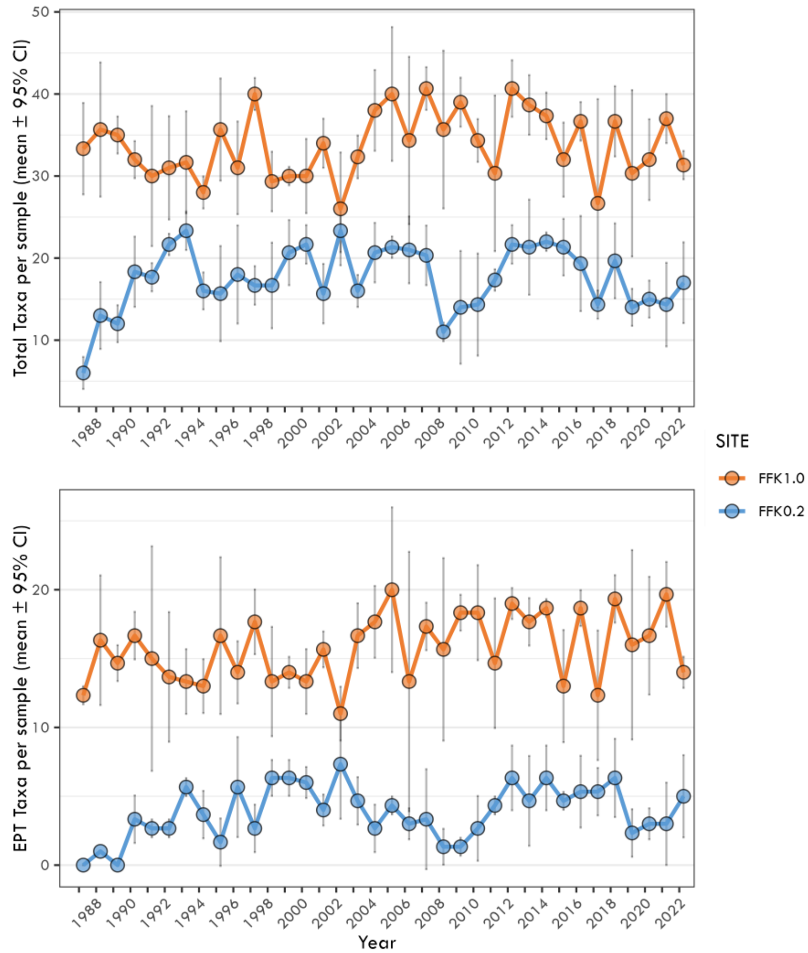
Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2022. Additionally, monitoring of the macroinvertebrate community in lower Melton Branch (MEK 0.6) continued under the OREM Water Resources Restoration Program (WRRP). Benthic macroinvertebrate samples are collected annually following TDEC protocols (since 2009), and protocols developed by ORNL staff (since 1987). The ORNL protocols provide a long-term record (35 years) of spatial and temporal trends in invertebrate communities from which the effectiveness of pollution abatement and RAs taken at ORNL can be evaluated and verified. The ORNL protocols also provide quantitative results that can be used to statistically evaluate changes in trends relative to historical conditions. The TDEC protocols provide a qualitative estimate of the condition of a macroinvertebrate community relative to a state-defined reference condition.

General trends in the results obtained using ORNL protocols indicated significant recovery in benthic macroinvertebrate communities since 1987, but community characteristics suggest that ecological impairment remains (Figures 5.31 and 5.32). Relative to respective upstream reference sites, total taxonomic richness (i.e., the number of different species per sample) and richness of the pollution-intolerant taxa (i.e., the number of different mayfly, stonefly, and caddisfly species per sample or Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa richness) continued to be lower at these downstream sites.

In lower First Creek (First Creek kilometer [FCK] 0.1), total taxa richness increased gradually in the 1990s and 2000s but was then lower for 4 years beginning in 2014 (Figure 5.33). Total taxa richness increased at FCK 0.1 from 2018 until

2021, reaching values observed before 2014, but then decreased in 2022. Similarly, the number of pollution-intolerant (EPT) taxa slowly increased in the 1990s and 2000s but then began to decrease in 2012. In 2014, EPT taxa richness was the lowest it had been since the early 1990s. EPT taxa richness values decreased in 2022 to pre-2018 levels after reaching a 10-year high in 2021. In upper First Creek (FCK 0.8), which serves as a reference for FCK 0.1, total taxa richness and EPT taxa richness declined from 2015 to 2017, increased from 2018 to 2021, and then decreased again in 2022. Although total and EPT taxa richnesses declined at FCK 0.1 and 0.8 in 2022, the low values in FCK 0.1 (especially for EPT tax richness) did not mirror those in FCK 0.8, which suggests that although climate or hydrological change may have influenced conditions within the entire stream (both FCK 0.1 and FCK 0.8), a more localized change also may have occurred in lower First Creek. If a change has occurred, it is not known whether it is related to a change in chemical conditions (e.g., change in water quality or the possible presence of a toxicant), physical conditions (e.g., unstable substrate, increased frequency of high-discharge events), or natural variation. Furthermore, it is unclear currently whether conditions at FCK 0.1 have declined temporarily or for the long term.

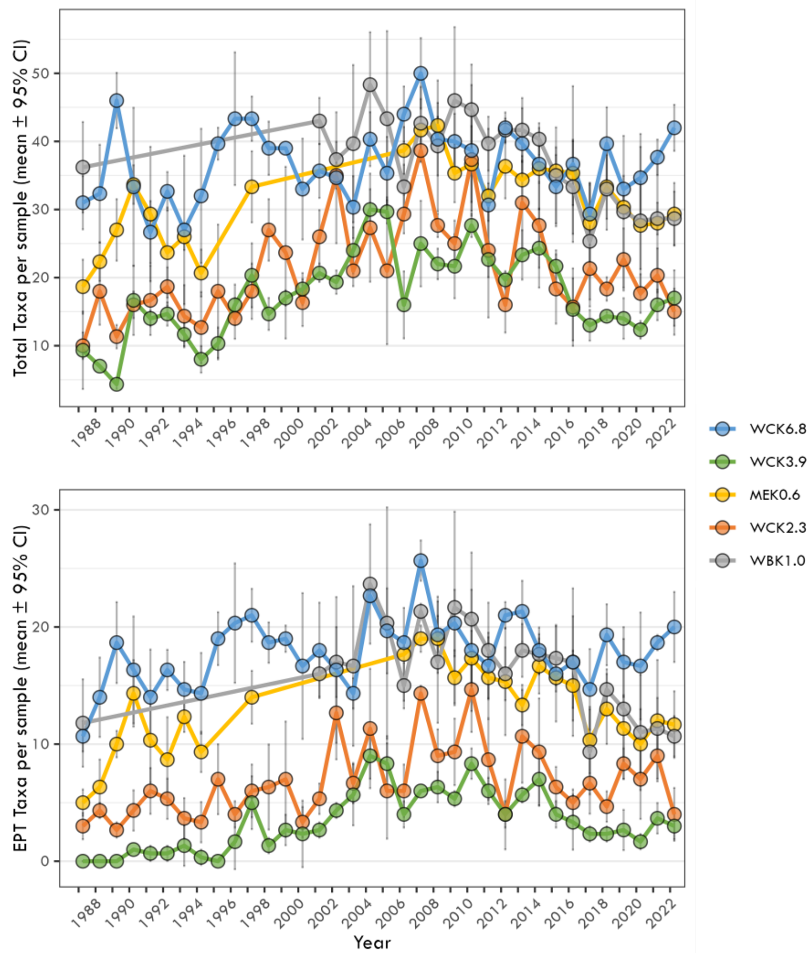
Total taxa richness at Fifth Creek kilometer (FFK) 0.2 increased in the late 1980s and early 1990s, and then was fairly consistent until decreasing significantly between 2007 and 2008 (Figure 5.31), suggesting that conditions changed at the site during that time. Total taxa richness returned to predecline levels over a period of about 5 years. EPT taxa richness at FFK 0.2 increased slowly from the late 1980s to early 2000s before decreasing for several years (~2003–2009). From 2011 to 2018, EPT taxa richness remained steady at about five to six EPT taxa per sample. However, EPT taxa richness decreased again from 2019 to 2021 before returning to pre-2019 values in 2022 (five EPT taxa per sample). The slight increase in total and EPT taxa richnesses between 2021 and 2022 appears to reflect interannual variation in invertebrate community composition.



Note: *Taxonomic richness (number of taxa per sample), 1987–2022. FFK 1.0 serves as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).

Acronyms:
CI = confidence interval
FFK = Fifth Creek kilometer

Figure 5.31. Benthic macroinvertebrate communities in Fifth Creek, 1987–2022



Note: *Taxonomic richness (number of taxa per sample), 1987–2022. WCK 6.8 and WBK 1.0 serve as reference sites.*

Top: Total taxonomic richness.

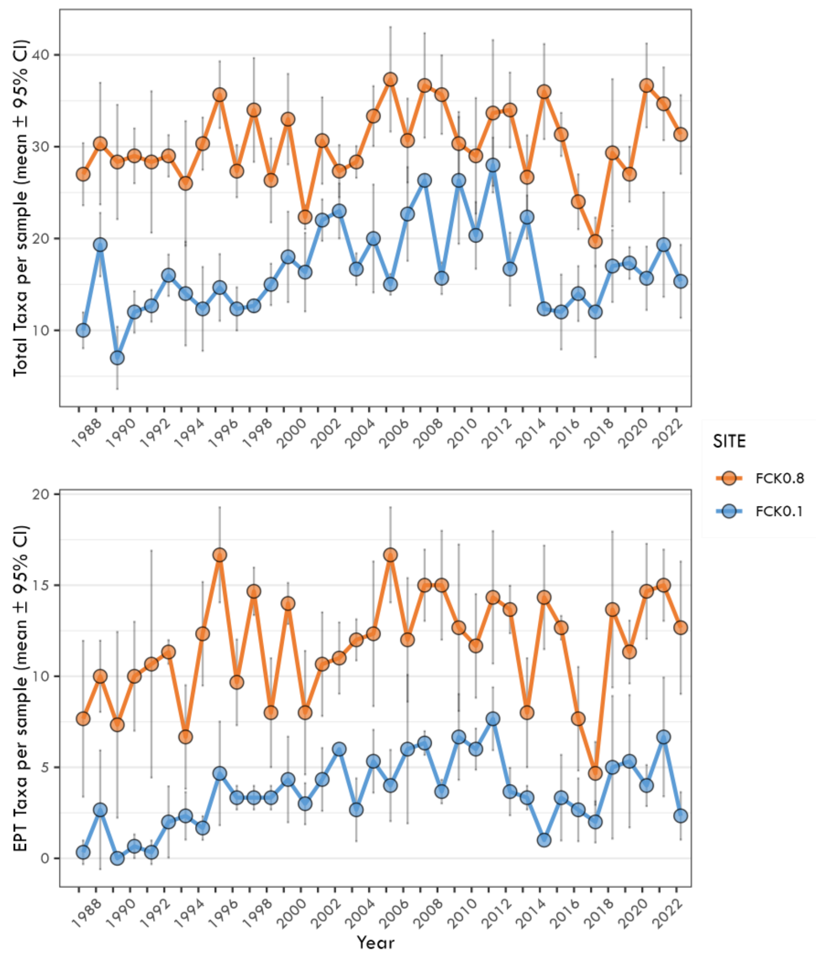
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).

Acronyms:

CI = confidence interval WBK = Walker Branch kilometer

MEK = Melton Branch kilometer WCK = White Oak Creek kilometer

Figure 5.32. Benthic macroinvertebrate communities in Walker Branch, Melton Branch, and White Oak Creek, 1987–2022



Note: *Taxonomic richness (number of taxa per sample), 1987–2022. FCK 0.8 serves as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).
Acronyms:
CI = confidence interval
FCK = First Creek kilometer

Figure 5.33. Benthic macroinvertebrate communities in First Creek, 1987–2022

Although total and EPT taxa richnesses declined between 2021 and 2022 at upper Fifth Creek (FFK 1.0), which serves as a reference for FFK 0.2, both values have consistently remained higher at FFK 1.0 than at FFK 0.2 since sampling began in 1987.

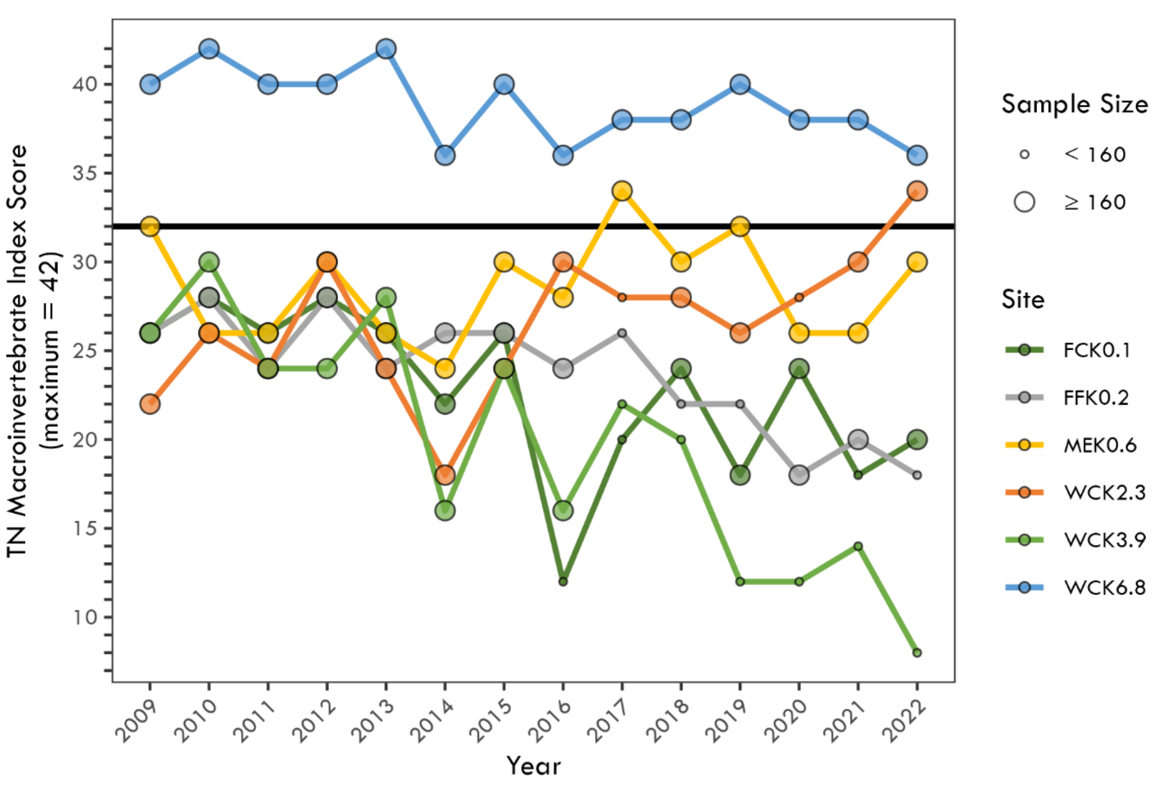
Invertebrate metric values for WCK 2.3 and WCK 3.9 continued to remain within the ranges of values found since the late 1990s and early 2000s, although total taxa richness and EPT taxa richness were lower at WCK 2.3 and WCK 3.9 over the past 7 to 8 years. As with FCK 0.1 and FFK 0.2, the total taxa richness and EPT taxa richness at WCK 2.3 and WCK 3.9 continued to be notably lower than at the reference sites. Since 2001 (except for one sampling event in 1987), Walker Branch (WBK 1.0) has served as an additional reference site for WOC mainstem sites downstream of Bethel Valley Road (Figure 5.32). Comparisons of WCK 6.8 with WBK 1.0 show that communities in WCK 6.8 represent ideal reference conditions. Additionally, the comparison of WBK 1.0 with downstream sites in WOC shows that those WOC communities remain impaired. Interestingly, a pattern similar to FCK 0.8 and FFK 1.0 occurred in both WCK 6.8 and WBK

1.0, where large declines in total taxa richness and EPT taxa richness were observed in 2017, though subsequent responses have varied across sites. This suggests that similar climatological or environmental changes may be contributing to some of the patterns observed since 2017 in the invertebrate metric values across the entire watershed, if not the entire ORR, but local drivers are also present.

Macroinvertebrate metrics for Melton Branch (MEK 0.6) suggested that total taxa and EPT taxa richness continued to be similar to those in reference sites in 2022, particularly WBK 1.0 (Figure 5.32). However, other invertebrate community metrics at MEK 0.6, such as the density of pollution-intolerant and pollution-tolerant species (not shown), continued to fluctuate annually between comparable values and values below those of the reference sites. For the past 7 years (2016–2022), EPT density has generally been lower in MEK 0.6 than WCK 6.8 and WBK 1.0, whereas the density of pollution-tolerant species (oligochaetes and chironomids) was higher in MEK 0.6 than in those two reference sites.

Based on TDEC protocols (TDEC 2021), scores for the TDEC Tennessee Macroinvertebrate Index (TMI) in 2022 rated the invertebrate communities at WCK 6.8 and the reference site, WCK 6.8, as passing biocriteria guidelines; scores from FCK 0.1, FFK 0.2, MEK 0.6, and WCK 3.9 were below these guidelines (Figure 5.34, Table 5.13). Scores improved at two of the four sites (MEK 0.6 and FCK 0.1) below the biocriteria threshold from 2021 to 2022 and declined at two sites (WCK 3.9 and FFK 0.2). The TMI score at WCK 3.9 has continually declined since monitoring using TDEC protocols began in 2009.

Low TMI scores in FCK 0.1, FFK 0.2, MEK 0.6, WCK 2.3, and WCK 3.9 were primarily due to low values for EPT percentage and EPT taxa richness (Table 5.13). However, all the sites except WCK 3.9 had low percentages of oligochaetes and chironomids (worms and nonbiting midges) and thus received high scores for this category. WCK 6.8 received the highest attainable scores for all categories except for total taxa richness and EPT taxa richness. In 2022, the TMI score in WCK 2.3 was above biocriteria guidelines for the first time in the 14 years ORNL has used the TDEC protocols, primarily due to an increase in the EPT percentage (Table 5.13.)



Note: *The black horizontal line shows the threshold for Tennessee Macroinvertebrate Index scores. The values above the threshold are passing scores; those below are not.*

Acronyms:

FCK = First Creek kilometer MEK = Melton Branch kilometer

FFK = Fifth Creek kilometer WCK = White Oak Creek kilometer

Figure 5.34. Temporal trends in Tennessee Department of Environment and Conservation Tennessee Macroinvertebrate Index scores for White Oak Creek watershed streams, August sampling, 2009–2022

Table 5.13. Tennessee Macroinvertebrate Index metric values, metric scores, and index scores for White Oak Creek, First Creek, Fifth Creek, and Melton Branch streams, August 22, 2022[a,b]

Site	Metric values							Metric scores							TMI[c]
	Taxa rich	EPT rich	EPT (%)	OC (%)	NCBI	Cling (%)	TN Nuttol (%)	Taxa rich	EPT rich	EPT (%)	OC (%)	NCBI	Cling (%)	TN Nuttol (%)	
WCK 2.3	220	56	46.5	3.9	3.7	57.5	34.6	4	2	6	6	6	6	4	34 [pass]
WCK 3.9	9	43	5.3	35.3	5.6	5.3	85.3	0	0	0	4	4	0	0	8
WCK 6.8	226	19	43.2	1.7	3	79.2	10.2	4	4	4	6	6	6	6	36 [pass]
FCK 0.1	115	32	0.5	1.5	5.7	31.4	5.9	2	0	0	6	4	2	6	20
FFK 0.2	114	75	13.6	5.1	5.6	31.4	60.2	2	2	0	6	4	2	2	18
MEK 0.6	124	59	26.1	1.9	4.5	48.8	38.6	4	4	2	6	6	4	4	30

*[a] TMI metric calculations and scoring and index calculations are based on TDEC protocols for Ecoregion 67f (TDEC 2021). Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys, TDEC Division of Water Resources, Nashville, Tennessee. Available **here**).*

[b] Taxa rich = Taxa richness; EPT rich = taxa richness of mayflies, stoneflies, and caddisflies; EPT = EPT abundance excluding Cheumatopsyche spp.; OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water; TN Nuttol = percent abundance of nutrient-tolerant organisms.

[c] TMI is the total index score. Higher index scores indicate higher quality conditions. A score of ≥32 is considered to pass biocriteria guidelines.

Acronyms:

EPT = Ephemeroptera, Plecoptera, and Trichoptera
FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
NCBI = North Carolina Biotic Index
OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges)
TDEC = Tennessee Department of Environment and Conservation
TMI = Tennessee Macroinvertebrate Index Score
TN Nuttol = nutrient-tolerant organism
WCK = White Oak Creek kilometer

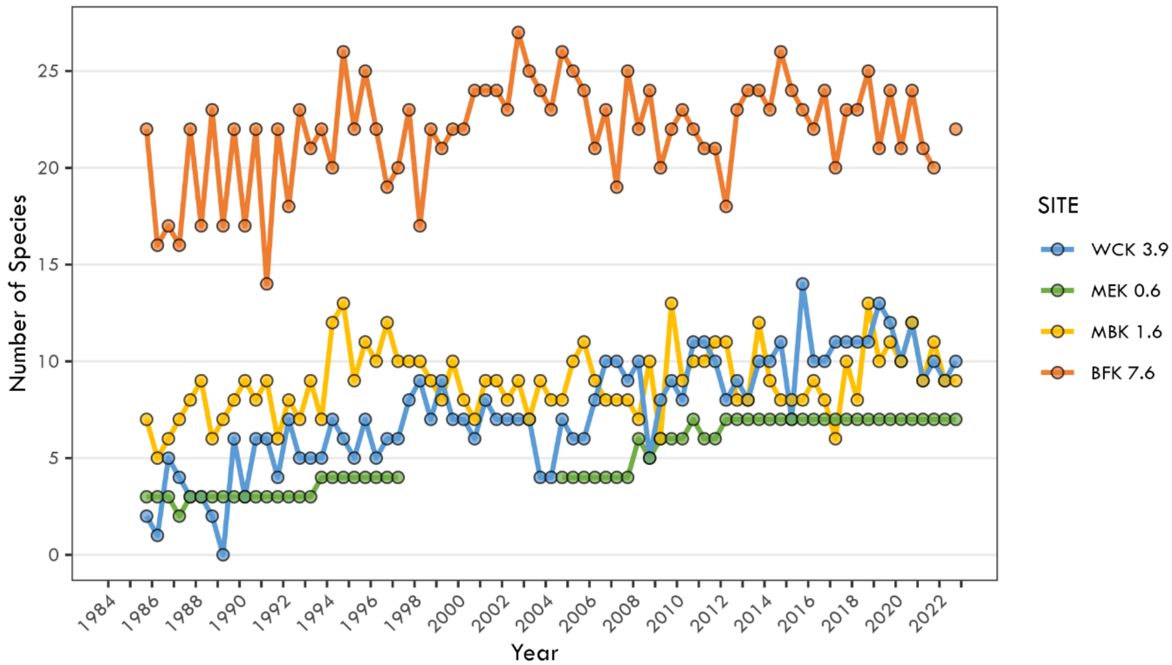
5.5.6.3. Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2022. Fish community surveys were conducted at 11 sites in the WOC watershed, including 5 sites in the main channel, 2 sites in First Creek, 2 sites in Fifth Creek, and 2 sites in Melton Branch. Streams located near or within the city of Oak Ridge (Mill Branch and Brushy Fork) were also sampled as reference sites for comparison.

In the WOC watershed, the fish community continued to be slightly degraded in 2022 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Figure 5.35) and fewer pollution-sensitive species than a slightly larger reference site and more closely resembled values found in a smaller reference reach. WOC sites also had more pollution-tolerant species and elevated densities (number of fish per square meter) of pollution-tolerant species compared with reference streams. Seasonal fluctuations in diversity and density are expected and may explain some of the variability seen at these sites. However, the combination of these factors indicates degraded water quality and/or habitat conditions. Overall, the fish communities in tributary sites adjacent to and downstream of ORNL outfalls continued to be negatively affected by ORNL effluent in 2022 relative to reference streams and upstream sites.

A project to introduce fish species that were not found in the WOC watershed but that exist in similar systems on ORR and that may have historically existed in WOC was initiated in 2008 with the stocking of seven such native species. Continuing reproduction has been noted for six of the species, and several species have expanded their ranges downstream and upstream from initial introduction sites to establish new reproducing populations. In general, introduced species have had more difficulty establishing populations at upstream sites in both WOC and Melton Branch. This is likely due to numerous structures located within the watershed that act as barriers to upstream fish migration. In response, introductions to supplement the small populations of those fish species were continued at sites within the watershed until 2019.

One exception to the apparent difficulty of expansion is the striped shiner (*Luxilus chrysocephalus*), which has expanded into upper Melton Branch, upper WOC, and lower First Creek, although established populations have not been observed in all those locations. The introductions have enhanced species richness at almost all sample locations within the watershed. This may indicate the capacity of this watershed to support increased fish diversity, which seems to be limited by impassible barriers such as dams, weirs, and culverts and by limited access to source populations downstream in the Clinch River below White Oak Lake.



Note: *BFK 7.6 was not surveyed in the spring of 2022 because of lack of access to the site.*
Acronyms:
BFK = Brushy Fork kilometer *MEK = Melton Branch kilometer*
MBK = Mill Branch kilometer *WCK = White Oak Creek kilometer*

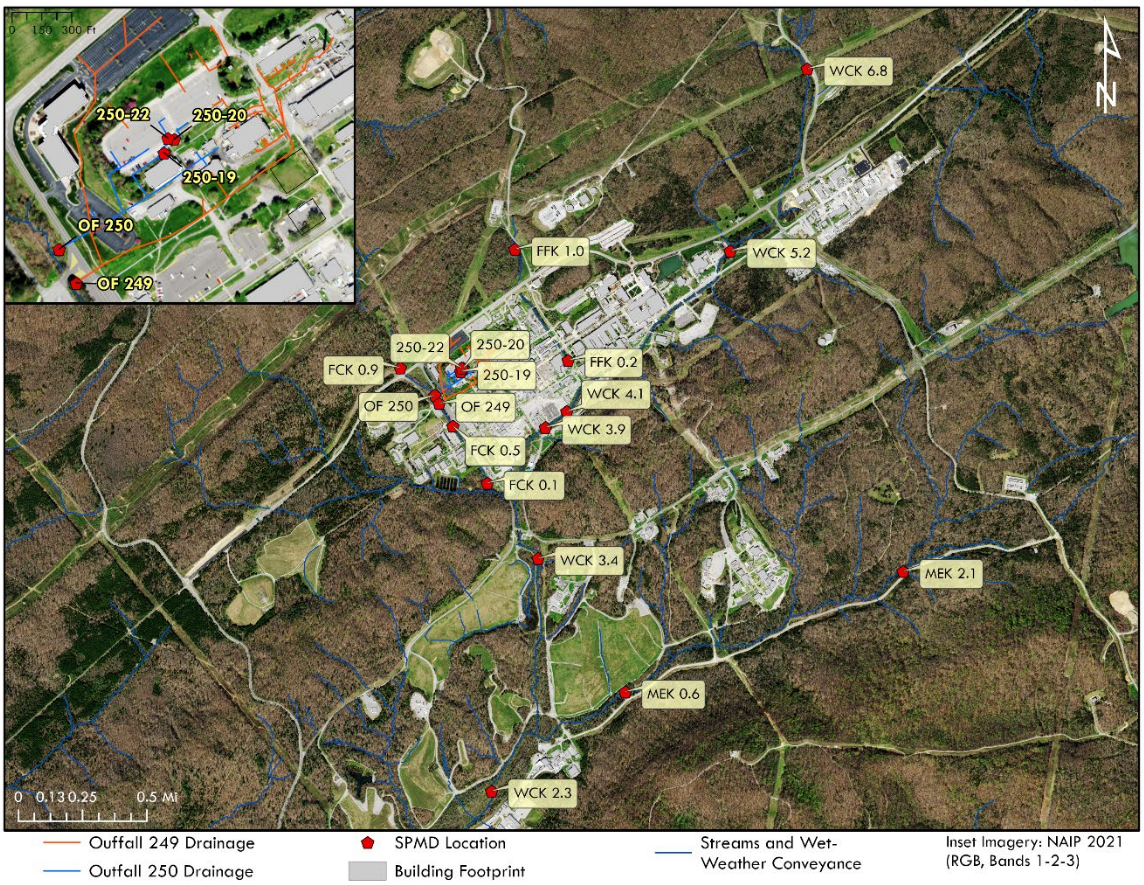
Figure 5.35. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams, Brushy Fork and Mill Branch, 1985–2022

5.5.7. Polychlorinated Biphenyls in the White Oak Creek Watershed

The initial objective of the source identification task in the WOC watershed was to identify the stream reaches, outfalls, or sediment areas that are contributing to elevated PCB levels in the watershed. PCB concentrations in largemouth bass collected from White Oak Lake have been higher than those recommended by TDEC and EPA for frequent consumption, confirming elevated exposures at this site. However, because fish are mobile, source identification is not possible from the data. PCBs are hydrophobic and do not readily dissolve in water. As a result, water samples taken from the WOC watershed and analyzed using conventional methods have historically shown PCBs to be below detection limits. Semipermeable membrane devices (SPMDs) have proven to be useful tools to identify sources of PCBs in the WOC watershed. SPMDs are thin plastic sleeves filled with oil in which PCBs are soluble. Because SPMDs are deployed at a given site for 4 weeks and have a high affinity for PCBs, they allow for a time-integrated semiquantitative index of the relative PCB concentrations in the water column rather than a "snapshot" value that would be obtained from a grab sample.

Over the past 13 years, ORNL's PCB monitoring efforts have identified upper parts of First Creek as a source of PCBs to the WOC watershed, particularly in the storm drain network leading to Outfall 250. In September 2019, catch basin sediment in the outfall 250 drainage network was cleaned out and disposed of as solid waste, but results from SPMD deployments in 2021 did not indicate that the sediment removal affected aqueous PCB concentrations in this network. In 2022, SPMDs were deployed throughout the WOC watershed and in the streams leading to WOC in the same locations selected for deployments in 2009 and 2010 (Figure 5.36) to determine whether there have been any changes in PCB sources to the WOC watershed. Forage fish were also collected at three sites in First Creek to examine PCB exposure to biota in this stream. The 2022 SPMD deployment showed very similar spatial patterns to the original deployments in 2009 and 2010 (Figure 5.37), with First Creek being the greatest contributor of aqueous PCBs to the WOC watershed. The outfall 250 storm drain network, particularly the location at 250-19, remains the greatest contributor of PCBs to the First Creek watershed, with concentrations in forage fish in First Creek decreasing with downstream distance from this outfall. Although SPMDs are semiquantitative, allowing for a relative assessment of PCB sources to the stream, the overall concentrations in the SPMDs were comparable to those in previous years, suggesting that there have been no major changes in aqueous PCB concentrations in this watershed over the past decade.

2022-ASER-M202301-tf9



Acronyms:

FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
OF = outfall
SPMD = semipermeable membrane device
WCK = White Oak Creek kilometer

Figure 5.36. Locations of monitoring points for First Creek source investigation

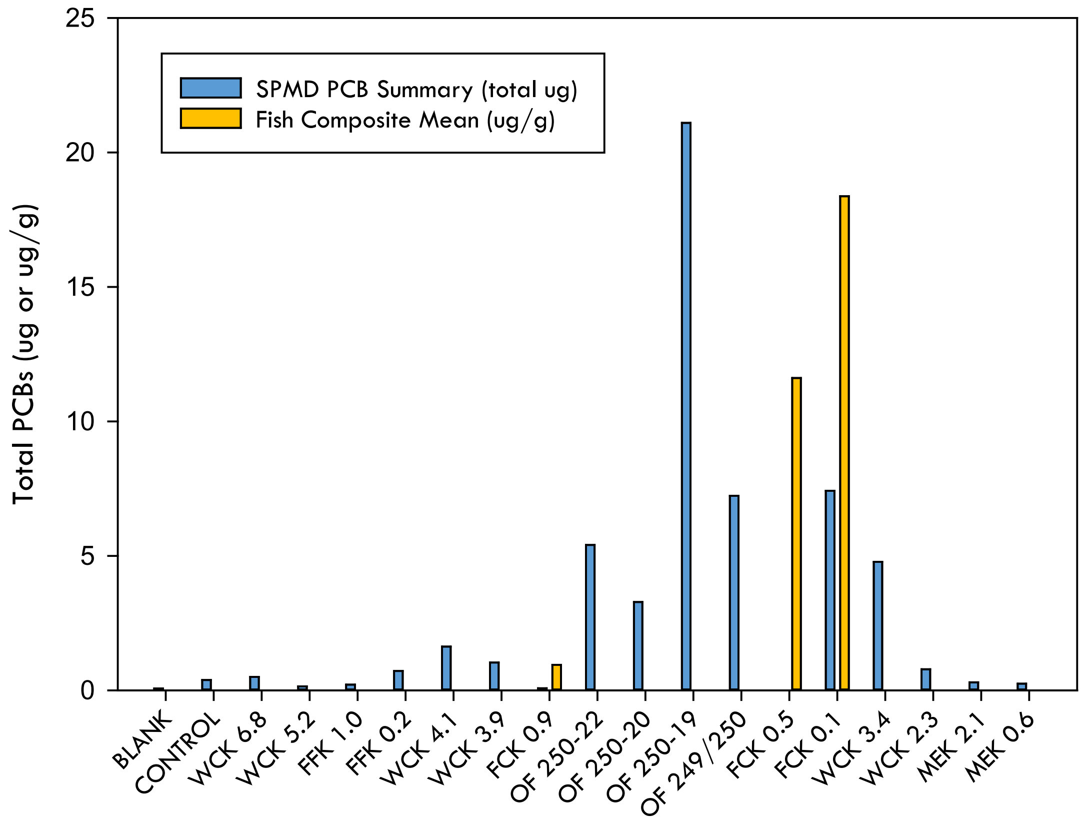


Figure 5.37. Total polychlorinated biphenyl content in semipermeable membrane devices in the White Oak Creek watershed and in First Creek forage fish composite samples (n = 3), 2022

5.5.8. Oil Pollution Prevention

CWA Section 311 regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of spill prevention, control, and countermeasures (SPCC) plans to minimize the potential for oil discharges. These requirements are provided in 40 CFR 112, "Oil Pollution Prevention." Each ORR facility implements a site-specific SPCC plan.

The HVC (home of NTRC and the Manufacturing Demonstration Facility), which is located off ORR, also has an SPCC plan covering the oil inventory at that location. CFTF is also located off ORR; however, that facility was evaluated, and a determination was made that an SPCC plan was not required. The ORNL SPCC plan was revised in 2022. The HVC SPCC plan was not changed in 2022. Inventories for both SPCC plans are maintained electronically in the ORNL geographic information system and are updated routinely throughout each year. There were no regulatory actions related to oil pollution prevention at ORNL or HVC in 2022. An oil-handler training program exists to comply with training requirements in 40 CFR 112.

5.5.9. Surface Water Surveillance Monitoring

The ORNL surface water monitoring program is conducted in conjunction with the ORR surface water monitoring activities discussed in Section 6.4 to enable assessing the impacts of ongoing DOE operations on the quality of local surface water. The sampling locations (Figure 5.38) are used to monitor conditions upstream of ORNL main plant waste sources (WCK 6.8), within the ORNL campus (FFK 0.1), and downstream of ORNL discharge points (WCK 1.0).

Sampling frequencies and parameters vary by site and are shown in Table 5.14. Monitoring at WCK 1.0 is conducted monthly for radiological parameters and quarterly for Hg under the ORNL WQPP (Section 5.5.3); therefore, those parameters are not duplicated by this program. Radiological monitoring at WCK 6.8 is also conducted monthly under the ORNL WQPP and therefore is not included in the ORNL surface water monitoring program.

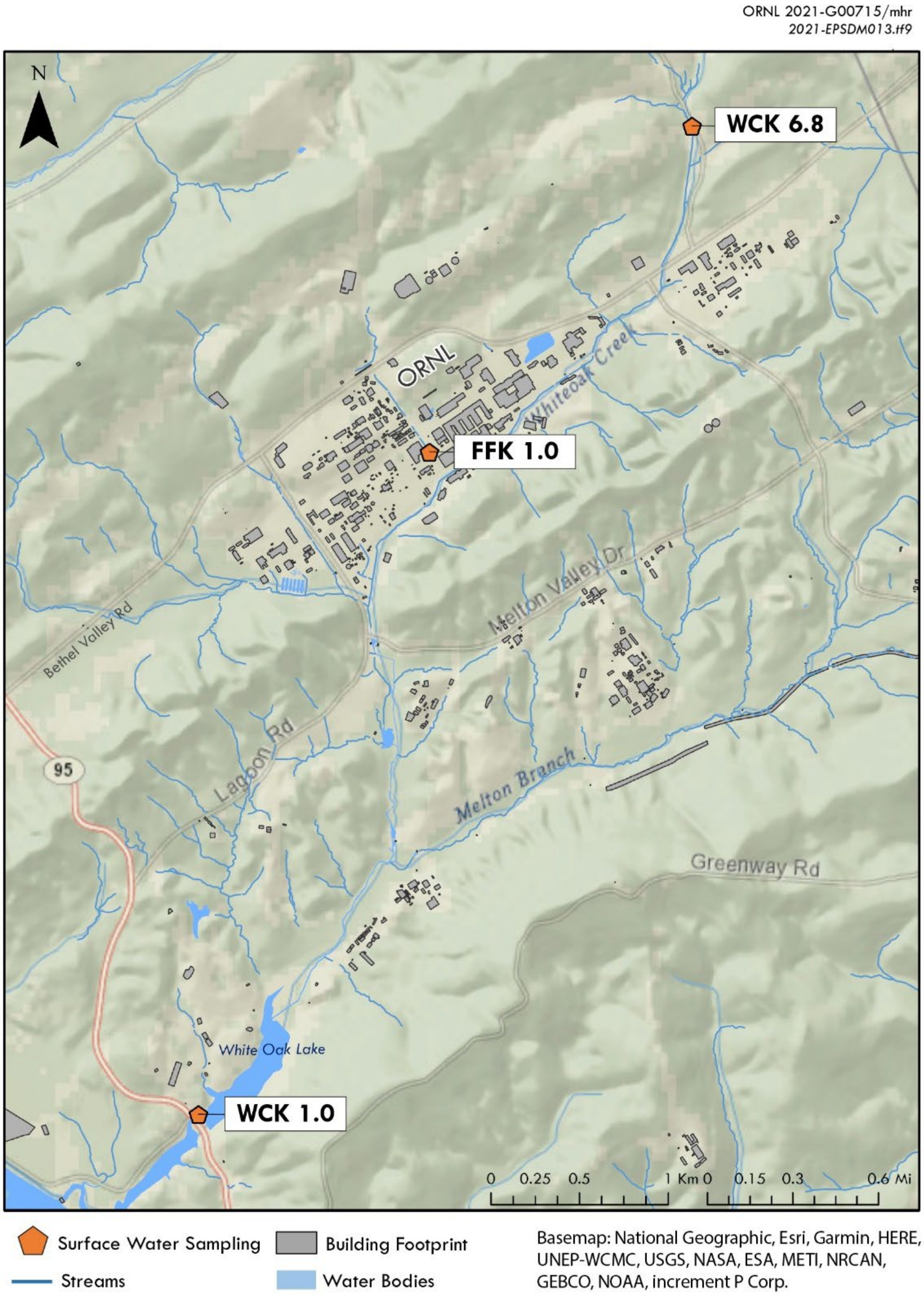
Samples are collected and analyzed for general water quality parameters and are screened for radioactivity at all locations (as part of this program or the WQPP). Samples are further analyzed for specific radionuclides when general screening levels are exceeded. Samples from WCK 1.0 are analyzed for volatile organic compounds (VOCs) and PCBs. Samples from WCK 6.8 are also analyzed for PCBs. The State of Tennessee has designated use classifications for all surface water bodies in the state. Each classification has different WQCs to protect waterbodies according to their designated uses. WCK 6.8 and WCK 1.0 are classified for freshwater fish and aquatic life. Tennessee WQCs associated with these classifications are used as references where applicable (TDEC 2015). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS (DOE 2021a) is used for radionuclide comparison.

No radionuclides were reported above 4 percent of the DCS at the Fifth Creek location (FFK 0.1) in 2022. Beta activity and $^{89/90}Sr$ were detected in samples from both sampling events at the Fifth Creek location and are related to known sources in the middle of the ORNL main campus. No $^{89/90}Sr$ results above 4 percent of the DCS were reported for samples collected at the upstream WOC sampling location (WCK 6.8). The other radionuclide results from WCK 6.8 and from samples collected at WOD (before WOC empties into the Clinch River) are discussed in Section 5.5.3.

Arochlor -1254 was detected at a low, estimated concentration in the September 2022 sample from WCK 1.0. PCBs were not detected in any other quarter at WCK 1.0 in 2022. Arochlor -1254 and -1260 were both detected at low, estimated concentrations in one quarter in 2021, and prior to that PCBs had not been detected at WCK 1.0 since 2017. Five VOCs were detected in samples from WCK 1.0 during 2022: ethylbenzene, toluene, and xylene were detected in the sample collected in September; methylene chloride was detected in the sample collected in December; and acetone was detected in the samples collected in both September and December. All VOC detections were at low, estimated values. Acetone, methylene chloride, ethylbenzene, and xylene were all detected in the associated trip blanks at levels similar to those in the WCK 1.0 samples, and methylene chloride and toluene were detected in the associated method blanks. All VOCs detected in 2022 except for ethylbenzene have previously been detected at WCK 1.0. In addition, acetone, methylene chloride, toluene, and xylene have occasionally been detected in at least one on-site groundwater well in past monitoring. Acetone, methylene chloride, and toluene are all common laboratory contaminants.

5.5.10. Carbon Fiber Technology Facility Wastewater Monitoring

Facility and process wastewater from activities at CFTF are discharged to the City of Oak Ridge sanitary sewer system under conditions established in City of Oak Ridge Industrial Wastewater Discharge Permit 1-12. Permit limits, parameters, and 2022 compliance status for this permit are summarized in Table 5.15.



Acronyms: *FFK = Fifth Creek kilometer* *WCK = White Oak Creek kilometer*

Figure 5.38. ORNL surface water sampling locations, 2022

Table 5.14. ORNL surface water sampling locations, frequencies, and parameters, 2022

Location[a]	Description	Frequency and type	Parameters
WCK 1.0[b]	White Oak Lake at WOD	Quarterly, grab	Volatiles, PCBs, field measurements[c]
WCK 6.8[d]	WOC upstream from ORNL	Quarterly, grab	PCBs, field measurements[c]
FFK 0.1	Fifth Creek just upstream of WOC (ORNL)	Semiannually, grab	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[c]

[a] Locations identify bodies of water and locations on them (e.g., WCK 1.0 is 1 km upstream from the confluence of WOC and the Clinch River).

[b] For this location, radiological parameters and mercury are monitored under another program (the WQPP) and therefore are not included in this program.

[c] Field measurements consist of dissolved oxygen, pH, and temperature.

[d] Radiological monitoring is performed at this location as part of the WQPP.

Acronyms:

FFK = Fifth Creek kilometer
ORNL= Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
WCK = WOC kilometer
WOC = White Oak Creek
WOD = White Oak Dam
WQPP = Water Quality Protection Plan

Table 5.15. Industrial and commercial user wastewater discharge permit compliance at the ORNL Carbon Fiber Technology Facility, 2022

Effluent parameters	Permit limits		Permit compliance		
	Daily max. (mg/L)	Monthly ave. (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[a]
		Outfall 01 (Underground Quench Water Tank)			
Cyanide	3.9	0.1	0	0	100
pH (standard units)	6–9		0	0	100
		Outfall 02 (Electrolytic Bath Tank)			
pH (standard units)	6–9		0	4	100
		Outfall 03 (Sizing Bath Tank)			
Copper	0.87	0.10	0	1	100
Zinc	1.24	0.60	0	1	100
Total phenol	4.20	-	0	1	100
pH (standard units)	6–9		0	1	100

[a] Percentage compliance = 100 − (number of noncompliances/number of samples) × 100

5.6. ORNL Groundwater Monitoring Program

Groundwater monitoring at ORNL was conducted under two sampling programs in 2022: DOE OREM monitoring and DOE SC surveillance monitoring. The DOE OREM groundwater monitoring program was conducted by UCOR in 2022. The SC groundwater monitoring surveillance program was conducted by UT-Battelle.

5.6.1. Summary of US Department of Energy Office of Environmental Management Groundwater Monitoring

Monitoring was performed as part of an ongoing comprehensive CERCLA cleanup effort in Bethel and Melton Valleys, the two administrative watersheds at the ORNL site. Groundwater monitoring for baseline and trend evaluation in addition to measuring effectiveness of completed CERCLA RAs is conducted as part of the WRRP. The WRRP is managed by UCOR for the DOE OREM program. The results of CERCLA monitoring for ORR for FY 2022, including monitoring at ORNL, are evaluated and reported in the 2023 *Remediation Effectiveness Report* (DOE 2023) as required by the ORR Federal Facility Agreement.

Groundwater monitoring conducted as part of the OREM program at ORNL includes routine sampling and analysis of groundwater in Bethel Valley to measure performance of several RAs and to continue contaminant and groundwater quality trend monitoring. In Melton Valley, where CERCLA RAs were completed in 2006 for the extensive waste management areas, the groundwater monitoring program includes monitoring groundwater levels to evaluate the effectiveness of hydrologic isolation of buried waste units. Additionally, groundwater is sampled and analyzed for a wide range of general chemical and contaminant parameters in 46 wells within the interior portion of the closed waste management area.

In FY 2010, DOE initiated a groundwater treatability study at the Bethel Valley 7000 Area VOC plume. This plume contains trichloroethylene and its transformation products cis-1,2-dichloroethene and vinyl chloride, all at concentrations greater than EPA primary drinking water standards. The treatability study is a laboratory and field demonstration to determine whether microbes inherent to the existing subsurface microbial population can fully degrade the VOCs to nontoxic end products. Post-treatment monitoring of the 7000 Area plume continues.

During FY 2022, post-remediation monitoring continued at Solid Waste Storage Area (SWSA 3) to evaluate the effectiveness of the 2011 hydrologic isolation of the area that included construction of a multilayer cap and an upgradient storm flow and shallow groundwater diversion drain. RAs and monitoring were specified in a CERCLA RA work plan that was developed by DOE and approved by EPA and TDEC before the project was started.

5.6.1.1. Bethel Valley

During FY 2011, construction was completed for RAs at SWSA 1 and SWSA 3, two former waste storage sites that were used for disposal of radioactively contaminated solid wastes between 1944 and 1950. Wastes disposed of at SWSA 1 originated from the earliest operations of ORNL; those at SWSA 3 originated from ORNL, Y-12, the K-25 Site (ETTP), and off-site sources. Although most of the wastes disposed of at SWSA 3 were solids, some were containerized liquid wastes. Some wastes were encapsulated in concrete after placement in burial trenches, but most of the waste was covered with soil. The Bethel Valley Record of Decision (ROD) (DOE 2002) selected hydrologic isolation using multilayer caps and groundwater diversion trenches as the RA for the waste burial grounds and construction of soil covers over the former contractor's landfill and contaminated soil areas near SWSA 3. The baseline monitoring conducted during FY 2010 included measurement of groundwater levels to obtain baseline data to allow evaluation of post-remediation groundwater level suppression. Sampling and analysis to evaluate groundwater quality and contaminant concentrations were also conducted. Post-remediation monitoring was specified for SWSA 3 in the *Phased Construction Completion Report for the Bethel Valley Burial Grounds at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE 2012). Required monitoring includes quarterly groundwater level monitoring in 42 wells with continuous water-level monitoring in 8 wells to confirm cap performance. Groundwater samples are collected semiannually at 13 wells for laboratory analyses to evaluate groundwater contaminant concentration trends.

FY 2022 monitoring results showed that the cap was effective, although target groundwater elevations have not yet been attained at four of eight wells. Drinking water standards are used as screening water quality concentrations to evaluate the site response to remediation. Concentrations of ^{90}Sr, a signature contaminant at SWSA 3, decreased significantly in groundwater and at the adjacent surface water monitoring sites at Raccoon Creek and the Northwest Tributary. Groundwater data trend evaluation shows that although within the past 10 years ^{90}Sr exceeded the 8 pCi/L maximum contaminant level derived concentration, only two wells had ^{90}Sr concentrations greater than the 8 pCi/L screening concentration during FY 2022. Mann–Kendall trends for ^{90}Sr in those two wells were stable for the most recent 5-year data evaluation period. Concentrations of benzene, potentially from natural sources, exhibited no defined trend in one well and an increasing trend in a second well; FY 2022 maxima were 0.006 mg/L for the first well and 0.008 mg/L for the second well, which are slightly greater than the 0.005 mg/L maximum contaminant level. During FY 2020, as part of the DOE OREM program, three groundwater monitoring wells in Bethel Valley to the west of Tennessee Highway 95 were monitored to detect and track contamination from the SWSA 3 area. Data from those three wells supplement data being collected from a multiport well (4579) near SWSA 3 for exit pathway groundwater monitoring in western Bethel Valley. Groundwater monitoring near SWSA 3 and the exit pathway as well as groundwater and surface water monitoring at the northwest tributary of WOC and in the headwaters of Raccoon Creek allow integration of data concerning SWSA 3 contaminant releases. The data are presented in the *2023 Remediation Effectiveness Report for the US Department of Energy Oak Ridge Site, Oak Ridge, Tennessee, Data and Evaluations* (DOE 2023). To enhance exit pathway groundwater monitoring near the ORR property boundary at the Clinch River in western Bethel Valley, three deep boreholes were drilled and characterized. During FY 2021, Westbay multizone sampling systems were installed to enable discrete zone sampling in the carbonate bedrock units. The three new exit pathway multizone wells were sampled quarterly throughout FY 2022 to assess groundwater quality conditions near the DOE property boundary at the western end of Bethel Valley. A report documenting the well installations and first-year monitoring results will be issued during 2023.

Groundwater monitoring continued at the ORNL 7000 Area during FY 2022 to evaluate treatability of the VOC plume at that site. Site characterization testing of the endemic microbial community showed that microbes present at that site are capable of fully degrading trichloroethylene and its degradation products if sufficient electron donor compounds are present in the subsurface environment. During FY 2011, a mixture of emulsified vegetable oil and a hydrogen-releasing compound was injected into four existing monitoring wells in the 7000 Area. Ongoing monitoring of VOC concentrations shows that the effects of the biostimulation test continue to be apparent, although at decreasing levels.

The other principal element of the Bethel Valley ROD (DOE 2002) remedy that requires groundwater monitoring is the containment pumping to control and treat discharges from the ORNL Central Campus Core Hole 8 plume. The original action for the plume was a CERCLA removal action that was implemented in 1995 with the performance goal of reducing ^{90}Sr in WOC.

Strontium-90 is a principal CERCLA contaminant of concern in surface water in WOC. The ROD established a 37 pCi/L goal for the annual average concentration of ^{90}Sr at the 7500 Bridge Weir. During FY 2022, as in FY 2020 and FY 2021, this goal was not attained. Over the past several years, various problems have occurred in Bethel Valley that have caused the failure to meet the ^{90}Sr concentration goal. Below ground infrastructure deterioration related to process liquid wastewater handling in the aging ORNL Central Campus area allowed contaminant releases. Furthermore, treatment facility upset conditions during startup of new treatment processes reduced the effectiveness of ^{90}Sr removal during part of FY 2021. The DOE EM program is investigating sources of groundwater ^{90}Sr contamination that seep directly into WOC as nonpoint discharges to the stream.

5.6.1.2. Melton Valley

The Melton Valley ROD (DOE 2000) established goals for reducing contaminant levels in surface water, reducing groundwater level fluctuation within hydrologically isolated areas, and mitigating impacts to groundwater. Groundwater monitoring to determine the effectiveness of the remedy in Melton Valley includes groundwater level monitoring in wells within and adjacent to hydrologically isolated shallow waste burial areas and groundwater quality monitoring in selected wells adjacent to buried waste areas.

Groundwater level monitoring shows that the hydrologic isolation component of the Melton Valley remedy is effectively minimizing the amount of percolation water contacting buried waste and is reducing contaminated leachate formation. The total amount of rainfall at ORNL during FY 2022 was about 62 in., which is about 8 in. more than the long-term annual average for ORR. In a few areas, groundwater levels within capped areas continue to respond to groundwater fluctuations imposed from areas outside the caps, but contact of groundwater with buried waste is minimal. Overall, the hydrologic isolation systems are performing as designed.

Groundwater quality monitoring in the interior of Melton Valley shows that in general, groundwater contaminant concentrations are declining or are stable following RAs. At SWSA 6, groundwater quality monitoring that is substantively equivalent to the former RCRA monitoring continues. Several VOCs continue to be detected in wells along the eastern edge of the site at essentially stable concentrations.

During the past 10 years of groundwater monitoring in the Melton Valley exit pathway, several site-related contaminants have been detected in groundwater near the Clinch River. Low concentrations of strontium, ^{3}H, uranium, and VOCs have been detected intermittently in several of the multizone sampling locations. Groundwater in the exit pathway wells has high alkalinity and sodium and exhibits elevated pH. During FY 2020, an off-site groundwater monitoring well array west of the Clinch River and adjacent to Melton Valley was monitored as part of the OREM program. Monitoring included groundwater level monitoring to evaluate potential flowpaths near the river and sampling and analysis for a wide array of metals, anions, radionuclides, and VOCs. Groundwater level monitoring showed that natural head gradient conditions cause groundwater seepage to converge toward the Clinch River from both the DOE (eastern) and off-site (western) sides of the river. Monitoring results are summarized in the *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision* (DOE 2021b).

5.6.2. DOE Office of Science Groundwater Surveillance Monitoring

DOE Order 458.1 (DOE 2020) is the primary requirement for a site-wide groundwater protection program at ORNL. As part of the groundwater protection program, and to be consistent with UT-Battelle management objectives, groundwater surveillance monitoring was performed to monitor ORNL groundwater exit pathways and UT-Battelle facilities ("active sites") potentially posing a risk to groundwater resources at ORNL. Results of the DOE SC groundwater surveillance monitoring are reported in the following sections.

Exit pathway and active-sites groundwater surveillance monitoring points sampled during 2022 included seep/spring and surface-water monitoring locations in addition to groundwater surveillance monitoring wells. Seep/spring and surface-water monitoring points located in appropriate groundwater discharge areas were used in the absence of monitoring wells.

Groundwater pollutants monitored under the exit pathway groundwater surveillance and active-sites monitoring programs are not regulated by federal or state rules. Consequently, no permit-required or other applicable standards exist for evaluating results. To assess groundwater quality at these monitoring locations, and to facilitate comparison of results among locations, results were compared with selected federal and state standards even though those standards are not directly applicable. For radionuclide parameters for which alternative standards were not identified, results were compared to 4 percent of the DCSs (DOE 2021a). Regardless of the standards selected for comparison, it is important to note that no members of the public consume groundwater from ORNL wells, nor do any groundwater wells furnish drinking water to personnel at ORNL.

5.6.2.1. Exit Pathway Monitoring

During 2022, exit pathway groundwater surveillance monitoring was performed in accordance with the exit pathway sampling and analysis plan (Bonine 2013). Groundwater exit pathways at ORNL include areas from watersheds or sub-watersheds where groundwater discharges to the Clinch River–Melton Hill Reservoir to the west, south, and east of the ORNL main campus. The exit pathway monitoring points were chosen based on hydrologic features, screened interval depths (for wells), and locations relative to discharge areas proximate to DOE facilities operated by or under the control of UT-Battelle. The groundwater exit pathways at ORNL include four discharge zones identified by a data quality objectives process. One of the original exit pathway zones was split into two zones for geographic expediency. The Southern Discharge Area Exit Pathway was carved from the East End Discharge Area Exit Pathway. The five zones are listed below. Figure 5.39 shows the locations of the exit pathway monitoring points targeted for sampling in 2022:

- The 7000/Bearden Creek Discharge Area Exit Pathway
- The East End Discharge Area Exit Pathway
- The Northwestern Discharge Area Exit Pathway
- The Southern Discharge Area Exit Pathway
- The WOC Discharge Area Exit Pathway

The efficacy of the exit pathway monitoring program was reviewed in late 2011. As a result, the groundwater monitoring program was modified through an optimization approach that included frequency analysis of parameters and their concentrations based on an exhaustive review of historical groundwater sampling data. The modification resulted in a staggered groundwater monitoring schedule and analytical suite selection. This approach was initiated in 2012. The groundwater monitoring that was conducted in 2022 is summarized in Table 5.16.

Unfiltered samples were collected. The organic suite comprised VOCs and semivolatile organic compounds; the metallic suite included heavy and nonheavy metals; and the radionuclide suite comprised gross alpha/gross beta activity, gamma emitters, $^{89/90}$Sr, and ^{3}H. In 2022, dry season samples were collected in May through August, and wet season samples were collected in December.

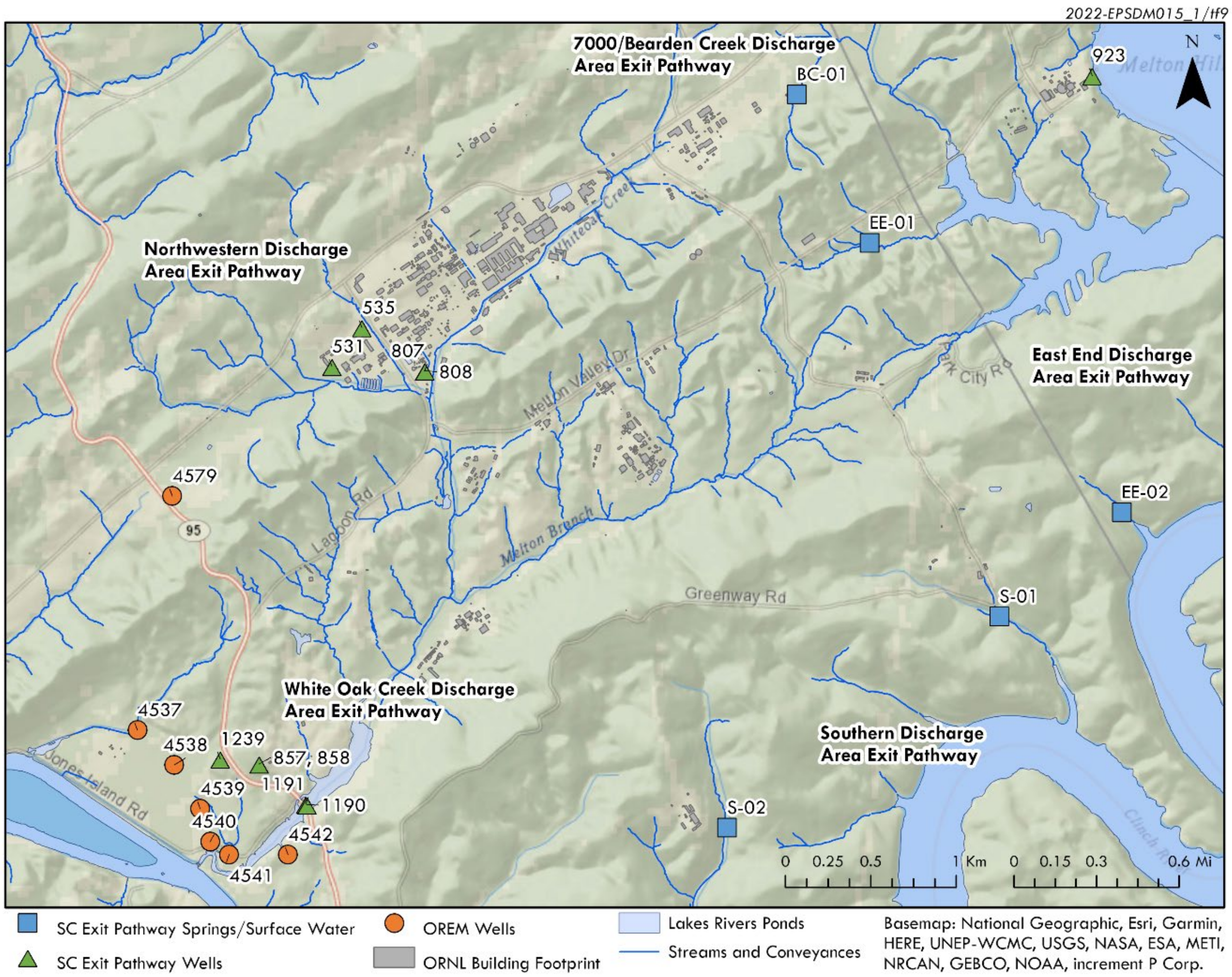
Exit pathway monitoring results

Table 5.17 summarizes radiological parameters detected in samples collected from exit pathway monitoring points during 2022. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

Exit pathway groundwater surveillance summary

Concentrations of metals and man-made radionuclides observed in groundwater exit pathway discharge areas in 2022 at ORNL were generally consistent with observations reported in past annual site environmental reports for ORR.

Based on the results of the 2022 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.



Acronyms:
OREM = DOE Oak Ridge Office of Environmental Management
SC = DOE Office of Science

Figure 5.39. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2022

Table 5.16. Exit pathway groundwater monitoring conducted in 2022

Monitoring point	Season	
	Wet	Dry
	7000 Bearden Creek Discharge Area	
BC-01	Radiological	Radiological
	East End Discharge Area	
923	Radiological, organics, and metals	Radiological
EE-01	Radiological	Radiological
EE-02	Not sampled[a]	*Radiological*
	Northwestern Discharge Area	
531	Radiological, organics, and metals	Radiological
535	Radiological	Radiological
807	Radiological	Radiological
808	Radiological, organics, and metals	Radiological
	Southern Discharge Area	
S-01	Not sampled[a]	Not sampled[a]
S-02	Radiological	Radiological
	White Oak Creek Discharge Area	
857	Radiological	Radiological
858	Radiological	Radiological
1190	Radiological, organics, and metals	Radiological, organics, and metals
1191	Radiological, organics, and metals	Radiological, organics, and metals
1239	Radiological, organics, and metals	Radiological

[a] Locations EE-02 and S-01 (stream locations) were not sampled in the 2022 wet season, and location S-01 was not sampled in the dry season because of lack of water flow.

Table 5.17. Radiological parameters detected in 2022 exit pathway groundwater monitoring

Monitoring Location	Parameter	Concentration (pCi/L)		
		Wet season[a]	Dry season[a]	Reference value[b]
		7000 Bearden Creek Discharge Area		
Spring BC-01	Alpha	U0.53	3.42	15
Spring BC-01	Beta	U2.16	3.73	50
Spring BC-01	^{214}Bi	15.5	ND	40,000
Spring BC-01	^{214}Pb	16.3	7.64	23,600
		East End Discharge Area		
Well 923	Beta	U0.442	4	50
Stream EE-01	Alpha	U0.701	2.94	15
Stream EE-01	^{214}Bi	31.9	ND	40,000
Stream EE-01	^{214}Pb	31.8	ND	23,600
Stream EE-02	Beta	NF	4.23	50
		Northwestern Discharge Area		
Well 531	Beta	2.76	U1.36	50
Well 531	^{214}Bi	ND	9.14	40,000
Well 531	^{214}Pb	ND	9.06	23,600
Well 535	Beta	2.14	U0.999	50
Well 535	^{214}Bi	ND	5.81	40,000
Well 535	^{214}Pb	ND	14.7	23,600
Well 807	Beta	4.96	4	50
Well 807	^{3}H	U175	252	20,000
Well 808	Beta	5.05	U2.51	50
Well 808	^{212}Pb	8.75	ND	292
		Southern Discharge Area		
Stream S-02	Beta	2.15	U0.254	50
		White Oak Creek Discharge Area		
Well 857	Beta	2.78	U0.293	50
Well 858	Beta	U0.264	5.81	50
Well 1190	Alpha	U0.521	3.12	15
Well 1190	Beta	2.85	4.66	50
Well 1190	^{212}Bi	ND	31.9	17,200
Well 1190	^{214}Bi	9.61	46.6	40,000
Well 1190	^{212}Pb	ND	9.88	292
Well 1190	^{214}Pb	ND	46.7	23,600
Well 1190	^{208}Tl	ND	5.3	NA
Well 1190	^{3}H	10,700	14,700	20,000
Well 1191	Alpha	4.12	4.42	15
Well 1191	Beta	180	206	50

Table 5.17. Radiological parameters detected in 2022 exit pathway groundwater monitoring (continued)

Monitoring Location	Parameter	Concentration (pCi/L)		
		Wet season[a]	Dry season[a]	Reference value[b]
Well 1191	^{214}Bi	ND	17.9	40,000
Well 1191	^{212}Pb	ND	5.27	292
Well 1191	^{214}Pb	ND	20.5	23,600
Well 1191	$^{89/90}Sr$	93.7	139	68
Well 1191	^{3}H	2,400	4,110	20,000
Well 1239	Beta	2.23	U0.00135	50
Well 1239	^{3}H	238	U106	20,000

[a] NF = there was no flow at the spring or stream sampling location during sampling attempts
ND = the analyte was not detected in the gamma scan that was performed
U = the analyte was measured but not detected above the practical quantitation limit/contractor-required detection limit
[b] Current federal and state standards were used as reference values. If no federal or state standard exists for the analyte, 4 percent of the DOE derived concentration standard is used as the reference value.

Nine radiological contaminants were detected in exit pathway groundwater samples collected in 2022. Gross beta and $^{89/90}$Sr were the only radiological parameters that exceeded reference values at any of the discharge areas. Consistent with previous monitoring, these parameters were observed at concentrations above their respective reference values in the WOC discharge area.

A new maximum concentration for ^{208}Tl was measured in the sample collected from groundwater well 1190 in the WOC discharge area during the dry-season sampling event. The measured ^{208}Tl concentration was 5.3 pCi/L (compared with a previous maximum of 4.25 pCi/L). Thallium-208 is a short-lived radioisotope in the decay chain of ^{232}Th (EPA 2021).

Bismoth-212, a short-lived radioisotope in the decay chain of naturally occurring ^{232}Th (EPA 2021), was detected for the first time at well 1190 (31.9 pCi/L) in the WOC discharge area in the dry-season sampling event. Bismoth-212 is occasionally encountered at similar concentrations in groundwater from the ORNL area.

Twenty-five metallic parameters were detected in exit pathway groundwater samples collected in 2022. Only two metals, iron and manganese, were detected at concentrations exceeding reference values. These metals are both commonly found in groundwater at ORNL.

One organic compound was detected at a concentration above the analytical method practical quantitation limit in exit pathway groundwater monitoring during 2022. Bis(2-ethylhexyl) phthalate was detected in the wet-season sample from well 1239 at 5.56 ug/L. Three organic compounds were detected at estimated concentrations (i.e., concentrations between the method analytical detection level and the practical quantitation limit). Acetone was detected during wet-season monitoring in the samples from wells 531, 923, 1190, 1191, and 1239. Bis(2-ethylhexyl) phthalate was detected in the sample from well 923 in wet-season monitoring. Toluene was detected in the sample from well 531 during wet-season monitoring. Acetone, toluene, and some phthalate compounds are common laboratory contaminants (EPA 2014).

5.6.2.2. Active Sites Monitoring—High Flux Isotope Reactor

Two storm water outfall collection systems (outfalls 281 and 383) intercept groundwater in the HFIR area and are routinely monitored under a monitoring plan associated with the ORNL

NPDES permit. (See Section 5.5.3 for a discussion of results.)

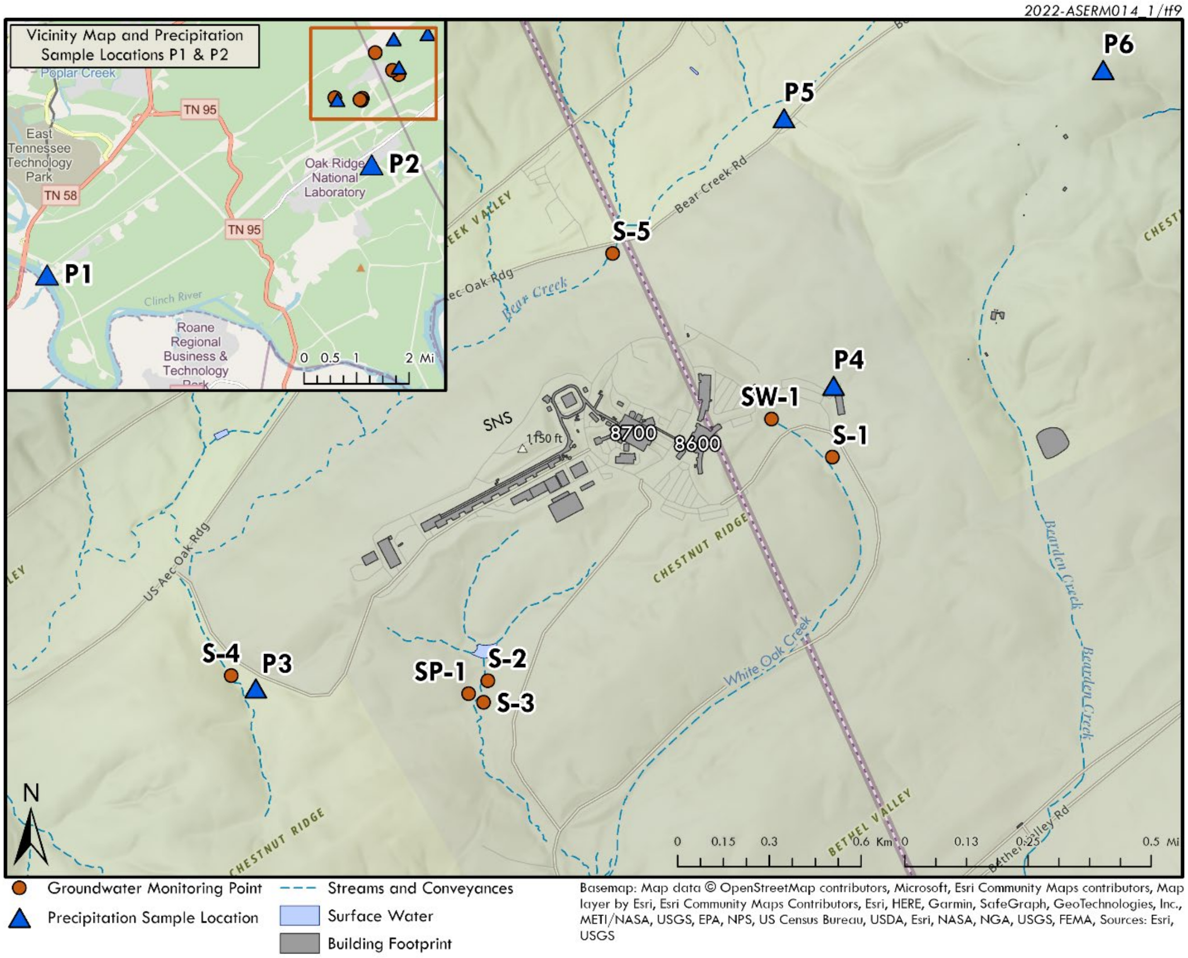
5.6.2.3. Active-Sites Monitoring—Spallation Neutron Source

Active-sites groundwater surveillance monitoring was performed in 2022 at the SNS site under the SNS operational monitoring plan (Bonine, Ketelle, and Trotter 2007) because of the potential for adverse impact on groundwater resources at ORNL should a release occur. Operational monitoring was initiated following a 2-year (2004–2006) baseline monitoring program and will continue throughout the duration of SNS operations.

The SNS site is located atop Chestnut Ridge, northeast of the main ORNL facilities. The site slopes to the north and south, and small stream valleys populated by springs and seeps lie on the ridge flanks. Surface water drainage from the site flows into Bear Creek to the north and WOC to the south.

The SNS site is a hydrologic recharge area underlain by geologic formations that form karst geologic features. Groundwater flow directions at the site are based on the generally observed tendency for groundwater to flow parallel to geologic strike (parallel to the orientation of the rock beds) and via karst conduits that break out at the surface in springs and seeps located downgradient of the SNS site. A sizable fraction of infiltrating precipitation (groundwater recharge) flows to springs and seeps via the karst conduits. SNS operations have the potential for introducing radioactivity (via neutron activation) in the shielding berm surrounding the SNS linac, accumulator ring, or beam transport lines. A principal concern is the potential for water infiltrating the berm soils to transport radionuclide contamination generated by neutron activation to saturated groundwater zones. The ability to accurately model the fate and transport of neutron activation products generated by beam interactions with the engineered soil berm is complicated by multiple uncertainties resulting from a variety of factors, including hydraulic conductivity differences in earth materials found at depth, the distribution of water-bearing zones, the fate and transport characteristics of neutron activation products produced, diffusion and advection, and the presence of karst geomorphic features found on the SNS site. These uncertainties led to the initiation of the groundwater surveillance monitoring program at the SNS site. Objectives of the groundwater monitoring program outlined in the operational monitoring plan include maintaining compliance with applicable DOE contract requirements and environmental quality standards and providing uninterrupted monitoring of the SNS site.

A total of seven springs, seeps, and surface water sampling points were routinely monitored as analogues to, and in lieu of, groundwater monitoring wells. Locations were chosen based on hydrogeological factors and proximity to the beam line. Since 2016, precipitation samples have also been collected for ^{3}H analyisis at six of the springs, seeps, and surface water locations. Figure 5.40 shows the locations of the specific monitoring points sampled during 2022.



Acronyms: *S = springs* *SP = seeps* *SW = surface water sampling areas*

Figure 5.40. Groundwater and precipitation monitoring locations at the Spallation Neutron Source, 2022

In November 2011, the SNS historical ^{3}H data were evaluated to determine whether sampling could be optimized. The influence of flow condition on the proportion of ^{3}H detects and nondetects in water samples collected at SNS from April 2004 through September 2011 was examined. In addition, the effect of seasonality on the proportion of detects and nondetects was examined for the same data set. The results of the analysis indicate that the proportion of detects to nondetects is not related to flow conditions or seasonality. This implies that samples could be collected during any flow condition and season with the expectation that there would be no statistical difference in the proportion of ^{3}H detects to nondetects. The results of the statistical analysis of the April 2004–September 2011 data set were the basis for the modified operational plan monitoring scheme implemented in 2012.

Quarterly sampling at each monitoring point continued in 2022, allowing the opportunity for monitoring in wet and dry seasons. All sampling performed in 2022 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions. Table 5.18 shows the sampling and parameter analysis schedule followed in 2022.

Table 5.18. Spallation Neutron Source monitoring program schedule, 2022

Monitoring location	Quarter 1 January–March	Quarter 2 April–June	Quarter 3 July–September	Quarter 4 October–December
SW-1	^{3}H	^{3}H	^{3}H and expanded suite[a]	^{3}H
S-1	^{3}H and expanded suite[a]	^{3}H	^{3}H	^{3}H and expanded suite[a]
S-2	^{3}H and expanded suite[a]	^{3}H	^{3}H	^{3}H and expanded suite[a]
S-3	^{3}H and expanded suite[a]	^{3}H	^{3}H	^{3}H
S-4	^{3}H	^{3}H and expanded suite[a]	^{3}H	^{3}H
S-5	^{3}H	^{3}H and expanded suite[a]	^{3}H	^{3}H
SP-1	^{3}H	^{3}H	^{3}H and expanded suite[a]	^{3}H

[a] *The expanded suite includes gross alpha and gross beta activity, ^{14}C, and gamma emitters.*

Spallation Neutron Source site results

Sampling at the SNS site occurred quarterly in 2022. Low concentrations of alpha and beta activities were detected at springs S-2 and S-5. The alpha and beta activities detected at the S-5 monitoring location are attributed to CERCLA contaminants in Bear Creek Valley associated with legacy waste management practices at the Y-12 facility. Table 5.19 summarizes SNS sampling locations and radionuclide detections for 2022. Analytical results were compared with current federal or state standards or 4 percent of the DCS. Only alpha activity measured at ths S-5 location exceeded its reference value in 2022.

In addition to SNS surface water sampling, precipitation monitoring for ^{3}H has been conducted at six locations since 2016. The precipitation sampling is conducted contemporaneously with the surface water sampling. Tritium can be an airborne constituent that is released from several DOE facilities at ORNL, from Tennessee Valley Authority reactor sites, and from commercial radiological waste processing facilities in the area. The precipitation sampling locations are shown in Figure 5.40, and the results are summarized in Table 5.20. Twenty-eight sampling events have been conducted at each of the precipitation monitoring locations. The highest ^{3}H concentrations and frequencies of detection were at sample location P1, approximately 6 miles southwest of the SNS site. The second-highest concentrations and detection frequency occurred at location P4, which is located within 2,000 ft northeast of the SNS target facility. Tritium rainout from atmospheric ^{3}H releases from sources including DOE facilities, Tennessee Valley Authority facilities, and commercial radiological waste-handling and -processing facilities creates a regional background of ^{3}H in some surface water and groundwater samples.

Table 5.19. Radiological concentrations detected in samples collected at the Spallation Neutron Source, 2022[a]

Parameter	Concentrations (pCi/L)				Reference value[b]
	February	June	September	November	
			***SW-1*[c]**		
^3H	1,110	2,950	1,330	2,310	20,000
			***S-1*[d]**		
^3H	714	717	440	296	20,000
			***S-2*[e]**		
^3H	597	579	602	1,209	20,000
			***S-3*[f]**		
Beta	5.85				50
^3H	732	U112	227	264	20,000
			***S-4*[g]**		
^3H	457	378	259	341	20,000
			***S-5*[g]**		
Alpha		15.2			15
Beta		14.9			50
^3H	560	340	281	275	20,000
			***SP-1*[c]**		
^3H	326	479	242	412	20,000

[a] *In addition to ^3H analyses, an extended suite of parameters was analyzed at each location during one 2022 sampling event. The extended suite includes gross alpha, gross beta, gamma scan, and ^{14}C. Reults for ^3H and detected concentrations from the extended suite are listed in the table.*

[b] *Current federal and state standards are used as reference values. If no federal or state standard exists for a particular radionuclide, 4 percent of the derived concentration standard for a radionuclide is used.*

[c] *Analysis of extended suite completed in September.*

[d] *Analysis of extended suite completed in November.*

[e] *Analysis of extended suite completed in February and November.*

[f] *Analysis of extended suite completed in February.*

[g] *Analysis of extended suite completed in June.*

Table 5.20. Summary of precipitation ^3H monitoring results, 2016–2022

Sample Location	Total Samples	Total Detects	Maximum Detect (pCi/L)	Date of Maximum Detect	Date of Most Recent Detect
P1	28	7	4,930	05/21/2016	11/11/2022
P2	28	2	1,070	05/21/2016	02/07/2018
P3	28	3	1,230	05/21/2016	06/27/2022
P4	28	5	2,010	10/22/2019	12/11/2021
P5	28	4	908	05/21/2016	08/29/2020
P6	28	2	1,240	02/07/2018	02/07/2018

5.6.2.4. Emerging Contaminant Assessment—Potential for Per- and Polyfluoroalkyl Substances in ORNL Area Groundwater

A group of fluorinated organic chemical compounds collectively referred to as per- and polyfluoroalkyl substances (PFAS) are contaminants of emerging concern. PFAS compounds are persistent in the environment, and some are known to bioaccumulate in humans or wildlife. They have been widely used in both consumer and industrial products, and traces have been detected in environmental media in many parts of the world.

Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are the two PFAS compounds that have been produced in the largest amounts in the United States and that have been studied most. Through 2001, PFOS and other PFAS compounds were used in the manufacture of aqueous film-forming foams (AFFFs), and use of such foams, including firefighting training activities, may have contributed to environmental releases. The information contained in this and the previous paragraph was summarized from EPA's *Technical Fact Sheet—Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)* (EPA 2017).

On June 21, 2022, EPA published updated health advisories for PFOA and PFOS of 0.004 ng/L and 0.02 ng/L, respectively (EPA 2022b). These replaced the final health advisory of 70 ng/L for combined PFOA and PFOS that was issued in 2016. At the same time, the EPA also issued final health advisiories for hexafluoropropylene oxide dimer acid and its ammonium salt (collectively referred to as GenX chemicals) and perflourobutane sulfonic acid (PFBS) and the related compound potassium perfluorobutane sulfonate (together referred to as PFBS) of 10 ng/L and 2,000 ng/L, respectively.

Historically, firefighter training at ORNL included training in the use of AFFFs, and the foams that were used in past training activities may have contained PFAS compounds. The discharges of these foams are suspected to be the most significant potential source of PFAS in environmental media at ORNL. Most of the training was conducted at four locations: adjacent to the ORNL Fire Station (Building 2500), at the Fire Training and Test Facility (Building 2648), on the southeast corner of First Street and Bethel Valley Road (near where Building 2040 was later constructed), and at a location on the north side of Old Bethel Valley Road in the Bearden Creek watershed. A sampling and analysis plan has been developed and will be implemented in 2023 to assess these areas for the presence of PFAS compounds in groundwater and in surface water bodies draining these areas. The plan also includes monitoring surface water locations draining other parts of the ORNL campus, including former waste storage areas, to determine if PFAS compounds from sources other than the use of AFFFs are present and are reaching surface water bodies. Surface water monitoring will include the use of passive sampling devices, which are deployed in stream environments for long periods (typically 4 weeks) and therefore can accumulate PFAS compounds and detect trace concentrations that might not be detectable with traditional water sampling techniques.

Neither groundwater nor surface water at ORNL is a direct source of drinking water. ORNL's water supply is municipal water purchased from the City of Oak Ridge. DOE owns the water distribution system on the ORNL site; limited sampling of the ORNL water distribution system for the presence of PFAS compounds is planned for 2023.

In August 2022, DOE issued the *PFAS Strategic Roadmap: DOE Commitments to Action 2022–2025*. In November 2022, SC directed each SC site to develop an implementation plan to address each of the relevant actions from the roadmap and to submit that implementation plan to SC's PFAS point of contact. ORNL developed the requested implementation plan in December 2022.

5.7. Quality Assurance Program

The UT-Battelle Quality Management System (QMS) has been developed to implement the requirements defined in DOE Order 414.1D, *Quality Assurance* (DOE 2011c). The methods used for successful implementation of the QMS rely on the integration and implementation of quality elements and criteria flowed down through multiple management systems and daily operating processes. These management systems and processes are described in SBMS, where basic requirements are communicated to UT-Battelle staff. Additional or specific customer requirements are addressed at the project or work activity level. The QMS provides a graded approach to implementation based on risk. The application of quality assurance (QA) and quality control (QC) programs specifically focused on environmental monitoring activities on ORR is essential for generating data of known and defensible quality. Each aspect of an environmental monitoring program from sample collection to data management and record keeping must address and meet applicable quality standards. The activities associated with administration, sampling, data management, and reporting for ORNL environmental programs are performed by the UT-Battelle Environmental Protection Services Division (EPSD).

UT-Battelle uses SBMS to provide a systematic approach for integrating QA, environmental, and safety considerations into every aspect of environmental monitoring at ORNL. SBMS is a web-based system that provides a single point of access to all the requirements for staff to safely and effectively perform work. SBMS translates laws, orders, directives, policies, and best-management practices into laboratory-wide subject areas and procedures.

5.7.1. Work/Project Planning and Control

UT-Battelle's work/project planning and control directives establish the processes and requirements for executing work activities at ORNL. All environmental sampling tasks are performed following the four steps required in the work control subject areas:

- Define scope of work.
- Perform work planning—analyze hazards and define controls.
- Execute work.
- Provide feedback.

In addition, EPSD has approved project-specific standard operating procedures for all activities controlled and maintained through the Integrated Document Management System.

Environmental sampling standard operating procedures developed for UT-Battelle environmental sampling programs provide detailed instructions on maintaining chain of custody; identifying, collecting, handling, and preserving samples; decontaminating equipment; and collecting QC samples such as field and trip blanks, duplicates, and equipment rinses.

5.7.2. Personnel Training and Qualifications

The UT-Battelle Training and Qualification Management System provides staff with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently with minimal supervision. This capability is accomplished by establishing site-level procedures and guidance for training program implementation with an infrastructure of supporting systems, services, and processes.

EPSD team leaders are responsible for identifying the training needs, qualifications, and requirements for staff who conduct sampling, data management, and reporting tasks associated with ORNL and ORR-wide environmental surveillance programs. Training status is routinely monitored by the division training officer, and notices of training needs or deficiencies are automatically sent to individual employees. The training program is supplemented by a division-wide required reading program. This program ensures that staff members have reviewed new or revised documents (e.g., procedures, lessons learned) that are applicable to their jobs. Likewise, the Training and Qualification program at TWPC provides employees with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently with minimal supervision. This capability is accomplished by establishing site-level procedures and guidance for training program implementation with an infrastructure of supporting systems, services, and processes.

5.7.3. Equipment and Instrumentation

The UT-Battelle QMS includes subject area directives that require all UT-Battelle staff to use equipment of known accuracy based on appropriate calibration requirements and traceable standards to ensure measurement quality and traceability. The UT-Battelle Facilities and Operations Instrumentation and Control Services team tracks all equipment used in EPSD environmental monitoring programs through a maintenance recall program to ensure that equipment is functioning properly and within defined tolerance ranges.

5.7.3.1. Calibration

The determination of calibration schedules and frequencies is based on a graded approach at the activity-planning level. EPSD environmental monitoring programs follow rigorous calibration schedules to eliminate gross drift and the need for data adjustments. Instrument tolerances, functions, ranges, and calibration frequencies are established based on manufacturer specifications, program requirements, actual operating environment and conditions, and budget considerations.

In addition, a continuous monitor used for CAA compliance monitoring at ORNL Boiler 6 is subject to rigorous QA protocols as specified by EPA methods. A relative accuracy test audit is performed annually to certify the Predictive Emissions Monitoring System for nitrogen oxides and oxygen. The purpose of a relative accuracy test audit is to provide a rigorous QA assessment in accordance with "Performance Specification 16" (40 CFR Parts 60 and 63.). The accuracy of Predictive Emissions Monitoring System is also evaluated by performing relative accuracy audits in accordance with "Performance Specification 16." The results of the QA tests are provided to TDEC quarterly, semiannually, or annually, as applicable.

5.7.3.2. Standardization

EPSD sampling procedures are maintained in the Enterprise Document and Record Management System and include requirements and instructions for the proper standardization and use of monitoring equipment. Requirements include the use of traceable standards and measurements; performance of routine, before-use equipment standardizations; and actions to perform when standardization steps do not produce required values. Standard operating procedures for sampling also include instructions for designating nonconforming instruments as "out-of-service" and initiating requests for maintenance.

5.7.3.3. Visual Inspection, Housekeeping, and Grounds Maintenance

EPSD environmental sampling personnel conduct routine visual inspections of all sampling instrumentation and sampling locations. These inspections identify and address any safety, grounds keeping, general maintenance, and housekeeping issues or needs.

5.7.4. Assessment

Independent audits, surveillance, and internal management assessments are performed to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. External assessments are scheduled based on requests from auditing agencies. Table 5.2 lists environmental audits and assessments performed at ORNL in 2022 and the number of findings identified. EPSD also conducts internal assessments of UT-Battelle environmental monitoring activities. Surveillance results, recommendations, and completion of corrective actions, if required, are also documented and tracked in the UT-Battelle Assessment and Commitment Tracking System.

Independent audits, surveillances, and internal management assessments are performed at TWPC and Building 3019 to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. Corrective actions at TWPC, if required, are documented and tracked in an issues management database or a deficiency reporting database, and Isotek corrective actions for Building 3019 are tracked in its Assessment and Commitment Tracking System.

5.7.5. Analytical Quality Assurance

Laboratories that analyze environmental samples collected for EPSD environmental sampling programs are required to have documented QA/QC programs, trained and qualified staff, appropriately maintained equipment and facilities, and applicable certifications. The laboratories also participate in accreditation, certification, and performance evaluation programs such as the National Environmental Laboratory Accreditation Program (NELAP), Mixed Analyte Performance Evaluation Program (MAPEP), Discharge Monitoring Report Quality Assurance Study (DMRQA), and DOE Environmental Management Consolidated Audit Program (DOECAP), which evaluate laboratories according to stringent and widely accepted criteria for quality, accuracy, reliability, and efficiency. Any issues identified through accreditation or certification programs or performance evaluation testing are addressed with analytical laboratories and are considered when determinations are made on data integrity. Blank and duplicate samples are submitted along with environmental samples to provide an additional check on analytical laboratory performance.

Environmental samples collected in support of EPSD environmental monitoring programs in 2022 were analyzed by one of the three contracted commercial laboratories discussed in this section, the UT-Battelle Radiochemical Materials Analytical Laboratory (RMAL), or the UT-Battelle Environmental Toxicology Laboratory. Contracts with analytical laboratories include statements of work that specify the scope of work, data deliverables, turnaround times, required methods, and detection limits.

GEL Laboratories, a contracted commercial radiochemistry and environmental laboratory in Charleston, South Carolina, holds more than 40 federal and state certifications, accreditations, and approvals, including for ISO 17025 (which contains general requirements for the competence of testing and calibration laboratories) and from the Department of Defense Environmental Laboratory Accreditation Program (DOD-ELAP), DOECAP, and NELAP. Four external audits were performed on-site in 2022. Ten internal audits focusing on analytical and support service activities were conducted to verify compliance with the requirements of the GEL QA/QC program and with client-specified terms. No issues were identified that would affect analytical data reported to clients. In 2022, GEL reported results from 5,331 performance test analyses (including DMRQA, MAPEP, DOECAP, and NELAP). Of these, 5,192 (97.4 percent) fell within acceptance ranges. Those that did not meet acceptance criteria were found to have no effect on data reported to clients.

The Fort Collins Colorado location of ALS, an analytical laboratory that performed testing, inspection, and certification, was contracted for many years to analyze environmental samples collected at ORNL and on ORR. In 2022, the Fort Collins radiochemistry and environmental laboratory closed, and GEL Laboratories was contracted to evaluate samples previously analyzed at ALS. Prior to closure, the Fort Collins laboratory was appropriately accredited, certified, and approved by third-party programs and state accrediting and licensing programs.

Eurofins, a contracted environmental laboratory in Tacoma, Washington, is accredited, licensed, or approved by 11 third-party programs, including ISO 17025, DOD-ELAP, DOECAP, NELAP, and several state licensing or accrediting programs. In 2022, Eurofins participated in MAPEP and DMRQA, and all applicable test results were within acceptable ranges.

RMAL does not hold any outside accreditations. However, in 2022 it initiated the process to obtain ISO 17025 2017 (ISO 2017) accrediation in 2023 and operated in compliance with ISO 17025, the DOD/DOE *Consolidated Quality Systems Manual* (DOD/DOE 2018), and requirements of DOE 414.1D (DOE 2011c) and 10 CFR 830 Subpart A, "Quality Assurance Requirements." The UT-Battelle Chemical Sciences Division's quality assurance plan also meets applicable requirements of the American Society of Mechanical Engineers' Nuclear Quality Assurance Program. In 2022, RMAL participated in several external audits, including the annual TDEC Waste Compliance Audit and 12 internal assessements, that focused on adherence to approved analytical methods, waste management, and recordkeeping. No issues that required reanalysis or data corrections related to environmental sampling results were identified. In 2022, RMAL participated in MAPEP and DMRQA, and all results for analyses that RMAL performs in support of EPSD environmental monitoring programs were within acceptable ranges.

The Environmental Toxicology Laboratory does not hold any outside accreditations, but it operates in compliance with all methods required by EPA, TDEC, and NPDES and the UT-Battelle Environmental Sciences Division's Quality Assurance Management Program. In 2022, five internal assessments focused on adherence to approved analytical methods and data analysis were performed. No issues requiring reanalysis or data corrections related to standard toxicity testing results were identified. Updates of all standard operating procedures, reference toxicity control charts, and training requirements were completed in 2021. All standard operating procedures and lab methods comply with EPA's acute and chronic testing requirements for freshwater species (EPA 2002a and EPA 2002b, respectively). In 2022, the Environmental Toxicology Laboratory participated in the DMRQA program for whole effluent toxicity testing of *Pimephales promelas* (the fathead minnow, a freshwater fish) and *Ceriodaphnia dubia* (the water flea, a freshwater invertebrate). In the initial test, *P. promelas* results were in acceptable ranges, but the *C. dubia* tests had to be redone. All *C. dubia* results were also in acceptable ranges in the retest.

5.7.6. Data Management and Reporting

Data collected by UT-Battelle in conjunction with ORR and ORNL environmental surveillance programs and CWA activities at ORNL is managed using the Environmental Surveillance System (ESS), a web interface data management tool. A software QA plan for ESS has been developed to document ESS user access rules; verification and validation methods; configuration and change management rules; release history; software registration information; and the employed methods, standards, practices, and tools.

Field measurements and sample information are entered into ESS, and an independent verification is performed on all records to ensure accurate data entry. Sample results and associated information are loaded into ESS from electronic files provided by analytical laboratories. An automated screening is performed to ensure that all required analyses were performed, appropriate analytical methods were used, holding times were met, and specified detection levels were achieved.

Following the screening, a series of checks is performed to determine whether results are consistent with expected outcomes and historical data. QC sample results (i.e., blanks and duplicates) are reviewed to check for potential sample contamination and to confirm repeatability of analytical methods within required limits. More in-depth investigations are conducted to explain results that are questionable or problematic.

ORNL radiological airborne effluent monitoring data are managed using the Rad-NESHAPs Inventory Web Application and the Rad-NESHAPs Source Data Application. Field measurements, analytical data inputs, and emission calculations results are independently verified.

5.7.7. Records Management

The UT-Battelle Requirements, Documents, and Records Management System provides the requirements for managing all UT-Battelle records. Requirements include creating, maintaining, and using records; scheduling, protecting, and storing records; and destroying records.

Records specific to TWPC and Building 3019 and associated records management programs include the requirements for creating and identifying record material, protecting and storing records in applicable areas, and destroying records.

5.8. Environmental Management and Waste Management Activities at ORNL

The three campuses on ORR have a rich history of research, innovation, and scientific discovery that shaped the course of the world. Unfortunately, today, despite their vitally important missions, they are hindered by environmental legacies of past operations. The contaminated portions of ORR are on the EPA National Priorities List, which includes hazardous waste sites across the nation that are to be cleaned up under CERCLA. Areas that require cleanup or further action on ORR have been clearly defined, and OREM is working to clean those areas under the Federal Facility Agreement with EPA and TDEC. The *Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2022) provides detailed information on DOE OREM's 2022 cleanup activities (**here**).

5.8.1. Wastewater Treatment

At ORNL, DOE OREM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2022, 376.4 million L of wastewater were treated and released at PWTC. In addition, the liquid LLW system at ORNL received 114,417 L of waste. The waste treatment activities of these facilities support both DOE OREM and DOE SC mission activities, ensuring that wastewaters from activities associated with projects of both offices are managed in a safe and compliant manner.

5.8.2. Newly Generated Waste Management

ORNL is the largest, most diverse DOE SC laboratory in the DOE complex. Although much effort is expended to prevent pollution and to eliminate waste generation, some waste streams are generated as by-products of performing research and operational activities and must be managed to ensure that the environment is protected from associated hazards. As the prime contractor for the management of ORNL, UT-Battelle is responsible for management of most of the wastes generated from R&D activities and wastes generated from operation of the R&D facilities. If possible, waste streams are treated by on-site liquid or gaseous waste treatment facilities operated by OREM. Other R&D waste streams are generally packaged by UT-Battelle in appropriate shipping containers for off-site transport to commercial waste-processing facilities. In 2022, ORNL performed 118 waste and recycle shipments to off-site hazardous, radiological, or mixed-waste treatment or disposal vendors.

5.8.3. Transuranic Waste Processing Center

TRU waste-processing activities performed for DOE in 2022 by NWSol and UCOR addressed both contact-handled and remotely handled solids and debris. These activities involved processing, treating, and repackaging waste. In 2022, LLW and mixed LLW were transported to the Nevada National Security Site or to another approved off-site facility for disposal.

In 2022, 117.6 m^3 of contact-handled TRU waste was shipped from TWPC in 17 shipments (560 containers). During 2022, 15.32 m^3 of contact-handled waste and 4.87 m^3 of remotely handled waste were processed, and 168.2 m^3 of mixed LLW (TRU waste that was recharacterized as LLW) was shipped off site.

5.9. References

10 CFR 830. "Nuclear Safety Management." *US Code of Federal Regulations*. https://www.govinfo.gov/content/pkg/CFR-2011-title10-vol4/pdf/CFR-2011-title10-vol4-part830.pdf (accessed May 5, 2021).

40 CFR 60, Appendix A-1. "Method 2—Determination of Stack Gas Velocity and

Volumetric Flow Rate (Type S Pitot Tube)." *US Code of Federal Regulations*.

40 CFR 60 and 63. "Performance Specification 16 for Predictive Emissions Monitoring Systems and Amendments to Testing and Monitoring Provisions." *US Code of Federal Regulations*. https://www.govinfo.gov/content/pkg/FR-2009-03-25/pdf/E9-6275.pdf (accessed June 4, 2020).

40 CFR 82. "Protection of Stratospheric Ozone." *US Code of Federal Regulations*. https://www.ecfr.gov/cgi-bin/text-idx?rgn=div6;node=40%3A18.0.1.1.2.6 (accessed June 3, 2020).

40 CFR 112. "Oil Pollution Protection." *US Code of Federal Regulations.* https://www.epa.gov/sites/production/files/2014-04/documents/b_40cfr112.pdf (accessed June 4, 2020).

40 CFR 280. "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)." *US Code of Federal Regulations.* https://www.ecfr.gov/cgi-bin/text-idx?SID=165cbbe4db4970349d085d9840b78873&mc=true&node=pt40.29.280&rgn=div5 (accessed June 9, 2020).

40 CFR 1508.4. "Categorical Exclusion." *US Code of Federal Regulations*. https://www.ecfr.gov/cgi-bin/text-idx?SID=079d239aa6c408b31009767e801d0d90&mc=true&node=pt40.37.1508&rgn=div5#se40.37.1508_14 (accessed May 2, 2020).

ANSI 1969. Guide *to Sampling Airborne Radioactive Materials in Nuclear Facilities*. ANSI N13.1-1969R. American National Standards Institute, Washington, DC.

ANSI 1999. *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities.* ANSI/HPS N13.1-1999. American National Standards Institute, Health Physics Society, New York, New York.

BJC 2009. *Integrated Safety Management System Description*. BJC-GM-1400/R12. Bechtel Jacobs, Inc., LLC, Oak Ridge, Tennessee.

Bonine 2013. Bonine, T. M. *UT-Battelle Sampling and Analysis Plan for Surveillance Monitoring of Exit Pathway Groundwater at Oak Ridge National Laboratory*. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Bonine, Ketelle, and Trotter 2007. Bonine, T. M., R. H. Ketelle, and S. M. Trotter. *Operational Groundwater Monitoring Plan for the Spallation Neutron Source Site*. SNS 102040000-ES0001-R01, ORNL/TM-2004/118. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

CAA 1970. *Clean Air Act.* Title 42 US Code §7401 et seq.

CERCLA 1980. *Comprehensive Environmental Response, Compensation, and Liability*. Title 42 US Code Chapter 103.

CWA 1972. *Clean Water Act.* Title 33 US Code §1251 et seq.

DOD/DOE 2018. *Department of Defense (DoD)/Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*. DoD/DOE QSM 5.5.1. https://denix.osd.mil/edqw/documents/documents/qsm-version-5-1-1-final/ (accessed April 30, 2021).

DOE 1992. *Federal Facility Agreement for the Oak Ridge Reservation*. FFA-PM/18-011, DOE/OR-014, January 1, 1992 or latest revision, US Environmental Protection Agency Region IV, US Department of Energy, and Tennessee Department of Environment and Conservation, Oak Ridge, Tennessee. https://www.energy.gov/sites/prod/files/em/2001_Agreements/ORR_FFA_1-1-92.pdf (accessed August 18, 2022).

DOE 2000. *Record of Decision for Interim Actions for the Melton Valley Watershed at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*. DOE/OR/01-1826&D3. US Department of Energy, Washington, DC.

DOE 2002. *Record of Decision for Interim Actions in Bethel Valley Watershed, Oak Ridge, Tennessee*. DOE/OR/01-1862&D4. US Department of Energy, Washington, DC.

DOE 2008. *Environmental Protection Program.* DOE Order 450.1A. Approved June 4, 2008. US Department of Energy, Washington, DC.

DOE 2011a. *Departmental Sustainability.* DOE Order 436.1. Approved May 2, 2011. US Department of Energy, Washington, DC.

DOE 2011b. *Final Draft U-233 Alternatives Analysis, Phase I Report: Screening of Alternative Disposition Approaches.* US Department of Energy, Washington, DC.

DOE 2011c. *Quality Assurance.* DOE Order 414.1D. Approved April 25, 2011. US Department of Energy, Washington, DC.

DOE 2011d. *Radiation Protection of the Public and the Environment.* DOE Order 458.1, Change 2. Approved June 6, 2011. US Department of Energy, Washington, DC.

DOE 2012. *Phased Construction Completion Report for the Bethel Valley Burial Grounds at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*. DOE/OR/01-2533&D2. UCOR, Oak Ridge, Tennessee.

DOE 2020. *Radiation Protection of the Public and the Environment.* DOE Order 458.1, Change 4. Approved September 15, 2020; US Department of Energy, Washington, DC.

DOE 2021a. *Derived Concentration Technical Standard*. DOE-STD-1196-2021. US Department of Energy, Washington, DC. July 2021. https://www.standards.doe.gov/standards-documents/1100/1196-astd-2021.

DOE 2021b. *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision, Oak Ridge, Tennessee*. DOE/OR/01-2824&D2. US Department of Energy Office of Science, Washington, DC.

DOE 2022a. *Vulnerability Assessment and Resilience Planning Guidance Version 1.2.* US Department of Energy Sustainability Performance Division, Washington, DC. https://www.energy.gov/sites/default/files/2022-02/DOE_VARP_Guidance_Feb2022%20v1.2.docx (accessed April 25, 2022).

DOE 2022b. *COVID-19 Workplace Safety and Reentry Framework*. US Department of Energy, Washington, DC. August 19, 2022. https://www.energy.gov/sites/default/files/2022-08/DOE-COVID-19-Safety-and-Reentry-Framework-08-19-22-Final_01.pdf (accessed February 16, 2023).

DOE 2023. *2023 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Site, Oak Ridge, Tennessee, Data and Evaluations.* DOE/OR/01-2938&D1, US Department of Energy, Washington, DC.

EA 2020. *The Energy Act of 2020*.

EISA 2007. *Energy Independence and Security Act of 2007*.

EO 1994. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. Issued February 11, 1994. https://www.federalregister.gov/documents/1994/02/16/94-3685/federal-actions-to-address-environmental-justice-in-minority-populations-and-low-income-populations (accessed May 5, 2023).

EO 2021a. Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*. Issued January 27, 2021. https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad (accessed April 5, 2022).

EO 2021b. Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*. Issued December 8, 2021. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/ (accessed May 5, 2023).

EPA 2000a. *Stressor Identification Guidance Document.* EPA-822-B-00-025. US Environmental Protection Agency, Office of Water, Washington, DC.

EPA 2002a. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*. EPA-821-R-02-012. US Environmental Protection Agency, Washington, DC. https://www.wbdg.org/FFC/EPA/EPACRIT/epa821_r_02_012.pdf (accessed April 17, 2021).

EPA 2002b. *Short-Term Methods for estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*. EPA-821-R-02-013. US Environmental Protection Agency, Washington, DC. https://www.epa.gov/sites/production/files/2015-08/documents/short-term-chronic-freshwater-wet-manual_2002.pdf (accessed April 17, 2021).

EPA 2009. *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*. EPA 841-B-09-001. US Environmental Protection Agency, Washington, DC. https://www.epa.gov/sites/default/files/2015-09/documents/eisa-438.pdf.

EPA 2014. *Laboratory Data Review for the Non-Chemist*. US Environmental Protection Agency, Region 9, San Francisco, California. October 2014. https://clu-in.org/conf/tio/rcraexpert_100516/slides/Data-Review-Manual-110114.pdf.

EPA 2016. *Criteria Air Pollutants*. US Environmental Protection Agency. July 21, 2016. https://www.epa.gov/criteria-air-pollutants.

EPA 2017. *Technical Fact Sheet—Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)*. EPA 505-F-17-001. US Environmental Protection Agency. November 2017. https://www.epa.gov/sites/production/files/2017-12/documents/ffrrofactsheet_contaminants_pfos_pfoa_11-20-17_508_0.pdf.

EPA 2021. "Radioactive Decay." US Environmental Protection Agency. https://www.epa.gov/radiation/radioactive-decay (accessed March 10, 2023).

EPA 2022a. *Final Rule—Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act.* US Environmental Protection Agency, Washington, DC. https://www.epa.gov/climate-hfcs-reduction/final-rule-phasedown-hydrofluorocarbons-establishing-allowance-allocation (accessed April 6, 2022).

EPA 2022b. "Lifetime Drinking Water Health Advisories for Four Perfluoroalkyl Substances." US Environmental Protection Agency, Federal Register, Vol. 87, No. 118. Approved June 21, 2022. https://www.govinfo.gov/app/details/FR-2022-06-21/summary (accessed March 19, 2023).

EPA 2023. "Environmental Justice." US Environmental Protection Agency, Washington, DC. https://www.epa.gov/environmentaljustice#:~:text=Environmental%20justice%20is%20the%20fair,laws%2C%20regulations%2C%20and%20policies (accessed March 19, 2023).

EPCRA 1986. *Emergency Planning and Community Right-to-Know*. Title 42 US Code Chapter 116.

ISO 2004. *Environmental Management Systems—Requirements with Guidance for Use*. ISO 14001:2004. International Organization for Standardization. http://www.iso.org.

ISO 2015. *Environmental Management Systems—Requirements with Guidance for Use*. ISO 14001:2015. International Organization for Standardization. http://www.iso.org.

ISO 2017. *General Requirements for the Competence of Testing and Calibration Laboratories*. ISO/IEC 17025. International

Organization for Standardization. https://www.iso.org/publication/PUB100424.html (accessed April 17, 2021).

Miller et al. 2015. Miller, C. L., D. B. Watson, B. P. Lester, J. Y. Howe, D. H. Phillips, F. He, L. Liang, and E. M. Pierce. "Formation of Soluble Mercury Oxide Coatings: Transformation of Elemental Mercury in Soils." *Environmental Science and Technology* 49, 12105 – 12111. DOI: 10.1021/acs.est.5b00263.

NEPA 1969. *National Environmental Policy*. Title 42 US Code Chapter 55.

NHPA 1966. *National Historic Preservation Act*. Public Law 89-665; Title 54 US Code §300101 et seq.

NRC 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575, Rev. 1/EPA 402-R-97-016, Rev. 1/DOE/EH-0624, Rev. 1. US Nuclear Regulatory Commission, Environmental Protection Agency, Department of Defense, and Department of Energy, Washington, DC.

NRC 2009. *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*. NUREG-1575, Supplement 1/EPA 402-R-09-001/DOE/HS-0004. US Nuclear Regulatory Commission, Environmental Protection Agency, Department of Defense, and Department of Energy, Washington, DC.

ORNL. 2022. Goins. M., A. A. Miller, M. Madgett, S. Sluder, L. Touton, and S. Stephenson. *Oak Ridge National Laboratory FY 2023 Site Sustainability Plan with FY 2022 Performance Data*. Oak Ridge National Laboratory, Oak Ridge, Tennessee. November 2022. https://info.ornl.gov/sites/publications/Files/Pub188057.pdf.

Pelletier 1995. Pelletier, R. F., "Application of DOE 5400.5 Requirements for Release and Control of Property Containing Residual Radioactive Material," correspondence to distribution. US Department of Energy, Office of Environmental Policy and Assistance, Washington, DC.

RCRA 1976. "Resource Conservation and Recovery Act." *Code of Federal Regulations* Title 40 parts 239–282.

Runkle et al. 2022. Runkle, J., K. E. Kunkel, D. R. Easterlng, L. E. Stevens, B. C. Stewart, R. Frankson, L. Romolo, J. Neilsen-Gammon, T. A. Joyner, and W. Tollefson. *Tennessee State Climate Summary 2022*. NOAA Technical Report NESDIS 150-TN. NOAA/NESDIS, Silver Spring, Maryland. https://statesummaries.ncics.org/chapter/tn/.

SARA 1986. *The Superfund Amendments and Reauthorization Act.* https://www.congress.gov/bill/99th-congress/house-bill/2005.

Souza et al. 2001. Souza, P. A., G. D. DuVall, and M. J. Hart. *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee.* DOE/ORO/2085. US Department of Energy, Washington, DC.

TDEC 2015. "General Water Quality Criteria." *Rules of the Tennessee Department of Environment and Conservation.* Chapter 04000-40-03. Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Supply. http://sharetngov.tnsosfiles.com/sos/rules/0400/0400-40/0400-40.htm.

TDEC 2021. *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys*. DWR-WP-P-01-QSSOP-Macroinvert-122821, Tennessee Department of Environment and Conservation Division of Water Resources, Nashville, Tennessee. https://www.tn.gov/content/dam/tn/environment/water/policy-and-guidance/DWR-PAS-P-01-Quality_System_SOP_for_Macroinvertebrate_Stream_Surveys-122821.pdf.

TDEC 2020. "Public Water Systems." *Rules of Tennessee Department of Environment and Conservation Division of Water Resources*. Chapter 0400-45-01. Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Supply.

https://publications.tnsosfiles.com/rules/0400/0400-45/0400-45-01.20190217.pdf.

TSCA 1976. *Toxic Substances Control Act.* Title 15 US Code §2601 et seq. https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act).

UCOR 2022. *2022 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup.* OREM-23-7632. US Department of Energy Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee. https://www.energy.gov/sites/default/files/2023-01/Cleanup%20Progress%202022_FINAL.pdf (accessed April 5, 2022).

Food sources are analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game. In 2022, 16 Canada geese from ORR were subjected to noninvasive, live whole-body gamma scans. All results were well below the administrative release limit of 5 pCi/g ^{137}Cs. Photograph by Manuel (Dobie) Gillispie

6

Oak Ridge Reservation Environmental Monitoring Program

ORR environmental surveillance is conducted to comply with DOE requirements to protect the public and the environment against undue risks associated with DOE activities. These requirements are established in DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), and related guidance is provided in *Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2015). The objective of the ORR environmental surveillance program is to characterize environmental conditions in areas outside the ORR facility boundaries, both on and off ORR.

6.1. Meteorological Monitoring

Eight meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on ORR. Data collected at the towers are used in routine dispersion modeling to predict impacts from facility operations and as input to emergency response atmospheric models, which are used for simulated and actual accidental releases from a facility. Data from the towers are also used to support various research and engineering projects. Additionally, ORNL and Y-12 operate three wind profilers on ORR to better characterize upper-level winds (winds higher than 60 m above ground level).

6.1.1. Data Collection and Analysis

The eight meteorological towers on ORR are described in Table 6.1 and depicted in Figure 6.1. In this document, the individual ORR-managed towers are designated by “MT” followed by a numeral. Other commonly used names for these towers are also provided in Table 6.1. Meteorological data are collected at different heights above the ground (2, 10, 15, 30, 33, 35, and 60 m) to assess the vertical structure of the atmosphere, particularly with respect to wind shear and stability. Stable boundary layers and significant wind shear zones (associated with the local ridge-and-valley terrain and the Great Valley of eastern Tennessee; see Appendix B) can significantly affect the movement of a plume after a facility release (Bowen et al. 2000). Data are collected at the 10 or 15 m level at most towers, but the wind measurement height is 25 m for MT11 and 20 m for MT13. Data are collected at some towers at 30, 33, 35, and 60 m levels. Temperature, relative humidity, and precipitation are measured at most sites at 2 m, but wind speed and wind direction typically are not. Atmospheric stability (a measure of the vertical mixing properties of the atmosphere) is measured at most towers; however, measurements involving vertical temperature profiles (i.e., measurements made by the solar radiation delta-T method) limit accurate determination of nighttime stability to the 60 m towers. Stability is also calculated for most sites using the sigma phi method, which relies heavily on the measurement of the standard deviation of vertical wind speed using three-dimensional sonic wind monitors. Barometric pressure is measured at one or more of the towers at each ORR plant (MT2, MT4, MT6, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 Complex; at MT13 at ETTP; and at MT2, MT3, MT4, and MT12 at ORNL. Solar radiation is measured at MT6 and MT9 at the Y-12 Complex and at MT2 and MT12 at ORNL. Instrument calibrations are managed by UT-Battelle and are performed every 6 months by an independent auditor (Holian Environmental). Additionally, Holian Environmental audits the Y-12–owned towers (MT6, MT9, MT11) every 3 months.

Table 6.1. ORR meteorological towers

Tower	Alternate tower names	Location (latitude, longitude)	Altitude above MSL (m)	Measurement heights (m)
		ETTP		
MT13	J, YEOC	35.93043N, -84.39346W	237	20
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	15, 30
MT12	F	35.95285N, -84.30314W	354	10
		Y-12 Complex		
MT6	W, West	35.98058N, -84.27358W	326	2, 10, 30, 60
MT9	Y, PSS Tower	35.98745N, -84.25363W	290	2, 15, 33
MT11	S, South Tower	35.98190N, -84.25504W	352	25

[a] Tower "C" before May 2014.

Acronyms:

ETTP = East Tennessee Technology Park
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex
YEOC = Y-12 Complex Emergency Operations Center

ORNL 2022-G00307/mhr
2022-ASER-M017/tf9

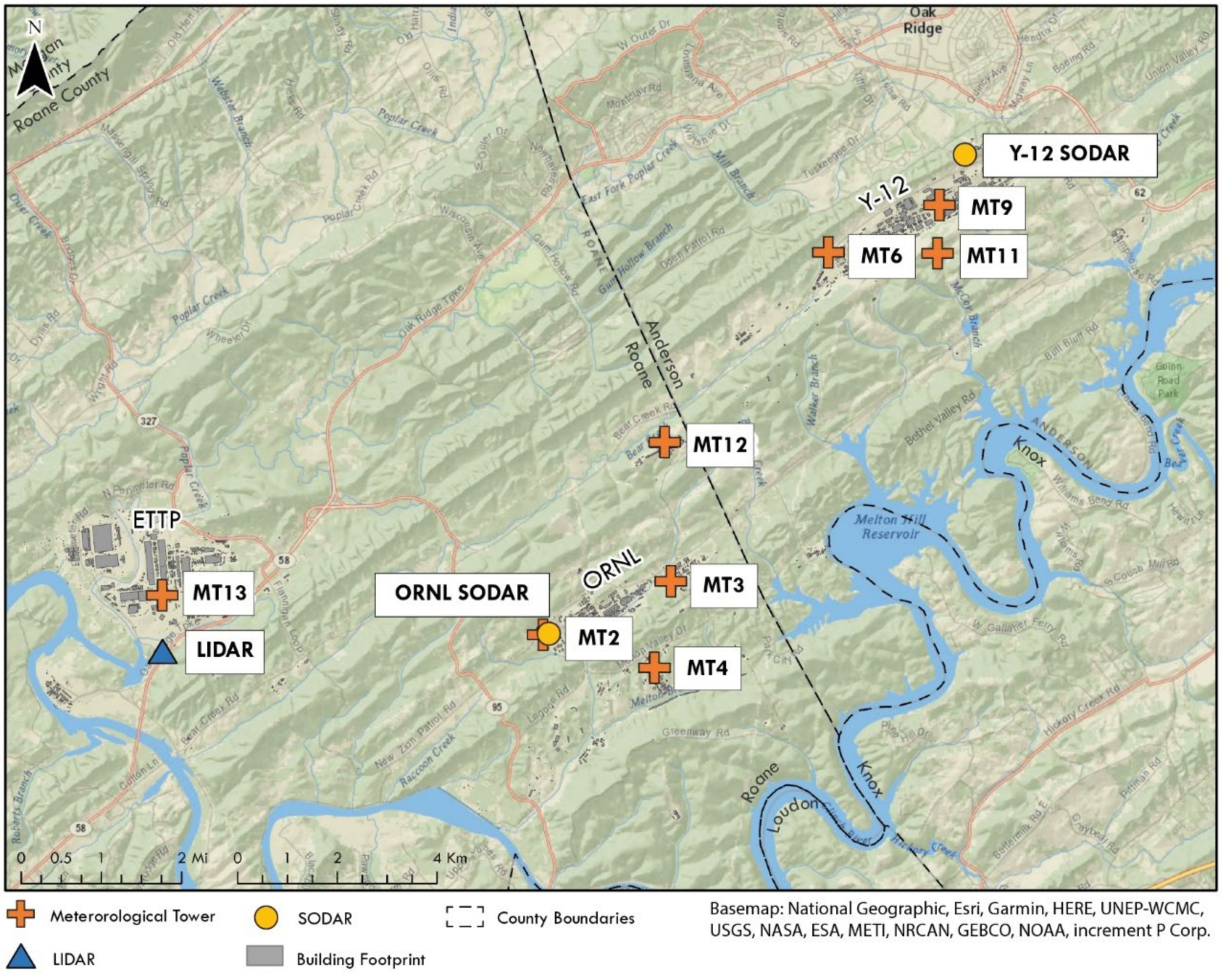


Figure 6.1. The ORR meteorological monitoring network, including light and sonic detection and ranging (LIDAR and SODAR) devices

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex (Pine Ridge) and adjacent to MT2 at ORNL. The SODAR devices use acoustic waves to estimate wind direction, wind speed, and turbulence at altitudes higher than the reach of meteorological towers (40–800 m above ground level). Although SODAR measurements are somewhat less accurate than measurements made on the meteorological towers, the SODAR devices provide useful information regarding stability, upper-air winds, and mixing depth. Mixing depth is the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could be mixed by turbulence within 1 h.

In 2021, ORNL installed a light detection and ranging (LIDAR) device, which provides data similar to SODAR data, near ETTP at ORR Air Monitoring Station 35 to provide wind data for the western part of ORR. This device replaces wind measurements previously taken at the now-defunct MT7 and MT10 meteorological towers.

Meteorological data are collected in real time from the meteorological towers at 1 min, 15 min, and hourly average intervals for emergency response purposes and for dispersion modeling at the ORNL and Y-12 Complex Emergency Operations Centers.

Annual dose estimates are calculated from the archived hourly data. Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked as invalid and excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the eight ORR towers.

6.1.2. Results

Prevailing winds generally flow up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast, a pattern that typically results from channeling effects produced by the parallel ridges flanking the ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of ORR, but flow variation is greater at ETTP, which is located within a less constrained open valley bottom.

On ORR, low wind speeds dominate near the valley surfaces, largely because of the decelerating influence of nearby ridges and mountains. Wind acceleration is sometimes observed at ridgetop level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over ORR is often dominated by stable conditions at night and for a few hours after sunrise. These conditions, when coupled with low wind speeds and channeling effects in the valleys, result in poor dilution of emissions from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may significantly mitigate these factors by increasing turbulence (atmospheric mixing). These features are captured in dispersion model data input and are reflected in modeling studies conducted for each facility.

Precipitation data from MT2 are used in stream-flow modeling and in certain research efforts. The data indicate the variability of regional precipitation: the high winter rainfall resulting from frontal systems and the uneven, but occasionally intense, summer rainfall associated with frequent air mass thunderstorms. The total precipitation at ORNL during 2022 (1,449.6 mm or 57.05 in.) was about 2 percent above the long-term 1991–2020 average of 1,417.8 mm (55.80 in.). The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2022 were greater than 89 percent for MT2 and MT3. Average recovery rates at MT4 and MT6 were greater than 97 and 92 percent, respectively. Annual wind data recovery from Y-12 meteorological towers during 2022 exceeded 81 percent for MT13. Y-12 tower MT6 was down the entire year for maintenance, and substitute data were used.

6.2. Ambient Air Monitoring

In addition to exhaust stack monitoring conducted at ORR installations (see Chapters 3, 4, and 5), ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities (Figure 6.2). Ambient air monitoring provides a means to verify that contributions of fugitive and diffuse sources are insignificant, serves as a check on dose-modeling calculations, and would enable the determination of contaminant levels at monitoring locations in the event of an emergency.

Figure 6.2. ORR ambient air station

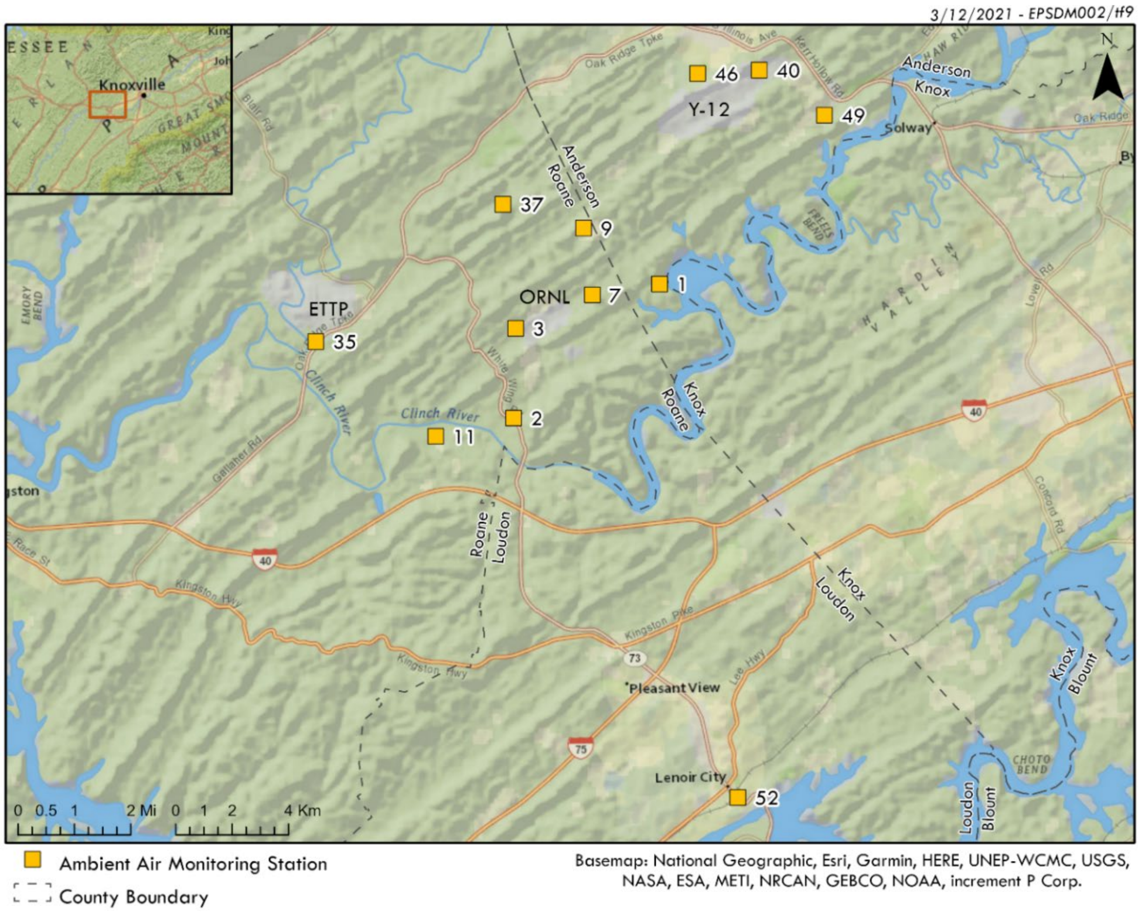
6.2.1. Data Collection and Analysis

Ambient air monitoring conducted by individual site programs is discussed in Chapters 3, 4, and 5. The ORR ambient air monitoring program complements the individual site programs and enables the impacts of ORR operations to be assessed on an integrated basis.

The objectives of the ORR ambient air monitoring program are to perform surveillance of airborne radionuclides at the reservation perimeter and to collect reference data from a location not affected by activities on ORR. The perimeter air monitoring network was established in the early 1990s and was modified in 2016 in response to changes in DOE activities and operations since the 1990s. The stations monitored in 2022 are shown in Figure 6.3. Reference samples are collected at Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2022 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.

Atmospheric dispersion modeling was used to select appropriate sampling locations likely to be affected most by releases from the Oak Ridge facilities. Therefore, in the event of a release, no residence or business near ORR should receive a radiation dose greater than doses calculated at the sampled locations.

The sampling system consists of two separate instruments. Particulates are captured by high-volume air samplers equipped with glass-fiber filters. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and gross beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second instrument is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap that contains indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, and then submitted to an analytical laboratory for ^{3}H analysis.



Notes:

1. *Reference samples are collected at Station 52 (Fort Loudoun Dam).*
2. *Station 7 is an ORNL site-specific monitoring location and is not part of the ORR perimeter network.*

Figure 6.3. Locations of ORR perimeter air monitoring stations

6.2.2. Results

Data from the ORR ambient air network are analyzed to assess the impact of DOE operations on the local air quality. Each measured radionuclide concentration (Table 6.2) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2021a). All radionuclide concentrations measured at the ORR ambient air stations during 2022 were less than 1 percent of applicable DCSs.

Table 6.2. Radionuclide concentrations at ORR perimeter air monitoring stations sampled annually, 2022

Station	Average concentration (pCi/mL)[a] (Number detects/n)										
	^{124}Sb	^{7}Be	^{210}Pb	^{212}Pb	^{40}K	^{99}Tc	^{208}Tl	^{3}H	^{234}U	^{235}U	^{238}U
01		4.4E-08 (4/4)	1.1E-08 (2/4)		9.5E-10 (2/4)			6.1E-06 (1/4)	1.9E-11 (4/4)	8.7E-13 (0/4)	1.9E-11 (4/4)
02		4.0E-08 (4/4)	5.0E-09 (1/4)		5.6E-10 (2/4)			6.6E-06 (1/4)	2.1E-11 (4/4)	1.9E-12 (1/4)	2.0E-11 (4/4)
03	4.7E-10 (1/4)	4.2E-08 (4/4)	7.1E-09 (1/4)		9.6E-10 (2/4)			8.7E-06 (1/4)	2.3E-11 (4/4)	1.3E-12 (0/4)	2.5E-11 (4/4)
09		4.5E-08 (4/4)	3.2E-09 (1/4)		6.3E-10 (1/4)			5.6E-05 (4/4)	2.2E-11 (4/4)	2.0E-12 (2/4)	2.6E-11 (4/4)
11		3.5E-08 (4/4)	4.1E-09 (1/4)		8.8E-10 (2/4)			6.6E-06 (1/4)	1.8E-11 (4/4)	8.4E-13 (1/4)	1.8E-11 (4/4)
35		3.6E-08 (4/4)	1.0E-08 (2/4)		5.0E-10 (1/4)	9.0E-10 (1/4)		8.7E-06 (1/4)	2.8E-11 (4/4)	1.7E-12 (3/4)	2.5E-11 (4/4)
37		3.4E-08 (4/4)	8.0E-09 (2/4)		5.0E-10 (1/4)			3.5E-06 (1/4)	2.3E-11 (4/4)	1.2E-12 (1/4)	1.9E-11 (4/4)
40		4.0E-08 (4/4)	4.4E-09 (1/4)	7.6E-11 (1/4)	8.1E-10 (2/4)			4.5E-06 (1/4)	3.2E-11 (4/4)	1.4E-12 (2/4)	2.9E-11 (4/4)
46		4.4E-08 (4/4)	1.2E-08 (2/4)		7.6E-10 (1/4)			5.5E-06 (1/4)	2.5E-11 (4/4)	8.7E-13 (0/4)	2.1E-11 (4/4)
49		4.2E-08 (4/4)	1.1E-08 (2/4)	9.1E-11 (1/4)	8.3E-10 (2/4)		9.6E-11 (1/4)	5.0E-06 (1/4)	2.4E-11 (4/4)	1.5E-12 (1/4)	2.6E-11 (4/4)
52[b]		4.7E-08 (4/4)	1.1E-08 (2/4)		7.0E-10 (2/4)	1.8E-09 (1/4)		2.0E-06 (0/4)	2.3E-11 (4/4)	2.7E-12 (3/4)	2.5E-11 (4/4)

[a] *1 pCi = 3.7 × 10^{-2} Bq.*
[b] *Station 52 is the reference location.*

6.3. External Gamma Radiation Monitoring

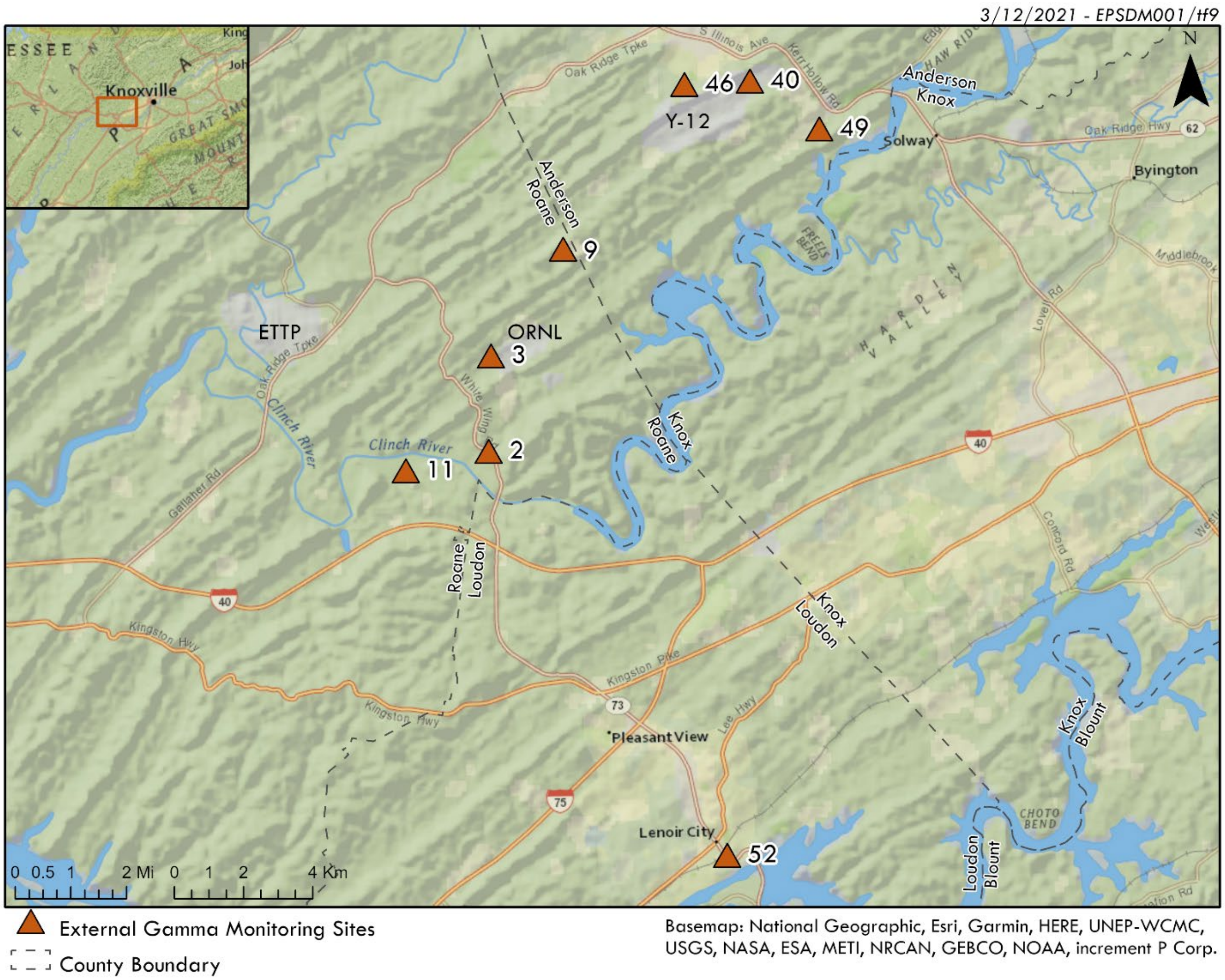
Members of the public could hypothetically be exposed directly to gamma radiation from radionuclides released into the environment, from previously released radionuclides deposited on soil and vegetation or in sediments, from radiation-generating facilities (especially high-energy accelerators), and from the storage of radioactive materials (DOE 2021b). Continuous direct radiation levels are monitored at locations around ORR to complement the sample data collected as part of the ORR ambient air monitoring program (see Section 6.2).

6.3.1. Data Collection and Analysis

External gamma exposure rates are continuously recorded every minute by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations 2, 3, 9, 11, 40, 46, 49, and 52 (see Section 6.2). The data are downloaded weekly and are averaged for the entire year. Figure 6.4 shows locations that were monitored during 2022; Table 6.3 summarizes the data for each station.

6.3.2. Results

The mean exposure rate for the reservation network in 2022 was 9.3 μR/h, and the mean rate at the reference location (Fort Loudoun Dam) was 8.7 μR/h. Background direct radiation exposure rates have been collected at the Fort Loudoun Dam (Station 52) reference location for many years. From 2012 through 2021, the exposure rates at the reference location ranged from 6.5 to 11.4 μR/h and averaged 8.8 μR/h.



Note:
Reference samples are collected at Station 52 (Fort Loudoun Dam).

Figure 6.4. External gamma radiation monitoring locations on ORR

Table 6.3. External gamma exposure rate averages for ORR, 2022

Air station number	Number of data points (daily)	Measurement (µR/h)[a]		
		Min	Max	Mean
02	358	8.0	10.7	8.7
03	363	8.3	11.3	9.0
09	365	8.4	12.3	8.9
11	359	9.1	12.2	9.8
40	363	8.7	10.6	9.4
46	365	9.7	12.8	10.2
49	365	8.6	12.0	9.3
52	365	8.0	11.4	8.7

[a] *To convert microroentgens per hour (µR/h) to milliroentgens per year, multiply by 8.760.*

6.4. Surface Water Monitoring

The ORR surface water monitoring program consists of sample collection and analysis from four locations on the Clinch River, including public water intakes (Figure 6.5). The program is conducted in conjunction with site-specific surface water monitoring activities to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water.

6.4.1. Data Collection and Analysis

Grab samples are collected quarterly at all four locations and are analyzed for general water quality parameters, screened for radioactivity, and analyzed for mercury and specific radionuclides when appropriate. Table 6.4 lists the locations and associated sampling frequencies and parameters. Once every 5 years, additional radiological analyses are performed to confirm dose calculations (see Chapter 7). In 2022, additional radionuclides analyzed included neptunium, plutonium, strontium, thorium, and uranium.

In 2022, a more sensitive analytical method for determining mercury concentrations in surface water samples was adopted. The new method enables detecting concentrations near 0.2 ng/L, whereas the detection limit for the previously used method is about 67 ng/L. As expected, the ability to detect mercury at much lower levels resulted in detections in 10 of the 12 surface water samples collected for mercury analyses in 2022, while in the past, with the less sensitive method, mercury was rarely detected. At the sampling locations, the Clinch River is classified by the State of Tennessee for multiple uses, including recreation and domestic supply. These two designated uses have numeric Tennessee Water Quality Criteria (WQCs) related to protection of human health. The WQCs are used as references where applicable (TDEC 2014). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used as the criterion for radionuclide comparison (DOE 2021a).

6.4.2. Results

In 2022, as has been the case since 2009, no statistical differences were found in the concentrations of routinely monitored radionuclides in surface water samples collected from the Clinch River upstream and downstream of DOE inputs.

The difference in concentrations of $^{233/,234}U$ detected downstream and upstream of DOE inputs was statistically significant. In June 2022, ^{238}U was detected at Clinch River kilometers (CRKs) 66, 58, and 16 with no statistically significant difference between upstream and downstream locations. However, ^{238}U was not detected in other 2022 samples. In March 2022, ^{230}Th was detected once at CRK 66 (upstream of DOE inputs) but was not detected at any other location or in any other quarter of 2022. No radionuclides were detected above 4 percent of the respective DCSs.

In 2021, ^{241}Am was detected by gamma spectroscopy analysis in the second-quarter grab sample from CRK 58 upstream of DOE inputs. It was not detected in samples from other surface water sampling locations and had not previously been detected at CRK 58. No ^{241}Am was detected in samples collected in the third or fourth quarters of 2021. Laboratory contamination was the suspected source of the ^{241}Am.

In 2022, as part of a regular 5-year rotation to confirm the dose modeling (see Chapter 7), additional analyses, including a more sensitive method for quantifying ^{241}Am, were performed at all ORR surface water monitoring locations on the Clinch River. There were no detections of ^{241}Am at any location in any quarter in 2022 using the more sensitive method.

Mercury was detected in 10 of the 12 samples collected in 2022. Results from one sample collected from CRK 32 and one from CRK 66 were below the method detection level. As previously discussed, an increase in mercury detections was anticipated because a more sensitive analytical method was used. All detected mercury values in 2022 were well below the 67 ng/L detection level of the test method previously used.

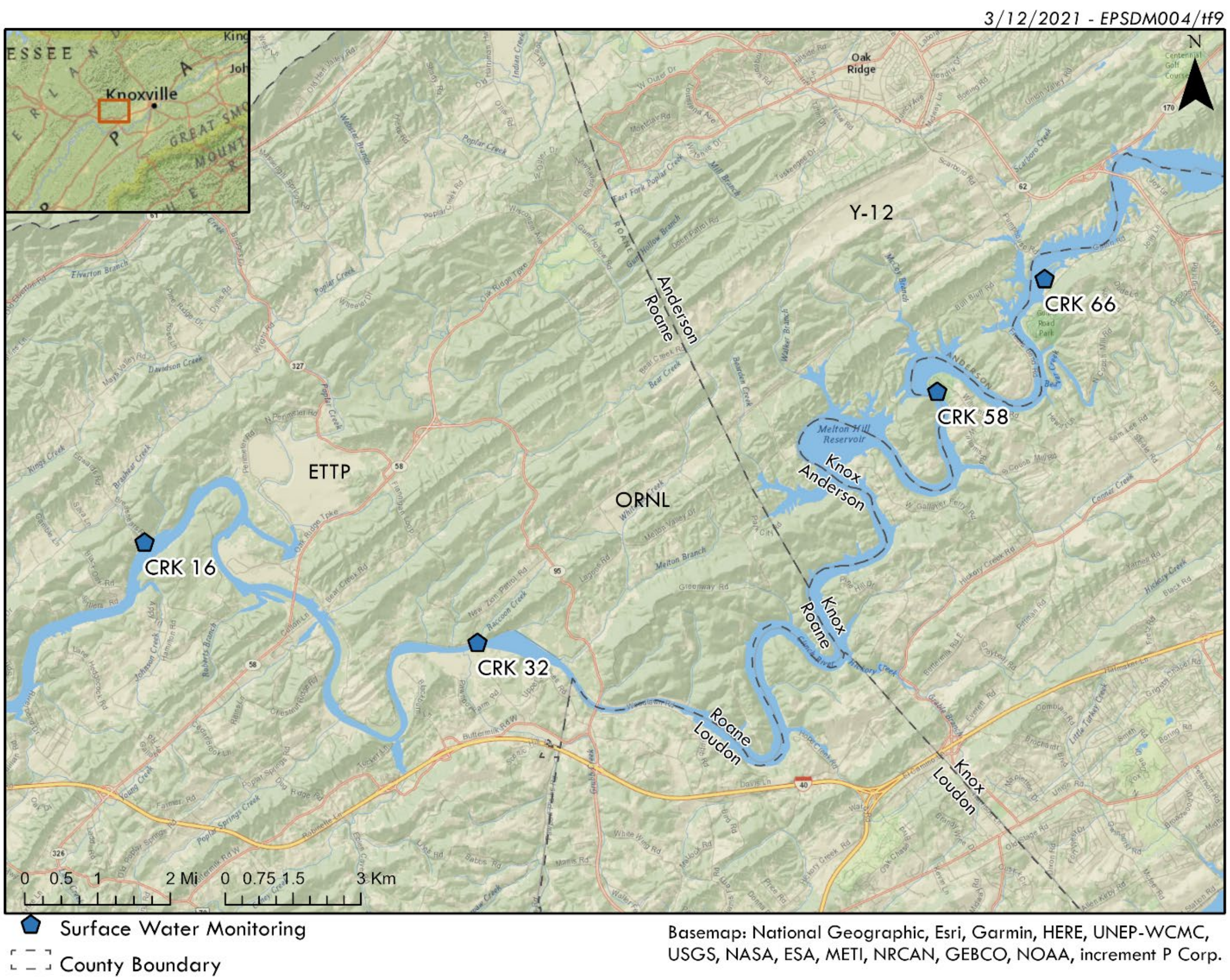


Figure 6.5. ORR surface water surveillance sampling locations

Table 6.4. ORR surface water sampling locations, frequencies, and parameters, 2022

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^3H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^3H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^3H, field measurements[b]
CRK 66	Melton Hill Reservoir above City of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^3H, field measurements[b]

[a] *Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River in the Watts Bar Reservoir).*

[b] *Field measurements consist of dissolved oxygen, pH, and temperature.*

Acronyms:

CRK = Clinch River kilometer
DOE = US Department of Energy
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

6.5. Groundwater Monitoring

Work continued in 2022 to implement key recommendations from the *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation* (DOE 2013), which was agreed to in 2014 by DOE, EPA, and the Tennessee Department of Environment and Conservation (TDEC). Work performed during 2022 under the ORR Groundwater Program included the first year of sampling from three multizone exit pathway groundwater monitoring wells in west Bethel Valley adjacent to the Clinch River. Work continued on site-scale groundwater flow models for ETTP.

6.5.1. Off-Site Groundwater Assessment

During fiscal year (FY) 2022, the Oak Ridge Office of Environmental Management (OREM) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. In addition, exit pathway groundwater monitoring in Melton Valley is conducted as part of the OREM program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542). Results of this monitoring are summarized in the 2023 *Remediation Effectiveness Report* (DOE 2023).

DOE completed an off-site groundwater assessment project and issued a final report in October 2017 (DOE 2017). The project was a cooperative effort among the parties to the ORR Federal Facility Agreement to investigate off-site groundwater quality and potential movement. To follow up on work from the off-site groundwater assessment, DOE conducts annual sampling and analysis of groundwater from several off-site residential wells and springs.

6.5.2. Regional and Site-Scale Flow Model

During FY 2017, DOE completed a project to construct and calibrate a regional-scale groundwater flow model that encompasses ORR and adjacent areas. The regional model provides a framework to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring the effectiveness of future cleanup decisions and actions. During FY 2022, DOE further refined groundwater flow models for the Molten Salt Reactor Experiment site to support the development of an updated feasibility study of remedial alternatives for that reactor facility.

6.6. Food

Food sources are analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides. Samples of hay, vegetables, milk, fish, deer, Canada geese, and turkeys are usually collected every year from areas that could be affected by activities on the reservation and from off-site reference locations. Milk was not collected in 2022 because no dairies were found in potential ORR deposition areas. Surveys are conducted annually to determine whether any dairies are operating in areas of interest.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on ORR are conservative and were established based on the "as low as reasonably achievable" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. This concept is not a dose limit but rather a philosophy that has the objective of maintaining exposures to workers, members of the public, and the environment below regulatory limits and as low as can be reasonably achieved. The administrative release limit of 5 pCi/g ^{137}Cs is based on the assumption that one person consumes all of the meat from a maximum-weight deer, goose, or turkey. This limit ensures that members of the public who harvest wildlife on the reservation will not receive significant radionuclide doses from that consumption pathway. In addition, a conservative administrative limit of 1.5 times background for gross beta activity has been established, a threshold that is near the detection limit for field measurements of $^{89/90}$Sr in deer leg bone.

6.6.1. Hay

Eating beef and drinking milk obtained from cattle that eat hay are potential radiation exposure pathways to humans. Hay from an area on the eastern edge of ORR is made available to an off-site farming operation and is sampled annually to characterize any possible doses from this pathway.

6.6.1.1. Data Collection and Analysis

Hay was collected and analyzed from the location on the eastern edge of ORR when it was cut for off-site use in August 2022. Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.1.2. Results

Radionuclides detected in hay are shown in Table 6.5.

Table 6.5. Concentrations of radionuclides detected in hay,[a] August 2022 (pCi/kg)[b]

Radionuclide	Result
Gross alpha	c
Gross beta	4,650
^{7}Be	7,020
^{40}K	9,920
^{234}U	c
^{235}U	c
^{238}U	c

[a] Detected radionuclides are those at or above minimum detectable activity.
[b] 1 pCi = 3.7 × 10^{-2} Bq.
[c] Value was less than or equal to minimum detectable activity.

6.6.2. Vegetables

Contaminants may reach vegetation by deposition of airborne materials, uptake from soil, and deposition of materials contained in irrigation water. As available, food crops are sampled annually from garden locations that have the potential to be affected by airborne releases from ORR to evaluate possible radiation doses to consumers. Vegetables are also sampled from a reference location for comparison. If available, crops that represent broad-leaf systems (e.g., lettuce, turnip greens), root-plant-vegetable systems (e.g., tomatoes), and root-system vegetables (e.g., turnips, potatoes) are obtained from each location and analyzed for radionuclides. Vegetable availability varies greatly from year to year.

6.6.2.1. Data Collection and Analysis

Tomatoes were purchased in 2022 from farms near ORR and from reference locations. No broad-leaf or root vegetables were available in 2022. The locations were chosen based on availability and the likelihood of being affected by routine releases from the Oak Ridge facilities. All vegetable samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.2.2. Results

Analytical results for vegetable samples are provided in Table 6.6. No gamma-emitting radionuclides were detected above the minimum detectable activity except for the naturally occurring radionuclide ^{40}K. Uranium isotopes were not detected above minimum detectable activities in any of the samples.

6.6.3. Milk

Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet. Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year, and milk sampling will resume when dairy operations in appropriate areas are located.

6.6.4. Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities by consuming fish caught in area waters. This potential exposure pathway is monitored annually by collecting fish from three locations on the Clinch River and by analyzing edible flesh for specific contaminants. The locations are as follows (Figure 6.6):

- Clinch River upstream from all DOE ORR inputs (CRK 70)
- Clinch River downstream from ORNL (CRK 32)
- Clinch River downstream from all DOE ORR inputs (CRK 16)

6.6.4.1. Data Collection and Analysis

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) and catfish (*Ictalurus punctatus*) are collected from each of the three locations to represent both top-feeding and bottom-feeding predator species. In 2022, a composite sample of each of those species at each location was analyzed for selected metals, polychlorinated biphenyls (PCBs), tritium, gross alpha, gross beta, gamma-emitting radionuclides, and total radioactive strontium. To accurately estimate exposure levels to consumers, only edible portions of the fish were submitted for analysis. Once every 5 years, additional radiological analyses are performed to confirm the dose calculations (see Chapter 7). In 2019, additional analyses were performed on fish samples, and detected radionuclides included neptunium, plutonium, thorium, and uranium isotopes. Based on the 2019 results, additional radionuclide analyses were again performed in 2020, 2021, and 2022, including analyses for americium, neptunium, plutonium, and thorium. Results are presented in Table 6.7.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. The advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a “do not consume” advisory for catfish in the entire Melton Hill Reservoir, not just in areas that could be affected by ORR activities, because of PCB contamination. Similarly, TDEC has issued a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir because of PCB contamination (TDEC 2020). TDEC also issues advisories for consumption of fish when mercury levels exceed 0.3 ppm; the three locations on the Clinch River where ORR fish are collected do not have mercury “do not consume” advisories (Denton 2007).

Table 6.6. Concentrations of radionuclides detected in tomatoes, 2022 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Tomatoes				
North of Y-12	*b*	2,030	*B*	1,970	*b*	*b*	*b*
East of ORNL	*b*	1,810	*B*	1,680	*b*	*b*	*b*
West of ETTP	*b*	1,460	*B*	1,200	*b*	*b*	*b*
Reference location	*b*	1,810	*B*	1,550	*b*	*b*	*b*

[a] *Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7 × 10^{-2} Bq.*
[b] *Value was less than or equal to minimum detectable activity.*
Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

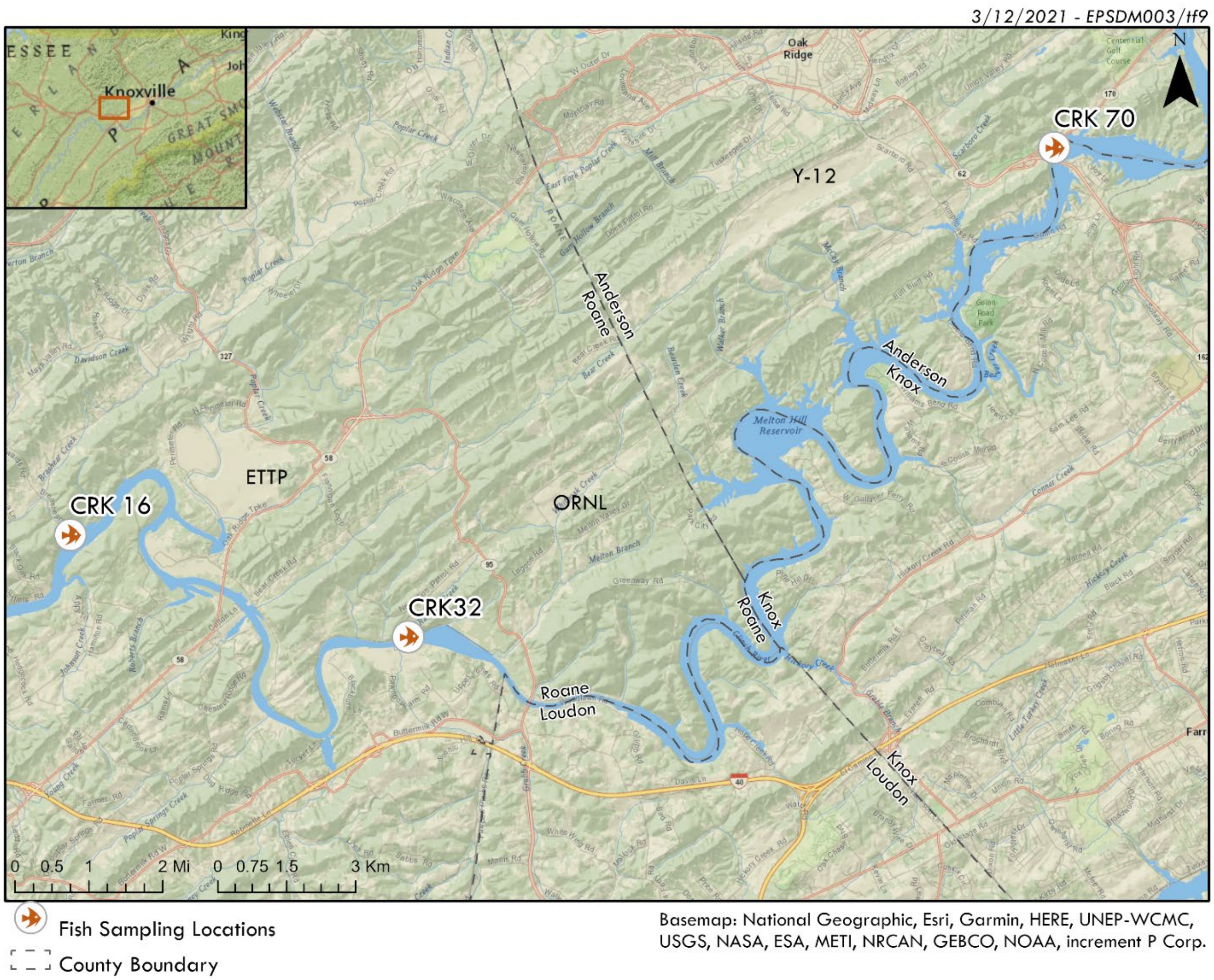


Figure 6.6. Fish-sampling locations for the ORR Surveillance Program

Table 6.7. Tissue concentrations in catfish and sunfish for detected PCBs and radionuclides, 2022[a]

	CRK 16 Downstream		CRK 32		CRK 70 Upstream	
	Catfish	Sunfish	Catfish	Sunfish	Catfish	Sunfish
Metals (mg/kg)						
Hg	*b*	*b*	B0.22[c]	*b*	*b*	*b*
Pesticides and PCBs (μg/kg)						
PCB-1254	197	*b*	20.3	*b*	*b*	*b*
PCB-1260	247	*b*	62.2	*b*	*b*	*b*
Radionuclides (pCi/g)						
Beta activity	2.2	3.3	2.6	2.8	2.5	2.2
^{40}K	*b*	3.2	2.8	3.7	3.1	2.9
^{230}Th	*b*	*b*	0.06	*b*	*b*	0.093
^{232}Th	*b*	*b*	*b*	0.0097	0.010	*b*

[a] Only parameters that were detected for at least one species are listed in the table.
[b] Value was less than or equal to minimum detectable activity.
[c] "B" indicates that the analyte was detected in the associated method blank.
Acronyms:
CRK = Clinch River kilometer
PCB = polychlorinated biphenyl

6.6.4.2. Results

PCBs, specifically Aroclor-1260 and 1254, were detected in catfish at CRK 16 and CRK 32 in 2022. Mercury was detected in catfish at CRK 32 within the historic range of values at this location; the lab reported that mercury was detected in the associated method blank, indicating this result may be biased high. Mercury was not detected above the minimum detectable level at any other location in 2022.These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

6.6.5. White-Tailed Deer

In 2022, three quota hunts were conducted on ORR: November 5 and 6, November 12 and 13, and December 10 and 11.

Since 1985, 13,674 deer have been harvested from the Oak Ridge Wildlife Management Area, of which 218 (approximately 1.59 percent) have been retained because of potential radiological contamination. The heaviest buck ever harvested weighed 218 lb (1998), and the heaviest doe ever harvested weighed 139 lb (1985). The average weight of all harvested deer is approximately 87 lb. (All weights are field-dressed weights.) The oldest deer harvested was a doe estimated to be 12 years old (1989); the average age of all harvested deer is approximately 2 years. See the ORR hunt information website **here** for more information.

6.6.6. Waterfowl

The consumption of waterfowl is a potential pathway for exposing members of the public to radionuclides released from ORR operations. Canada goose hunting was allowed on the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend) during the statewide season in 2022, one-half hour before sunrise until noon on September 5, 10–11, and 17–18, and on October 8–9 and 15–16. Hunting was allowed for wood duck and teal on September 10–11.

6.6.6.1. Data Collection and Analysis

Canada geese are rounded up each summer for noninvasive gross radiological surveys to characterize concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR.

6.6.6.2. Results

Sixteen geese (4 adults and 12 juveniles) were captured during the June 23, 2022, roundup on ORR. All 16 captured geese were subjected to live whole-body gamma scans. Gamma scan results showed that all were all well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.7. Wild Turkey

Two wild turkey quota hunts were scheduled for April 16–17 and April 23–24. However, the turkey hunts were cancelled because of the COVID-19 pandemic.

Since 1997, 924 turkeys have been harvested on spring turkey hunts. Eleven additional turkeys have been harvested since 2012 by archery hunters during fall deer hunts. The largest turkey ever harvested on ORR weighed 25.7 lb (harvested in 2009). Of all turkeys harvested, only three (less than 0.34 percent) have been retained because of potential radiological contamination: one in 1997, one in 2001, and one in 2005. Additional information is available on the ORR hunt website **here**.

6.7. Habitat Quality Improvement

Maintaining ecosystems, protecting natural areas, and ensuring functioning of facilities and their support infrastructures (power and communications rights-of-way, roadways, and waterways) through active management is crucial, not only in natural areas, but in developed areas as well. A portion of ecosystem maintenance involves control of invasive plants. Invasive plants disrupt vital habitats of threatened and endangered species as well as other native wildlife and plant life by decreasing native plant diversity through crowding out native plants and disrupting natural plant-animal interactions. Another aspect of habitat quality improvement, once invasive plant control has been accomplished, is restoration of native plant communities.

6.7.1. Invasive Plant Management.

Invasive non-native plant species are among the greatest ecological threats to the United States and the world. Invasive plants can threaten forests, wetlands, and cultural and other resources by increasing the risk of fire and storm damage and by encroaching onto roads, railroads, power structures, waterways, and agricultural sites. To address these threats, the Federal Noxious Weed Act (1974) was amended and incorporated into the Federal Plant Protection Act (2000), which mandates federal agencies to develop and coordinate a management program for controlling invasive plants on lands under their respective jurisdictions. Each agency must adequately fund an integrated pest management plan that will meet the regulatory requirements of federal laws, executive orders, presidential memoranda, contracts, and agreements. Other federal directives regarding control of invasive plants and subsequent restoration practices include “Environmentally and Economically Beneficial Practices on Federal Landscaped Ground” (Presidential Memorandum 1994), which was replaced in 2000 by Executive Order 13148; *Federal Memorandum of Understanding to Establish a Federal Interagency Committee for the Management of Noxious and Exotic Weeds* (1994); Executive Order 13112 (1999); Presidential Memorandum (2014), which involves “creating a federal strategy to promote the health of honeybees and other pollinators,” including control and removal of invasive plants and restoration and establishment of natural habitats; and Executive Order 13751, “Safeguarding the Nation from the Impacts of Invasive Plants” (2016). DOE has maintained an invasive plant management plan on ORR since 2004. Details of federal and state laws and regulations driving this plan can be found in *Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004) and in the two subsequent revisions of that report (Quarles et al. 2011, McCracken and Giffen 2017).

The technical report *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National*

Environmental Research Park (Drake et al. 2002) details the results of extensive survey efforts. These and subsequent surveys have been performed to identify invasive plant problems on ORR. The data are used to develop control plans identifying which invasive species to target and in which locations.

More than 1,100 species of plants are found on ORR, and approximately 170 are non-native. Fifty-seven aggressive non-native (invasive) plant species have been identified on ORR, but control efforts have been primarily focused on a subset of 12 highly invasive species (see Table 6.8). These species have been found across ORR in disturbed areas; on powerline and gas line rights-of-way; throughout riparian buffer zones; and along state highways, railroad lines, and remote-access fire roads. They have invaded natural areas to varying degrees, causing vast ecological harm in both plant and animal communities. Other invasive plant species are also targets for control and are addressed according to the guidance found in *Early Detection and Rapid Response* (DOI 2020).

Table 6.8. Twelve most problematic invasive plants on ORR

Common name	Scientific name
Japanese grass, Nepal grass	*Microstegium vimineum*
Japanese honeysuckle	*Lonicera japonica*
Chinese privet	*Ligustrum sinense*
Kudzu	*Pueraria montana*
Multiflora rose	*Rosa multiflora*
Tree of heaven	*Ailanthus altissima*
Autumn olive	*Elaeagnus umbellate*
Oriental bittersweet	*Celastrus orbiculatus*
Princess tree	*Paulownia tomentosa*
Winter creeper	*Euonymus hederaceus*
Bradford/Callery pear	*Pyrus calleryana*
Mimosa	*Albizia julibrissin*

The 32,258.54-acre ORR consists mostly of undeveloped land, such as forested land, extensive areas of undisturbed wetlands, open waterways and riparian vegetation, and several hundred acres of grassland communities and fallow fields. Three major developed facilities lie within ORR boundaries: ORNL, the Y-12 Complex, and ETTP. Surrounding these developed facilities and woven throughout ORR are safety and security areas, utility corridors, access roads, research and education areas, cultural and historic preservation sites, contamination areas that are undergoing cleanup and remediation, regulatory and monitoring sites, emergency corridors, new facility construction and laydown areas, and public use areas. This multiplicity of land uses presents challenges for effectively preventing and managing invasive species.

Numerous DOE contractors have responsibilities for land management of portions of ORR, as do other federal and state agencies, such as the Tennessee Valley Authority and the Tennessee Wildlife Resources Agency. The Natural Resources Management Team for ORR receives sitewide funding annually, a portion of which is designated for creation and implementation of an invasive plant management plan mainly directed toward control efforts in natural areas and reference areas; however, efforts have included specific invasive plant incursions into locations within and surrounding campuses of developed facilities on ORR. The *Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004) and two subsequent revisions (Quarles et al. 2011, McCracken and Giffen 2017) explain options for addressing the problem of invasive plants on ORR and discuss selection of appropriate control measures. Areas selected for invasive plant control tend to cover several acres or are spread out across portions of ORR. Use of select herbicides is the most cost-effective treatment method in most cases, and the invasive plants that are present determine which herbicides will be most effective without harming surrounding native plant and animal habitats.

Invasive plant control on ORR has been conducted annually from 2003, when the invasive plant management program began, through 2022. Table 6.9 indicates the extent of annual invasive plant treatments; Figure 6.7 shows the major treatment areas.

Table 6.9. Invasive plant control on ORR, 2003–2022

Year	Treated area	
	Acres	Road miles
2003	98	
2004	136	
2005	125	
2006	254	
2007	236	
2008	427	
2009	526	
2010	884	
2011	806	
2012	615	
2013	329	
2014	950	
2015	629	
2016	952	
2017	542	47
2018	507	53
2019	450	57
2020	400	65
2021	400	51
2022	266	77

Invasive plant management activities were completed in 2022 in the following locations at each of the three facilities and in natural areas on the ORR (Figure 6.7):

- ORNL
  - First Creek, Fifth Creek, and White Oak Creek riparian buffer zones
  - First Creek grassland area management
  - Demonstration plot at Spallation Drive and Bethel Valley Road management
  - Bethel Valley Road and Old Bethel Valley Road invasive plant control
  - East Bethel Valley Road native grasslands
  - Check Station native grasslands
  - Haw Ridge former steam line kudzu patch
  - Fire road invasive plant control
  - Three Bends Area invasive plant control
  - Gallaher Bend kudzu control using goats
- Y-12
  - Kudzu control on Pine Ridge and Chestnut Ridge overlooking the Y-12 campus
  - Midway Turnpike invasive plant control
  - Coal ash ponded area kudzu control
  - Walnut Orchard four corners kudzu control
  - Watson Road fields invasive plant control
  - Old County Road, McNew Hollow Road, and Gum Branch Road invasive plant control
- ETTP
  - McKinney Ridge kudzu control
  - Black Oak Ridge Conservation Easement—West kudzu and invasive plant control
  - Black Oak Ridge Conservation Easement—East greenway and trail invasive plant control
  - Powerhouse Trail invasive plant control
  - Wheat Church Vista invasive plant control

ORNL 2022-G00306/mhr
2022-ASERM017/tf9

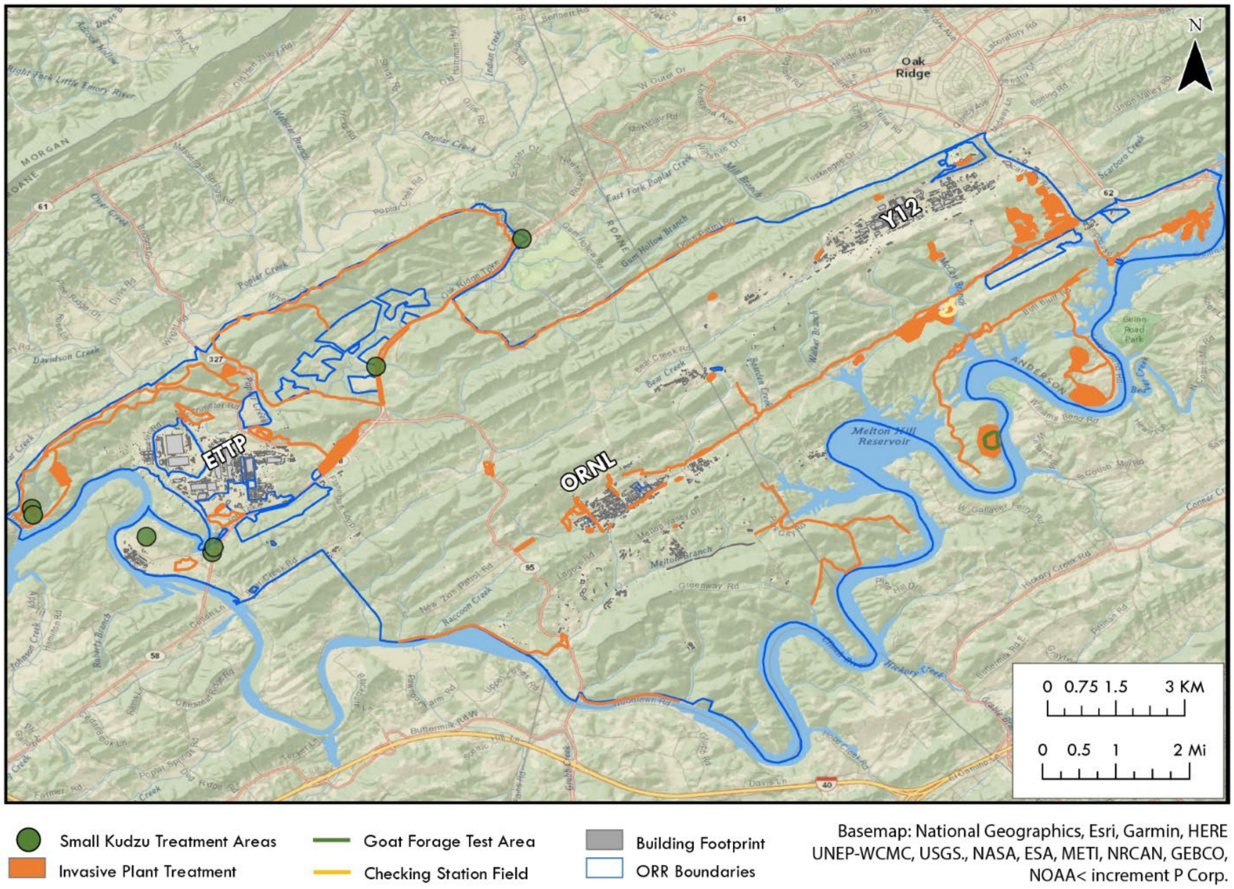


Figure 6.7. Map of invasive plant treatment areas on ORR for 2022

6.7.2. Wetlands

Wetland delineations are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetland protection requirements. In 2022, a wetland delineation was conducted on ORR on land along the Oak Ridge Turnpike. The wetland delineation was used to define easement boundaries and land use requirements.

6.7.3. Special Projects

Invasive plant treatment methods generally have involved a combination of herbicide use, mechanical removal, and prescribed burning. Biological control methods can also be used to control invasive plants. In the summers of 2020, 2021, and 2022, a project was carried out on Gallaher Bend (Figure 6.8) to investigate the effectiveness and costs of using goats for kudzu control. Goats were rotated through fenced sections of a 46-acre plot during the summer of 2020. A prescribed burn of the area was conducted after grazing season in the spring of 2021. In 2021, goats were rotated through the same fenced sections twice during grazing season. A reduced area of 20 acres was managed using goats in 2022. Results from this 3-year study indicate that using only goats to control large patches of mature kudzu is not economically feasible, nor is it particularly successful. Indications are that multiple years of continual grazing would be needed to control mature kudzu plots. Additionally, goat grazing can leave areas barren of most plants and subject to erosion.

Figure 6.8. Experimental kudzu control using goats grazing. The area to the left of the road was managed using goats, whereas the area to the right of the road was not managed. Photograph by Kitty McCracken

6.8. Fire Protection Management and Planning

Wildland fire management is an important part of DOE's overall management of ORR. A comprehensive wildfire management program has been established and implemented for the entire ORR. The *Oak Ridge Reservation Wildland Fire Management Plan* (WFMP) (DOE 2021c) assigns responsibilities for wildland fire management and is reviewed every 3 years and revised as needed. The *Oak Ridge Reservation Wildland Fire Implementation Plan* (WFIP) (DOE 2021d) contains details on program implementation. The WFMP was prepared to satisfy the requirements of DOE Order 420.1C, *Facility Safety, Change 3* (DOE 2019); DOE Standard 1066, *Fire Protection* (DOE 2016); and relevant portions of Chapters 19 through 23 in National Fire Protection Association 1140, *Standard for Wildland Fire Protection* (NFPA 2022).

The WFMP outlines the overall goals and strategies necessary to manage, plan, and respond to fire in the wildland areas of ORR and to reduce the risk of wildland fire to personnel and facilities on the ORR and to the public. The WFMP is reviewed at least annually.

The WFMP applies to all DOE employees, contractors, and subcontractors working on the ORR and to all DOE ORR tenant activities. The DOE ORR federal manager is responsible for ORR wildland fire management activities.

The primary goal of the WFMP is to lower the overall risk of wildland fire on ORR by conducting fire prevention activities and actions to reduce the spread of a fire should one start. Another goal of the WFMP is to contain wildfires that do start to the ORR unit of origin by conducting suppression activities.

The WFMP is implemented by multiple organizations, including non-DOE entities such as the City of Oak Ridge and the State of Tennessee Division of Forestry. Memorandums of understanding that ensure collaboration between organizations are maintained for each organization that provides firefighting support on ORR.

DOE actions associated with wildland fire management include the following:

- Controlling ignition sources in the wildland areas, particularly on days when fire danger is forecasted
- Managing wildfire fuels in and near developed areas
- Developing and implementing controlled burning plans authorized by the DOE ORR federal manager
- Preparing and updating wildland fire pre-plans that include maps of fuel types, topographic features, roads, cultural resources, sensitive natural resources, contamination areas, and potential hazards
- Developing stakeholder involvement plans in support of the wildland fire program
- Reviewing current data to determine the potential for wildland fire, including indications of wildland fire risk
- Preparing a wildland fire risk report, including a wildland fire hazard severity analysis based on the *Standard for Wildland Fire Protection* (NFPA 2022)
- Maintaining a wildland fire road grid to support fire detection, containment, and suppression
- Conducting tabletop wildland fire exercises at least once every 3 years and full-scale exercises at least once every 5 years
- Incorporating wildland fire mitigation and response activities and procedures into the ORR land use planning process

The DOE roads and grounds contractor is responsible for establishing and maintaining the wildland fire roads, many of which delineate wildland management units (Figure 6.9), and for maintaining barricades that control access to ORR secondary roads. The management contractors at each of the three major ORR sites are responsible for providing personnel and equipment for initial response to wildland fire events and for establishing incident command. The City of Oak Ridge has entered into a mutual aid agreement with DOE to provide assistance for wildland fire activities. The State of Tennessee Department of Agriculture Division of Forestry has entered into a memorandum of understanding to provide trained personnel and heavy equipment, including fire plows, when requested to assist with wildland fires on ORR.

2021-ASER-M018/tf9

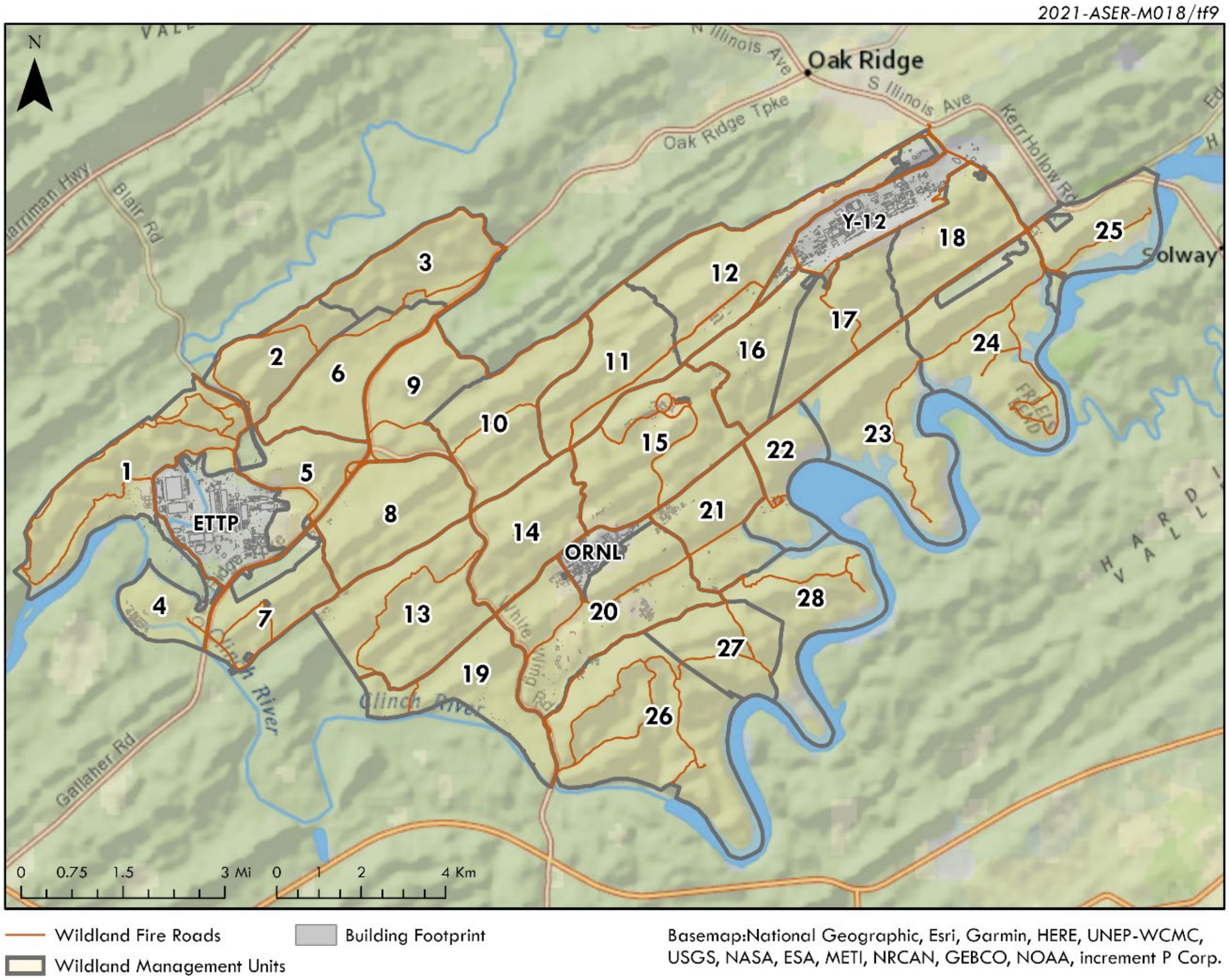


Figure 6.9. Wildland management units on ORR

Because ORR is a large (32,258.54 acres), mostly forested property with access restrictions, it is a challenge for site emergency personnel to maintain familiarity with all remote areas and back roads and to quickly recognize and assess concerns associated with those areas. Wildland management unit pre-fire plans are designed to aid responders who may or may not be familiar with an area.

The pre-fire plans are concise documents for each of the 28 ORR wildlife management units (Figure 6.9) that summarize access issues, assets, and hazard concerns. Each plan includes the wildlife management unit's name and identification number, its general location within ORR, and its boundaries and size. Important information and hazard descriptions are listed early in the document, followed by guidance on tactics, access, vegetation and fuels, water sources, topographic considerations, and hazard controls. Plan maps depict access points, utilities, hazards, research areas, fuel types, water sources, urban interface areas, and sensitive resources. Pre-fire plans are reviewed on a 3-year cycle and are updated as significant changes occur.

Copies of the plans are kept in responder vehicles for immediate reference during remote events and are available to site fire departments and emergency operations centers, shift superintendent offices, and appropriate management staff. The plans are easily updated, stored, and shared electronically. They are meant to enable quick decisions but not to dictate tactics. The ORR forester is the point of contact for plan distribution.

The 2016 Great Smoky Mountains wildfires, also known as the Gatlinburg wildfires, demonstrated that large fires, although more frequent in western states, can occur on or near ORR. Issues related to wildland/urban interface areas are a growing concern. These areas may be characterized by relatively high housing density and increasing recreational use by the public. DOE has prioritized interface areas and has conducted controlled wildfire fuel reduction burns to limit the spread of fire to and from the community. The presence of dense pine forests increases community vulnerability to potential high-intensity wildfires. Actions to protect these areas include thinning or replacing dense pine growth, mechanical treatments to proactively thin younger pine, and mulching heavy logging slash and insect-damaged timber to interrupt fuel beds.

6.9. Quality Assurance

UT-Battelle performs the activities associated with administration, sampling, data management, and reporting for ORR environmental surveillance programs. Project scope is established by a task team whose members represent DOE, UT-Battelle, Consolidated Nuclear Security LLC, and United Cleanup Oak Ridge LLC. UT-Battelle integrates quality assurance, environmental, and safety considerations into every aspect of ORR environmental monitoring. (See Chapter 5, Section. 5.7, for a detailed discussion of UT-Battelle quality assurance program elements for environmental monitoring and surveillance activities.)

6.10. References

Bowen et al. 2000. Bowen, B. M., J. A. Baars, and G. L. Stone. “Nocturnal Wind Shear and Its Potential Impact on Pollutant Transport.” *Journal of Applied Meteorology* 39(3), 437–45.

Denton 2007. Denton, G. M. *Mercury Levels in Tennessee Fish.* Tennessee Department of Environment and Conservation, Nashville, Tennessee. https://www.tn.gov/content/dam/tn/environment/water/documents/fishmercurylevels.pdf

DOE 2013. *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee*. Volume 1. Main Text. DOE/OR/01-2628/V1&D1. US Department of Energy Office of Environmental Management, Washington, DC. (PDF version available through online catalog at http://doeic.science.energy.gov/)

DOE 2015. *Environmental Radiological Effluent Monitoring and Environmental Surveillance*. DOE-HDBK-1216-2015. US Department of Energy, Washington, DC. https://www.standards.doe.gov/standards-documents/1200/1216-bhdbk-2015 (accessed May 18, 2021).

DOE 2016. *Fire Protection*. DOE-STD-1066-2016. US Department of Energy, Washington, DC. https://www.standards.doe.gov/standards-documents/1000/1066-astd-2016.

DOE 2017. *Offsite Groundwater Assessment Remedial Site Evaluation, Oak Ridge, Tennessee*. DOE/OR/01-2715&D2_R. US Department of Energy Office of Environmental Management, Washington, DC.

DOE 2019. *Facility Safety*. DOE Order 420.1C. US Department of Energy, Washington, DC. https://www.directives.doe.gov/directives-documents/400-series/0420.1-BOrder-C-chg3-ltdchg (accessed June 15, 2021).

DOE 2020. DOE Order 458.1, *Radiation Protection of the Public and the Environment*. US Department of Energy, Washington, DC.

DOE 2021a. *Derived Concentration Technical Standard*. DOE-STD-1196-2021. US Department of Energy, Washington, DC. https://www.standards.doe.gov/ standards-documents/1100/1196-astd-2021/@@images/file (accessed March 28, 2022).

DOE 2021b. *Environmental Monitoring Plan for the Oak Ridge Reservation, Calendar Year 2021*. DOE/ORO-228/R12. US Department of Energy Office of Science, Washington, DC. https://doeic.science.energy.gov/ASER/ORR_EMP_CY2021_Final.pdf (accessed April 11, 2021).

DOE 2021c. *Oak Ridge Reservation Wildland Fire Management Plan.* US Department of Energy Office of Science. Washington, DC.

DOE 2021d. *Oak Ridge Reservation Wildland Fire Implementation Plan.* US Department of Energy Office of Science. Washington, DC.

DOE 2023. *2023 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Site, Oak Ridge, Tennessee: Data and Evaluations.* DOE/OR/01-2938&D1. Prepared by the Water Resources Restoration Program, UCOR for the US Department of Energy Office of Environmental Management, Oak Ridge, Tennessee.

DOI 2020. *Early Detection and Rapid Response.* National Invasive Species Council, US Department of the Interior, Washington, DC. https://www.doi.gov/invasivespecies/early-detection-and-rapid-response (no date, accessed April 20, 2021)

Drake et al. 2002. Drake, S. J., J. F. Weltzin, and P. D. Parr, *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National Environmental Research Park.* ORNL/TM-2001/113. Oak Ridge National Laboratory, Oak Ridge, Tennessee (2002).

Executive Order 13112, "Invasive Species" (1999). https://www.invasivespeciesinfo.gov/executive-order-13112

Executive Order 13148, "Greening the Government Through Leadership in Environmental Management." (2000). https://www.govinfo.gov/content/pkg/WCPD-2000-05-01/pdf/WCPD-2000-05-01-Pg891.pdf

Executive Order 13751, "Safeguarding the Nation from the Impacts of Invasive Species." (2016). https://www.invasivespeciesinfo.gov/executive-order-13751

Federal Memorandum of Understanding to Establish a Federal Interagency Committee for the Management of Noxious and Exotic Weeds (1994). https://my.usgs.gov/confluence/download/attachments/535986746/1994_FICMNEW-MOU-508.pdf?version=1&modificationDate=1530204027466&api=v2

Federal Noxious Weed Act 1974. Public Law 93-629 (7 U.S.C. 2801 et seq.; 88 Stat. 2148).

Federal Plant Protection Act 2000. (part of Pub.L. 106–224) https://www.govinfo.gov/content/pkg/STATUTE-114/pdf/STATUTE-114-Pg358.pdf#page=1

McCracken and Giffen 2017. McCracken, M. K., and N. R. Giffen, *Invasive Plant Management Plan for the Oak Ridge Reservation*. ORNL/TM-2004/98/R2. Oak Ridge National Laboratory, Oak Ridge, Tennessee (2017).

NFPA 2022. *Standard for Wildland Fire Protection*. NFPA 1140. National Fire Protection Association, Quincy, Massachusetts. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1140

Parr et al. 2004. Parr, P. D., M. G. Ryon, H. D. Quarles, N. R. Giffen, M. S. Salk, and J. W. Webb. *Invasive Plant Management Plan for the Oak Ridge Reservation*. ORNL/TM-2004/98. Oak Ridge National Laboratory, Oak Ridge, Tennessee (2004).

Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," (2014). https://obamawhitehouse.archives.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b

Presidential Memorandum, "Environmentally and Economically Beneficial Practices on Federal Landscaped Ground" (1994). https://www.govinfo.gov/content/pkg/WCPD-1994-05-02/pdf/WCPD-1994-05-02-Pg916.pdf

Quarles et al. 2011. Quarles, H. D., M. S. Salk, P. D. Parr, M. G. Ryon, and N. R. Giffen. *Invasive Plant Management Plan for the Oak Ridge Reservation.* ORNL/TM-2004/98/R1. Oak Ridge National Laboratory, Oak Ridge, Tennessee (2011).

TDEC 2014. *The Status of Water Quality in Tennessee*. 305b Report. Tennessee Department of Environment and Conservation, Division of Water Resources, Nashville, Tennessee. (https://www.tn.gov/content/dam/tn/environment/water/documents/wr_wq_report-305b-2014.pdf)

TDEC 2020. *Posted Streams, Rivers, and Reservoirs in Tennessee*. Tennessee Department of Environment and Conservation, Division of Water Resources, Nashville, Tennessee. (https://www.tn.gov/content/dam/tn/environment/water/planning-and-standards/wr_wq_fish-advisories.pdf)

Radionuclides discharged to surface waters on ORR can potentially reach members of the public who use the Clinch and Tennessee Rivers for fishing, swimming, boating, or drinking water. Water and fish samples are collected at several locations on the Clinch River and are analyzed to ensure that members of the public are not exposed to harmful levels of radioactivity.
ORNL photograph

7

Dose

Activities on ORR have the potential to release small quantities of radionuclides and hazardous chemicals to the environment. The releases could expose members of the public to low concentrations of radionuclides or hazardous chemicals. Monitoring of materials released from ORR and environmental monitoring and surveillance on and around the reservation provide data used to show that doses from released radionuclides and chemicals are in compliance with the law.

In 2022, a hypothetical maximally exposed individual (MEI) would have received an effective dose (ED) of about 0.2 mrem from radionuclides emitted to the atmosphere from all ORR sources; this is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem/year for protection of the public (40 CFR Part 61).

A worst-case analysis of exposures to waterborne radionuclides for all pathways combined gives a maximum possible individual ED of about 0.9 mrem. This dose is based on a person eating 27 kg/year (60 lb/year) of fish, drinking 730 L/year (193 gal/year) of drinking water, and using the shoreline for 60 h/year as well as swimming, boating, and irrigation.

In addition, if a person consumed one maximum-weight harvested deer and two maximum-weight harvested geese, all containing the maximum ^{137}Cs concentration, that person could have received an ED of about 2 mrem. This calculation provides an estimated upper-bound ED from consuming wildlife harvested from ORR. Turkey hunts normally conducted on ORR were canceled in 2022 due to the COVID-19 pandemic; however, deer hunts resumed in 2022.

Therefore, the annual dose for 2022 to an MEI from the combined exposure pathways is estimated to have been about 3 mrem. No significant doses from discharges of radioactive constituents from ORR other than those reported are known. DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), limits the ED that a member of the public may receive from all radionuclide exposure pathways during 1 year to no more than 100 mrem. The 2022 maximum ED from ORR was about 3 percent of the DOE Order 458.1 limit.

The potential doses to aquatic and terrestrial biota from contaminated soil and water were evaluated using a graded approach. Results of the screening calculations indicate that contaminants released from ORR site activities do not have an adverse impact on aquatic or terrestrial biota.

7.1. Radiation Dose

Small quantities of radionuclides were released to the environment from operations at ORR facilities in 2022. Those releases were described, characterized, and quantified in previous chapters of this report. This chapter presents estimates of potential radiation doses to the public from the releases. Dose estimates were obtained using monitored and estimated release data, environmental monitoring and surveillance data, estimated exposure conditions that tend to maximize calculated doses, and environmental transport and dosimetry codes that may also tend to overestimate the calculated doses. Therefore, dose calculations are likely overestimates of the doses received by actual people in the ORR vicinity.

7.1.1. Terminology

Exposures to radiation from nuclides located outside the body are called *external exposures*; exposures to radiation from nuclides deposited inside the body are called *internal exposures*. This distinction is important because external exposures occur only when a person is near or in a radionuclide-containing medium, whereas internal exposures continue while the radionuclides remain inside a person. Also, external exposures may result in uniform irradiation of the entire body, including all organs, whereas internal exposures usually result in nonuniform irradiation of the body and organs because most radionuclides deposit preferentially in specific organs or tissues. Several specialized terms and units used to characterize exposures to ionizing radiation are defined in Appendix E.

ED is a risk-based dose equivalent that is used to estimate health effects or risks to exposed persons. It is a weighted sum of dose equivalents to specified organs and is expressed in rem or sieverts (1 rem = 0.01 Sv). One rem of ED regardless of radiation type or method of delivery, has the same total radiological (also biological) risk effect. Because the doses discussed here are very small, EDs are expressed in millirem (mrem), which is one one-thousandth of a rem.
(See Appendix E for a comparison and description of various dose levels.)

7.1.2. Methods of Evaluation

The following sections summarize the methods and pathways used to determine potential doses to members of the public and to aquatic and terrestrial biota from radionuclides originating from ORR. Dose calculations are made for a variety of media using both computer models and measured radionuclide concentrations in samples collected on or near ORR.

7.1.2.1. Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 2022 were characterized by calculating EDs to maximally exposed on- and off-site members of the public and to the entire population residing within 80 km (50 mi) from the center of ORR. The calculations were performed for each major facility and for the entire ORR. The dose calculations were made using the Clean Air Act Assessment Package—1988 (CAP-88 PC) Version 4 (EPA 2015), a software program developed under EPA sponsorship to demonstrate compliance with 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. CAP-88 PC implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses food chain models to calculate radionuclide concentrations in foodstuffs (e.g., vegetables, meat, and milk) and subsequent intakes by humans.

In this assessment, adult dose coefficients were used to estimate doses. The coefficients are weighted sums of equivalent doses to 12 specified tissues or organs plus a remainder term that accounts for the rest of the tissues and organs in the body.

A total of 27 emission points on ORR were modeled during 2022. The total includes 3 (2 combined) points at Y-12, 23 points at ORNL, and 1 point at ETTP. Table 7.1 lists the emission point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations for 2022 were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. (See Table 7.2 for a summary of tower locations used to model the various sources.) During 2022, rainfall, as averaged over the six rain gauges located on ORR, was about 150.2 cm (59 in.). The average air temperature was 14.9°C (59°F) at the 10 to 15 m levels. The average mixing layer height (i.e., the depth of the atmosphere adjacent to the surface within which air is mixed) was 679.2 m (2,228 ft) for ETTP, 691.0 m (2,267 ft) for ORNL, and 679.2 m (2,228 ft) for Y-12. For occupants of residences, the dose calculations assume that the occupant remained at home during the entire year and obtained food according to the rural pattern. This pattern specifies that 70 percent of the vegetables and produce, 44 percent of the meat, and 40 percent of the milk consumed are produced in the local area (e.g., a home garden). The remaining portion of each food category is assumed to be produced within 80 km (50 mi) of ORR. The same assumptions are used for occupants of businesses, but the resulting doses are divided by 2 to compensate for the fact that businesses are occupied for less than half a year and less than half of a worker's food intake occurs at work. For collective ED estimates, production of beef, milk, and crops within 80 km (50 mi) of ORR was calculated using the production rates provided with CAP-88 PC Version 4.

Table 7.1. Emission point parameters and receptor locations used in the dose calculations, 2022

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Distance (m) and direction to the maximally exposed individual			
				From each site		From ORR	
			ORNL				
X-laboratory hoods							
X-1000	15	0.5	0	5,710	ENE	9,990	NE
X-2000	15	0.5	0	5,410	E	9,640	NE
X-3000	15	0.5	0	5,090	E	9,250	NE
X-4000	15	0.5	0	4,870	E	9,100	NNE
X-7000	15	0.5	0	4,280	ENE	9,560	NNE
X-2026	22.9	1.05	6.88	5,430	E	9,510	NE
X-2099	3.66	0.18	16.42	5,420	E	9,520	NE
X-3001	6.86	0.44	7.50	5,250	E	9,320	NE
X-3020	61	1.22	13.53	5,290	E	9,360	NE
X-3026-East	0.81	0.97	0[b]	5,150	E	9,320	NE
X-3026-West	0.81	0.97	0[b]	5,150	E	9,320	NE
X-3039	76.2	2.44	5.36	5,150	E	9,300	NE
X-3544	9.53	0.28	24.80	5,170	ENE	9,570	NNE
X-3571	3.35	0.29	0[b]	5,160	E	9,440	NNE
X-3608 filter press	8.99	0.36	9.27	5,010	ENE	9,470	NNE
X-4501	19.81	0.71	9.71	4,930	E	9,150	NNE

Table 7.1. Emission point parameters and receptor locations used in the dose calculations, 2022 (continued)

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Distance (m) and direction to the maximally exposed individual			
				From each site		From ORR	
			ORNL (continued)				
X-7503	30.5	0.91	13.12	4,320	ENE	9,390	NNE
X-7830 group	4.6	0.25	9.66	5,610	ENE	10,910	NNE
X-7856-CIP	18.29	0.48	11.70	5,610	ENE	10,980	NNE
X-7877	13.9	0.41	13.56	5,640	ENE	10,970	NNE
X-7880	27.7	1.52	15.00	5,670	ENE	10,990	NNE
X-7911	76.2	1.52	13.79	4,310	ENE	9,620	NNE
X-7935 building stack	15.24	0.51	24.27	4,330	ENE	9,540	NNE
X-7935 glove box	9.14	0.25	0[b]	4,330	ENE	9,540	NNE
X-7966	6.10	0.29	6.40	4,270	ENE	9,460	NNE
X-8915	104.0	1.22	7.25	4,420	ESE	6,280	NE
X-decom areas	15	0.5	0	4,840	E	9,060	NNE
			ETTP				
K-1407-AL CWTS	2.74	0.15	0[b]	400	SW	13,450	ENE
			Y-12 Complex				
Y-monitored	20	0.5	0	1,090	NNE	1,090	NNE
Y-unmonitored processes	20	0.5	0	1,090	NNE	1,090	NNE
Y-unmonitored lab hoods	20	0.5	0	1,090	NNE	1,090	NNE

[a] Exit gas temperatures are ambient air temperatures.
[b] The direction of exhaust is horizontal. Therefore, an exit velocity of 0 m/s is used.

Acronyms:
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom = Decommissioned
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

Results

EDs from radionuclides released to the atmosphere from ORR were calculated for ORR as a whole and for each site on ORR for MEIs and for the collective population (1,272,478 persons) residing within 80 km (50 mi) of ORR based on 2020 census data (Census 2020). CAP-88 PC Version 4 was used in 2022 to calculate individual and collective doses.

The location of the ORR MEI (i.e., the location where a hypothetical individual would receive the maximum ED from radionuclides emitted to the atmosphere from ORR) is about 1,090 m (0.7 m) north-northeast of the main Y-12 release point, about 9,620 m (6.0 mi) north-northeast of the 7911 stack at ORNL, and about 13,450 m (8.4 mi) east-northeast of the K-1407-AL Chromium Water Treatment System (CWTS) at ETTP (see Figure 7.1). This individual could have received an ED of about 0.2 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.07 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation (40 CFR 61, Subpart H). The maximum individual EDs calculated for each site and for ORR are listed in Table 7.3.

Table 7.4 lists the collective EDs. The calculated collective ED was about 11.5 person-rem, which is about 0.003 percent of the 381,743 person-rem that this population received from natural sources of radiation (based on an individual dose of about 300 mrem/year).

Table 7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2022

Tower	Height (m)	Source
		Y-12 Complex
MT6 (West Y-12)	30	All Y-12 sources
		ETTP
MT13 (Tower J)	20	K-1407-AL CWTS
		ORNL
MT4 (Tower A)	15	X-7830 group, X-7935 glove box, X-7966, and X-7000 lab hoods
	30	X-7503, X-7856-CIP, X-7877, X-7880, X-7911, and X-7935 building stack
MT2 (Tower D)	15	X-2099, X-3001, X-3026-East, X-3026-West, X-3571, X-3608 FP, X-decom hoods, X-1000, X-2000, X-3000, and X-4000 lab hoods
	35	X-2026, X-3544, and X-4501
	60	X-3020 and X-3039
MT12 (Tower F)	10	X-8915

Acronyms:
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom = Decommissioned
ETTP = East Tennessee Technology Park
FP = Filter Press
ORNL = Oak Ridge National Laboratory
Y-12 Complex = Y-12 National Security Complex

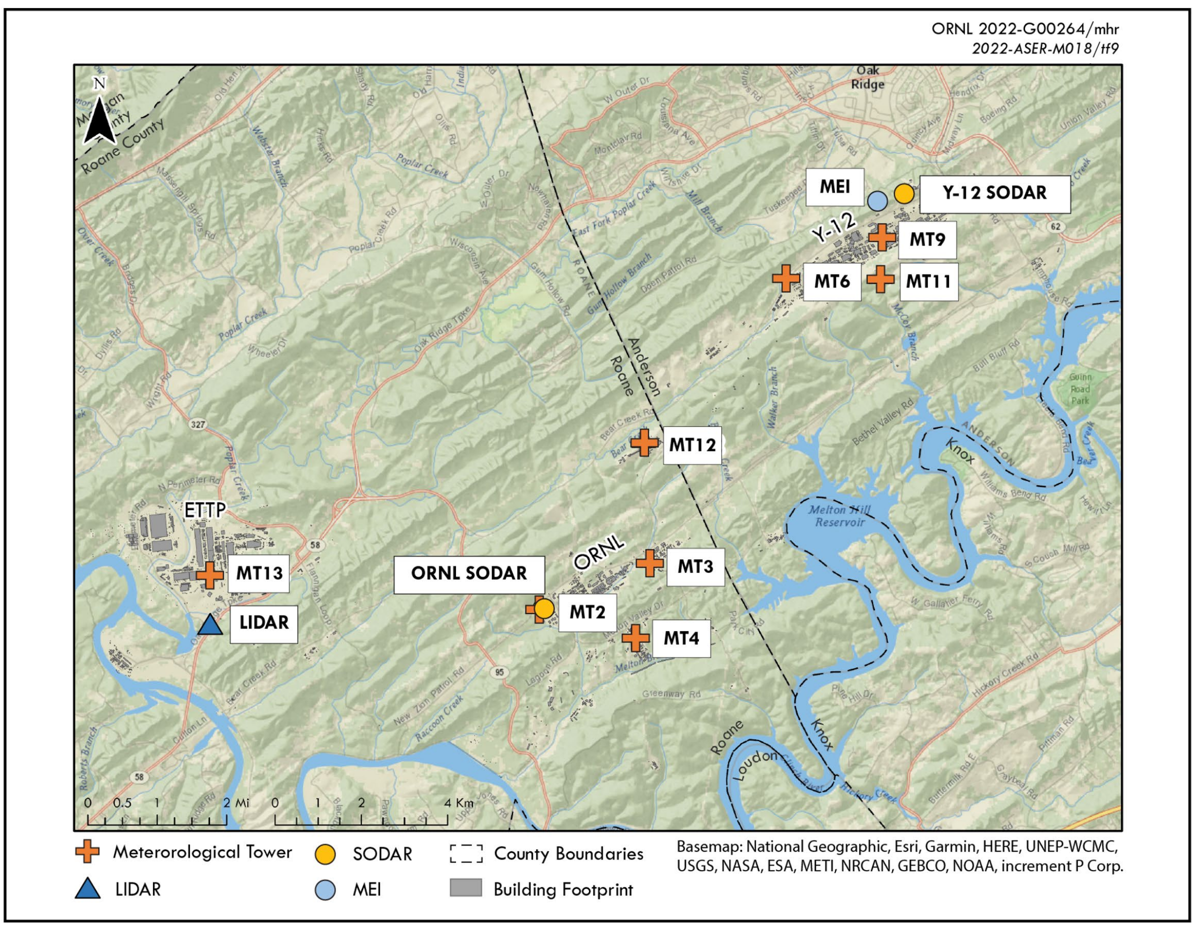


Figure 7.1. Location of the maximally exposed individual for ORR, 2022

Table 7.3. Calculated radiation doses to maximally exposed individuals from airborne releases from ORR, 2022

Site	Maximum effective dose, mrem and mSv			
	From each site		From ORR	
	mrem	mSv	mrem	mSv
ORNL[a]	0.2	0.002	0.08	0.0008
ETTP[b]	0.0002	2×10^{-6}	2×10^{-6}	2×10^{-8}
Y-12 Complex[c]	0.1	0.001	0.1	0.001
Entire ORR[d]	e	e	0.2	0.002

[a] *The ORNL MEI was located 5,150 m E of X-3039 and 4,310 m ENE of X-7911.*
[b] *The ETTP MEI was located 400 m SW of K-1407-AL Chromium Water Treatment System.*
[c] *The Y-12 MEI was located 1,090 m NNE of the main Y-12 Complex release point.*
[d] *The MEI for the entire ORR is 1,090 m NNE of Y-12 Complex release point, 9,300 m NE of X-3039, and 13,450 m ENE of K-1407-AL Chromium Water Treatment System.*
[e] *Not applicable.*

Acronyms:
ETTP = East Tennessee Technology Park
MEI = maximally exposed individual
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

Table 7.4. Calculated collective effective doses from airborne releases, 2022

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
ORNL	9.9	0.099
ETTP	0.0001	1×10^{-6}
Y-12 Complex	1.6	0.016
Entire ORR	11.5	0.115

[a] *Collective effective dose to the 1,272,478 persons residing within 80 km (50 mi) of the ORR (based on 2020 census data).*

Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

The MEI for Y-12 was located at a residence about 1,090 m (0.7 mi) north-northeast of the main Y-12 release point. This individual could have received an ED of about 0.1 mrem from Y-12 airborne emissions. Uranium radioisotopes (i.e., ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 92 percent, and other radionuclides accounted for about 8 percent of the dose (Figure 7.2). The contribution of Y-12 emissions to the 50-year committed collective ED to the population residing within 80 km (50 mi) of ORR was calculated to be about 1.6 person-rem, which is about 14 percent of the collective ED for ORR.

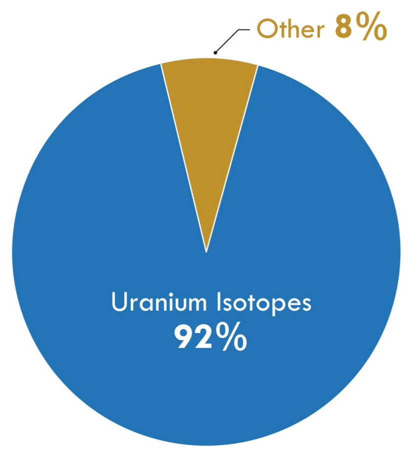


Figure 7.2. Nuclides contributing to effective dose at the Y-12 Complex, 2022

The MEI for ORNL was located at a residence about 5,150 m (3.2 m) east of the 3039 stack and 4,310 m (2.7 mi) east-northeast of the 7911 stack. This individual could have received an ED of about 0.2 mrem from ORNL airborne emissions. Lead-212 contributed about 42 percent, ^{138}Cs contributed about 21 percent, ^{11}C contributed about 21 percent, and ^{41}Ar contributed about 4 percent to the ORNL ED (Figure 7.3). The total contribution from uranium radioisotopes (i.e., ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}U, and ^{240}U) accounted for about 0.4 percent of the dose. Of those, ^{238}U made the largest contribution. The contribution of ORNL emissions to the collective ED to the population residing within 80 km (50 mi) of ORR was calculated to be about 9.9 person-rem or about 86 percent of the collective ED for ORR.

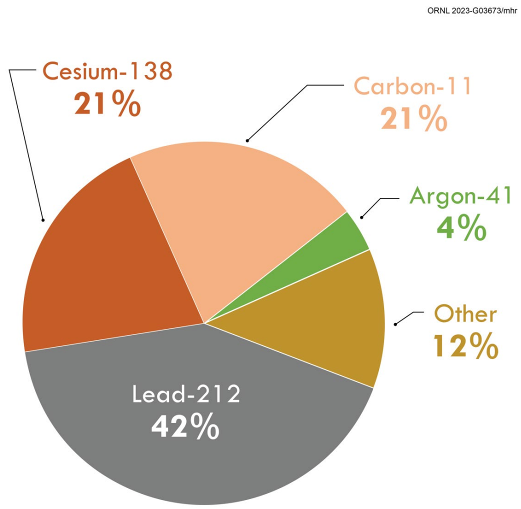


Figure 7.3. Nuclides contributing to effective dose at ORNL, 2022

The MEI for ETTP was located at a business about 400 m (0.24 mi) southwest of the K-1407-AL CWTS. The ED received by this individual from airborne emissions was calculated to be about 0.0002 mrem. About 91 percent of the dose was from uranium radioisotopes (^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U), about 3 percent of the dose was from progeny of uranium isotopes, and about 6 percent of the dose was from ^{99}Tc (Figure 7.4).
The contribution of ETTP emissions to the collective ED to the population residing within 80 km (50 mi) of ORR was calculated to be about 0.0001 person-rem, or about 0.001 percent of the collective ED for ORR.

To evaluate the validity of the estimated doses calculated using CAP-88 PC Version 4 and emissions data (Table 7.5), the doses were compared to the EDs calculated using radionuclide air concentrations (excluding naturally occurring ^{7}Be and ^{40}K) measured in samples collected at the ORR ambient air locations (Figure 6.3). In 2022, analysis of ambient air samples transitioned to a different laboratory, resulting in possible variations in analytical procedures and reporting methodologies. Analyses included gross alpha, gross beta, gamma emitters, isotopic uranium, and ^{3}H.

In 2022, in addition to ^{3}H and uranium isotopes, ^{214}Bi, ^{210}Pb, ^{212}Pb, ^{124}Sb, ^{208}Tl, and ^{99}Tc were detected at ORR ambient air stations. Lead-210, a naturally occurring radioisotope, was detected at all ORR ambient air sampling locations and at the background location, Station 52 (Table 7.5). On average, the dose contribution from ^{210}Pb at ambient air sampling locations was nearly 2.3 mrem. Measured air concentrations of ^{210}Pb were excluded in calculated EDs because it is naturally occurring and was only emitted from one source on ORR at levels significantly below those measured in ambient air samples.

ORNL 2022-G00310/mhr

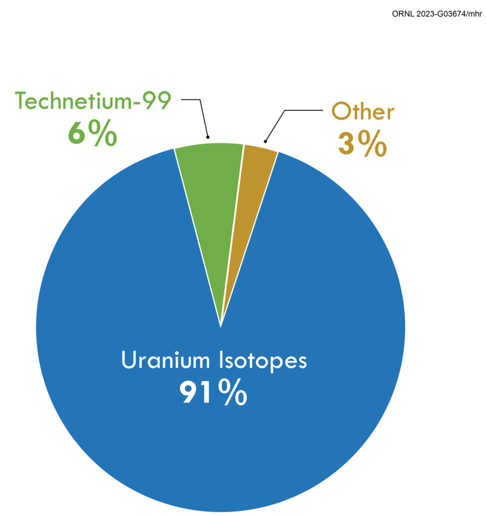


Figure 7.4. Nuclides contributing to effective dose at ETTP, 2022

Based on measured air concentrations, hypothetical individuals assumed to reside at the ambient air stations could have received EDs between 0.02 and 0.06 mrem/year, while EDs calculated using CAP-88 PC Version 4 and emissions data were between 0.05 and 0.4 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data tended to be greater than or similar to EDs calculated using measured air concentrations.

Station 52, located remotely from ORR, gives an indication of potential EDs from background sources. Samples from Stations 35 and 52 were analyzed for ^{99}Tc in 2022. Technetium-99 was detected at the background location and in the sample at Station 35. Based on measured air concentrations (excluding the naturally occurring isotopes ^{7}Be and ^{40}K), the ED at Station 52 was estimated to be 0.06 mrem/year. Based on air concentrations calculated using CAP-88 PC Version 4, the ED was estimated to be 0.01 mrem/year.

Table 7.5. Hypothetical effective doses from living near ORR and ETTP ambient air monitoring stations, 2022

Station	Calculated effective doses			
	Using air monitor data		Using CAP-88[a] and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
		ORR		
1	0.03	0.0003	0.2	0.002
2	0.03	0.0003	0.2	0.002
3	0.04	0.0004	0.4	0.004
11	0.03	0.0003	0.2	0.002
35[b]	0.06	0.0006	0.05	0.0005
37	0.02	0.0002	0.1	0.001
40	0.03	0.0003	0.2	0.002
46	0.03	0.0003	0.1	0.001
49	0.03	0.0003	0.08	0.0008
52[b,c]	0.06	0.0006	0.01	0.0001
		ETTP		
K11	3×10^{-5}	3×10^{-7}	0.03	0.0003
K12	*d*	*d*	0.03	0.0003

[a] CAP-88 PC Version 4 software, developed under US Environmental Protection Agency sponsorship to demonstrate compliance with 40 CFR 61, Subpart H.
[b] In 2022, analysis to detect ^{99}Tc was requested for Stations 35 and 52.
[c] Background ambient air monitoring station.
[d] No radionuclides were detected during 2022 at this location.
Acronyms:
ETTP = East Tennessee Technology Park
ORR = Oak Ridge Reservation

The measured air concentrations of ^{7}Be were similar at ORR stations and at the background air monitoring station.

EDs calculated using measured air concentrations of radionuclides at ambient air stations located near the MEIs for each site are significantly less than EDs calculated using source emissions data. Station 1 is located near the off-site MEI for ORNL. The ED calculated with measured air concentrations was 0.03 mrem/year, and the ED estimated using source emissions data was 0.2 mrem/year. Station 46 is located near the off-site MEI for the Y-12 Complex and ORR. The ED calculated with measured air concentrations was 0.03 mrem/year, and the ED estimated using source emissions data was 0.1 mrem/year. Station K11 is located near the on-site MEI for ETTP. The ED calculated with measured air concentrations was 3×10^{-5}, and the ED calculated using source emissions data was 0.03 mrem/year.

7.1.2.2. Waterborne Radionuclides

Radionuclides discharged to surface waters from ORR enter the Tennessee River system by way of the Clinch River. Discharges from Y-12 enter the Clinch River via Bear Creek and East Fork Poplar Creek (EFPC), which both enter Poplar Creek before it enters the Clinch River. Discharges from Rogers Quarry enter McCoy Branch, which flows into Melton Hill Lake. Discharges from ORNL enter the Clinch River via White Oak Creek (WOC) and enter Melton Hill Lake via small drainage creeks. Discharges from ETTP enter the Clinch River either directly or via Poplar Creek. This section discusses the potential radiological impacts of these discharges to persons who get drinking water from the Clinch and Tennessee Rivers and use them for fishing, swimming, boating, and other shoreline activities.

For assessment purposes, surface waters potentially affected by ORR are divided into the following seven segments:

- Melton Hill Lake above all possible ORR inputs
- Melton Hill Lake
- Upper Clinch River (from the Melton Hill Dam to confluence with Poplar Creek)
- Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River)
- Upper Watts Bar Lake (from near the confluence of the Clinch and Tennessee Rivers to below Kingston)
- The lower system (the remainder of Watts Bar Lake and Chickamauga Lake to Chattanooga)
- Poplar Creek (including the confluence of EFPC)

Two methods are used to estimate potential radiation doses to the public. The first method uses radionuclide concentrations in water and fish determined by laboratory analyses of water and fish samples (see Sections 6.4 and 6.6.4). The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated streamflows. Both methods use reported concentrations of radionuclides to estimate radiation doses if the reported value is statistically significant and/or detected.

The advantage of the first method is the use of radionuclide concentrations measured in water and fish; disadvantages are the inclusion of naturally occurring radionuclides (e.g., ^{40}K, uranium and its progeny, thorium and its progeny, and unidentified alpha and beta activities), the possible inclusion of radionuclides discharged from sources not part of ORR, and the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured. The advantages of the second method are that most radionuclides discharged from ORR can be quantified and that naturally occurring radionuclides may not be considered or may be accounted for separately. The disadvantage is the use of models to estimate the concentrations of the radionuclides in water and fish. Both methods use the same models (Hamby 1991) to estimate radionuclide concentrations in media and at locations other than those that are sampled (e.g., downstream), and the doses are calculated using per capita committed ED coefficients for water ingestion (DOE 2021). Utilizing the two methods to estimate potential doses accounts for field measurements and discharge measurements.

Drinking Water Consumption

Estimated maximum EDs to a person drinking water were calculated using both measured radionuclide concentrations in off-site surface water and measured radionuclide discharges to the off-site surface water, excluding naturally occurring radionuclides such as ^{40}K and ^{7}Be. During FY 2022, the Oak Ridge Office of Environmental Management (OREM) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. Currently, no water is consumed from these off-site groundwater wells.

Water drawn into treatment plants from the Clinch and Tennessee River systems could be affected by discharges from ORR. Because they are based on radionuclide concentrations in water before it enters a processing plant, the dose estimates given in this section likely are high. (No in-plant radionuclide concentration data are available for the treatment plants.)

Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, the drinking water consumption rate for the MEI is 730 L/year (193 gal/year), and the drinking water consumption rate for the average person is 370 L/year (98 gal/year). The average drinking water consumption rate is used to estimate the collective EDs. The EDs for the seven surface water segments are as follows:

- **Upper Melton Hill Lake above all possible ORR inputs.** Based on samples from Melton Hill Lake above possible ORR inputs (at Clinch River kilometer [CRK] 66 near the City of Oak Ridge water intake plant), an MEI drinking water at this location could have received an ED of about 0.1 mrem. The collective ED to the 46,765 persons who drink water from the City of Oak Ridge water plant would be 3 person-rem.
- **Melton Hill Lake.** The only water treatment plant located on Melton Hill Lake that could be affected by discharges from ORR is a Knox County plant. This plant is located near surface water sampling location CRK 58. An MEI could have received an ED of about 0.1 mrem; the collective dose to the 70,666 persons who drink water from this plant could have been 4 person-rem.
- **Upper Clinch River.** There are no known drinking water intakes in this river segment.
- **Lower Clinch River.** There are no known drinking water intakes in this river segment (from the confluence of Poplar Creek with the lower Clinch River to the confluence of the lower Clinch River with the Tennessee River).
- **Upper Watts Bar Lake.** The Kingston and Rockwood municipal water plants draw water from the Tennessee River not far from its confluence with the Clinch River. An MEI could have received an ED of about 0.03 mrem. The collective dose to the 31,325 persons who drink water from these plants could have been about 0.4 person-rem.
- **Lower system.** Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. An MEI drinking water from those plants could have received an ED of about 0.02 mrem. The collective dose to the 307,526 persons who drink water from the lower system could have been about 3 person-rem.
- **Poplar Creek/lower EFPC.** No drinking water intakes are located on Poplar Creek or on lower EFPC.

Fish Consumption

Fishing is common on the Clinch and Tennessee River systems. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, avid fish consumers were assumed to have eaten 27 kg (60 lb) of fish during 2022. The average person used for collective dose calculations was assumed to have consumed 11 kg (24 lb) of fish in 2022. The maximum ED at each location is estimated using one of two methods: the first method uses measured radionuclide concentrations in fish; the second method calculates possible radionuclide concentrations in fish from measured radionuclide discharges and known or estimated streamflows. The number of individuals who could have eaten fish is based on lake creel surveys and commercial fishing reporting conducted annually by the Tennessee Wildlife Resources Agency (TWRA) (TWRA 2019, TWRA 2021, TWRA 2022). Routine fish tissue analyses include gross alpha, gross beta, gamma spectroscopy for gamma emitters, and ^{3}H. Detected and/or statistically significant radionuclides in 2022 included ^{40}K, ^{3}H, ^{90}Sr, ^{230}Th, and ^{232}Th.

In 2022, the maximum EDs from fish consumption at upper Melton Hill Lake and upper Clinch River were determined using measured radionuclide concentrations in fish samples collected at CRK 70 and CRK 32. However, the maximum fish consumption EDs at the remaining locations were estimated using the measured radionuclide concentrations in water to estimate radionuclide concentrations in fish.

- **Upper Melton Hill Lake above all possible ORR inputs.** For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 70, which is above all possible ORR inputs, could have received an ED of about 0.7 mrem. The collective ED to the 13 persons who could have eaten fish harvested at that location was about 0.004 person-rem.

- **Melton Hill Lake.** An avid fish consumer who ate fish from Melton Hill Lake could have received an ED of about 0.4 mrem. The collective ED to the 119 persons who could have eaten fish harvested at that location could be about 0.02 person-rem.

- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River could have received an ED of about 0.5 mrem. The collective ED to the 42 persons who could have eaten fish harvested at that location could have been about 0.008 person-rem.

- **Lower Clinch River.** An avid fish consumer who ate fish from the lower Clinch River could have received an ED of about 0.4 mrem. The collective ED to the 99 persons who could have eaten fish harvested at that location could have been about 0.02 person-rem.

- **Upper Watts Bar Lake.** An avid fish consumer who ate fish from upper Watts Bar Lake could have received an ED of about 0.08 mrem. The collective ED to the 283 persons who could have eaten fish harvested at that location could be about 0.009 person-rem.

- **Lower system.** An avid fish consumer who ate fish from the lower system could have received an ED of about 0.07 mrem. The collective ED to the about 8,650 persons who could have eaten fish harvested at that location could have been about 0.2 person-rem.

- **Poplar Creek/lower EFPC.** An avid fish consumer who ate fish from Poplar Creek/lower EFPC could have received an ED of about 0.1 mrem; it is considered unlikely that a person would consume fish from those locations. Assuming 200 people could have eaten fish from lower EFPC and from Poplar Creek, the collective ED could have been about 0.007 person-rem.

Other Uses

A highly exposed "other user" was assumed to swim or wade for 30 h/year, boat for 63 h/year, and use the shoreline for 60 h/year. The average individual who is used for collective dose estimates was assumed to swim or wade for 10 h/year, boat for 21 h/year, and use the shoreline for 20 h/year. The potential EDs from these activities were estimated from measured and calculated concentrations of radionuclides in water. The equations that were used were derived from the LADTAP XL code (Hamby 1991) and were modified to account for radioactive data and shoreline use. The number of individuals who could have been other users are different for each section of water. Recreational activities for Melton Hill Reservoir are based on surveys conducted by the University of Tennessee (Stephens et al. 2006). Another survey was conducted regarding visitor and property owner activities for Chickamauga and Watts Bar Reservoirs (Poudyal et al. 2017). The data from these surveys were used to identify the variety of recreational activities on these water bodies. It was found that respondents often participated in more than one recreational activity.

Upper Melton Hill Lake above all possible ORR inputs. A hypothetical maximally exposed other user of upper Melton Hill Lake above possible ORR inputs (CRK 66) could have received an ED of about 2×10^{-5} mrem. The collective ED to the 14,483 other users could have been 2×10^{-5} person-rem.

- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 0.002 mrem. The collective ED to the 40,044 other users could have been about 0.005 person-rem.

- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 0.001 mrem. The collective ED to the 13,114 other users could have been about 0.001 person-rem.

- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 0.001 mrem. The collective ED to the 30,599 other users could have been about 0.004 person-rem.
- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 0.0004 mrem. The collective ED to the 87,424 other users could have been about 0.003 person-rem.
- **Lower system (Watts Bar and Chickamauga Lakes).** An individual other user of the lower system could have received an ED of about 0.0003 mrem. The collective ED to the 3,173,423 other users could have been about 0.06 person-rem.
- **Poplar Creek/lower EFPC.** An individual other user of lower EFPC above its confluence with Poplar Creek could have received an ED of about 0.0002 mrem. The collective ED to the 200 other users of Poplar Creek and lower EFPC could have been about 3×10^{-6} person-rem.

Irrigation

Although there are no known locations that use water from water bodies around ORR to irrigate food or feed crops, it was decided to determine whether irrigation could contribute to radiation doses to a member of the public. To make this determination, the method described by the Nuclear Regulatory Commission (NRC 1977) was used. Based on measured and calculated instream concentrations of radionuclides at CRK 16, which is a location on the lower Clinch River and downstream of ORR, the maximum potential dose (excluding the naturally occurring radionuclides ^{7}Be and ^{40}K) to an individual due to irrigation ranged from 1×10^{-7} to 0.1 mrem in 2022. The average instream dose at CRK 16 was estimated to be about 0.04 mrem. Based on all water discharges at CRK 16, the sum of doses was estimated to be 2×10^{-6} mrem. The individual was assumed to consume 24 kg of leafy vegetables, 90 kg of produce, 321 L of milk, and 63 kg of meat (beef) during the year. Additionally, the doses are calculated using per capita committed ED coefficients for water and milk ingestion (DOE 2021).

Summary

Table 7.6 summarizes potential EDs from identified waterborne radionuclides around ORR. The estimated maximum individual ED would be about 0.8 mrem to a person obtaining his or her drinking water and annual complement of fish (60 lb) from those water systems and participating in other water uses throughout those systems. The total collective ED from waterborne radionuclides to the population engaging in these activities was estimated to be about 10 person-rem. The relative percentages of individual and collective doses are small; they constitute about 0.3 percent of the average individual background dose of roughly 300 mrem/year and 0.003 percent of the 381,743 person-rem that the 80 km (50 mile) population received from natural sources of radiation.

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2022[a,b]

Effective dose	Source			Total[c]
	Drinking water	Eating fish	Other uses	
Upstream of all Oak Ridge Reservation discharge locations (CRK 66, City of Oak Ridge water plant)				
Individual	0.1	0.7[d]	0.00002	0.8
Collective	3	0.004[d]	0.00002	3
Melton Hill Lake (CRK 58, Knox County water plant)				
Individual	0.1	0.4	0.002	0.5
Collective	4	0.02	0.005	4
Upper Clinch River (CRK 23, 32)				
Individual	NA[e]	0.5[d]	0.001	0.5
Collective	NA[e]	0.008[d]	0.001	0.01
Lower Clinch River (CRK 16)				
Individual	NA[e]	0.4	0.001	0.4
Collective	NA[e]	0.02	0.004	0.02
Upper Watts Bar Lake (Kingston municipal water plant)				
Individual	0.03	0.08	0.0004	0.1
Collective	0.4	0.009	0.003	0.4
Lower system (lower Watts Bar Lake and Chickamauga Lake)				
Individual	0.02	0.07	0.0003	0.1
Collective	3	0.2	0.06	3
Lower East Fork Poplar Creek and Poplar Creek				
Individual	NA[e]	0.1	0.0002	0.1
Collective	NA[e]	0.007	0.000003	0.007

[a] 1 mrem = 0.01 mSv.
[b] Doses based on measured radionuclide concentrations in water or estimated from measured discharges and known or estimated streamflows.
[c] Total doses and apparent sums over individual pathway doses may differ because of rounding.
[d] Doses based on measured radionuclide concentrations in fish samples.
[e] Not at or near drinking water supply locations.
Acronym: *CRK = Clinch River kilometer*

7.1.2.3. Radionuclides in Food

The CAP-88 PC computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that could potentially contain radionuclides released from ORR.

Milk, vegetables, hay, wildlife, and fish are sampled annually, as available, for analysis to characterize doses from radionuclides that could be consumed in food products that originated at local farms and gardens and in game harvested by hunting and fishing on or near ORR.

Milk

Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year. A small dairy operation located in the vicinity of ORR was identified in 2020, but milk samples could not be to be obtained. No additional suitable locations were identified in 2021 or 2022. Milk sampling will resume when dairy operations in appropriate areas are located.

Vegetables

The food crop sampling program is described in Chapter 6. Samples of leafy greens and root vegetables were not available in 2022, but tomatoes were obtained from three local gardens and one distant background location. The background location was in Claiborne County. Only ^{40}K was detected in tomatoes at all locations. No additional radionuclides were detected in the tomatoes. Potassium-40 is found in the natural environment and may also be emitted from ORR. Potassium-40 concentrations in tomatoes were similar at all garden locations, including the background location. In 2022, a hypothetical person consuming tomatoes at any of these garden locations, including the distant (background) garden location, would not receive a committed ED in excess of that from naturally occurring ^{40}K.

An example of a naturally occurring and fertilizer-introduced radionuclide is ^{40}K, which was identified in the samples and accounted for most of the beta activity. The presence of ^{40}K in the samples added, on average, about 2 mrem to the hypothetical home gardener's ED. In 2022, gardeners who provided vegetable samples were asked about water sources and fertilizers used. Fertilizers were used at two of the three garden locations and at the background location.

Water sources for the gardens typically include city water. Most of the activity found in vegetables is thought to be due to the ^{40}K and to unidentified, naturally occurring beta-emitting radionuclides, not emissions from ORR.

Hay

Another environmental pathway that is typically evaluated is eating beef and drinking milk obtained from hypothetical cattle that eat hay harvested from one location on ORR. Hay samples collected on ORR are normally analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. In 2022, statistically significant concentrations of ^{7}Be and ^{40}K were detected in hay samples. Both ^{7}Be and ^{40}K are naturally occurring and are not included in reported EDs from drinking milk and eating beef. Hay samples were not available in 2021, however from 2016 to 2020, the ED from drinking milk and eating beef ranged from 0.0009 mrem to 0.09 mrem.

White-Tailed Deer

The annual deer hunts were cancelled in 2020 and 2021 because of the COVID-19 pandemic but resumed in 2022. In 2022, TWRA conducted three 2-day deer hunts on ORR. (See Sect.6.6.5.) During the hunts, 280 deer were harvested and taken to the TWRA checking station, where a bone sample and a muscle tissue sample were collected from each deer. The samples were field-counted for radioactivity to ensure that the deer met the wildlife release criteria of net counts less than 1.5 times background (~20 pCi/g $^{89/90}$Sr) of beta activity in bone and the administrative limit of 5 pCi/g of ^{137}Cs in edible tissue (ORNL 2011; ORNL 2020).[1] No deer exceeded the wildlife release criteria in 2022.

The average ^{137}Cs concentration in muscle tissue of the 280 released deer was 0.5 pCi/g; the maximum ^{137}Cs concentration in released deer was 0.8 pCi/g. The ^{137}Cs activity in each sample was less than minimum detectable levels. The average weight of released deer was approximately 47 kg (103 lb); the maximum weight was 87 kg (192 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from about 0.1 to 1 mrem, with an average of about 0.6 mrem.

Potential doses from the consumption of deer that might have moved off ORR and been harvested elsewhere were also evaluated. In this scenario, if an individual consumed one average-weight deer (47 kg [103 lb], assuming that 55 percent of the field weight is edible meat) with the 2022 average field-measured concentration of ^{137}Cs (0.5 pCi/g), that invidiual could have received an ED of about 0.6 mrem. The maximum field-measured ^{137}Cs concentration was 0.8 pCi/g, and the maximum deer weight was 87 kg (192 lb). If an individual consumed a deer of maximum weight and ^{137}Cs

[1] The 2020 version of CSD-AM-RML-RA01 supersedes the 2011 version.

content, that individual could have received an ED of about 2 mrem.

In 2022, muscle tissue samples from seven released deer were collected and analyzed for radionuclides. Analyses included ^{137}Cs, ^{90}Sr, and ^{40}K. Comparison of the released-deer field results with analytical ^{137}Cs concentrations showed that the field concentrations were greater than the analytical results and that all concentrations were less than the administrative limit of 5 pCi/g (ORNL 2011; ORNL 2020).[1] Using the analytical results for ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses for the seven released deer ranged from about 0.1 to 1 mrem.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. Thirty-three hunters harvested either two or three deer from ORR. Based on ^{137}Cs concentrations determined by field counting and actual field weights, the ED to a hunter who consumed two or more deer was estimated to be between about 0.4 and 2 mrem.

The collective ED from eating venison from all the deer harvested on ORR in 2022 is estimated to be about 0.2 person-rem based on the 2022 average field-derived ^{137}Cs concentration of 0.5 pCi/g and an average weight of 47 kg (103 lb). The collective dose is based on number of harvested deer. Additional individuals may also have consumed the harvested venison, but the collective dose would be essentially the same.

Canada Geese

Sixteen geese were captured during the 2022 goose roundup and were subjected to live whole-body gamma scans. The geese were field-counted for radioactivity to ensure that they met wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). The average ^{137}Cs concentration was 0.3 pCi/g. The maximum ^{137}Cs concentration in the released geese was 0.4 pCi/g. All ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the geese screened during the roundup was about 2.7 kg (6 lb), and the maximum weight was about 4.3 kg (9.5 lb).

The EDs attributed to field-measured ^{137}Cs concentrations of the geese ranged from 0.017 to 0.019 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 2.7 kg (6 lb) and an average ^{137}Cs concentration of 0.3 pCi/g, the estimated ED would be approximately 0.02 mrem. About half the weight of a Canada goose is assumed to be edible. The estimated ED would be about 0.04 mrem for an individual who consumed a goose with the maximum ^{137}Cs concentration of 0.4 pCi/g and maximum weight of 4.3 kg (9.5 lb).

It is possible that a person could eat more than one goose that spent time on ORR. The average seasonal goose bag per active hunter from Tennessee in the Mississippi Flyway ranged from 1.9 to 3.0 geese per hunting season between 1999 and 2010 (TWRA 2010). Hypothetically, a person who consumed two geese of maximum weight with the highest measured concentration of ^{137}Cs, would have received an ED of about 0.1 mrem.

Between 2000 and 2009, 22 samples of goose tissue were analyzed. An evaluation of potential doses was made based on laboratory-determined concentrations of the following radionuclides: ^{40}K, ^{137}Cs, ^{90}Sr, thorium (^{228}Th, ^{230}Th, ^{232}Th), uranium ($^{233/234}$U, ^{235}U, ^{238}U), and transuranic elements (^{241}Am, $^{243/244}$Cm, ^{238}Pu, $^{239/240}$Pu). The total potential dose, omitting the contribution of naturally occurring ^{40}K, ranged from 0.01 to 0.5 mrem. The average potential dose was 0.2 mrem (EP&WSD 2010).

Eastern Wild Turkey

Wild turkey hunts scheduled on ORR for 2020 through 2022 were canceled because of the COVID-19 pandemic. Typically, hunters are permitted to harvest one turkey from the reservation in each hunting season. Harvested turkeys are field-counted for radioactivity to ensure that they meet wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). If the release criteria are not met, the turkey is retained, and the hunter is permitted to harvest another turkey.

No turkeys were retained from 2015 through 2019. The average weights of the released turkeys for those years ranged from 8.1 kg (17.8 lb) to 8.9

kg (19.5 lb) and the maximum weights ranged from 10 kg (22 lb) to 11.3 kg (25 lb). The average ^{137}Cs concentration in turkeys harvested on ORR from 2015 through 2019 was 0.1 pCi/g; maximum concentrations ranged from 0.16 to 0.3 pCi/g. Almost all ^{137}Cs concentrations were below minimum detectable activity levels.

The EDs attributed to ^{137}Cs concentrations from field-measurementson on turkeys harvested from 2015 through 2019 ranged from 0.004 to 0.04 mrem. For bounding purposes, if a person consumed an average weight released turkey with an average ^{137}Cs concentration during years 2015 through 2019, the estimated ED would have been approximately 0.02 mrem. About half the weight of a turkey is assumed to be edible. The estimated ED to an individual who consumed a turkey assumed to have the maximum ^{137}Cs concentration and maximum weight ranged from about 0.04 to 0.08 mrem.

No tissue samples were analyzed from 2015 through 2019, and hunts scheduled on ORR for 2020 through 2022 were canceled. Earlier evaluations of doses based on laboratory-determined concentrations of radionuclides included ^{40}K, ^{137}Cs, ^{90}Sr, ^{230}Th, ^{3}H, ^{234}U, ^{235}U, ^{238}U, and transuranic elements (^{241}Am, ^{244}Cm, ^{237}Np, ^{239}Pu). The total dose, omitting the contribution of naturally occurring ^{40}K, ranged from 0.06 to 0.2 mrem (EP&WSD 2010).

7.1.2.4. Direct Radiation

The principal sources of natural external exposure are the penetrating gamma radiations emitted by ^{40}K and the series originating from ^{238}U and ^{232}Th (NCRP 2009). Because of radiological activities on ORR, external radiation exposure rates are measured at six of the ORR ambient air monitoring stations and at Station 52, the reference ambient air station (Figure 6.2). External gamma exposure rates were continuously recorded by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations. In 2022, exposure rates averaged about 9.4 μR/h and ranged from 8.0 to 12.8 μR/h. The exposure rates correspond to an annual average dose of about 58 mrem with a range of 49 to 79 mrem. At the background ambient air station, the exposure rate averaged about 9 μR/h and ranged from 8.0 to 11.4 μR/h. The resulting average annual dose was about 54 mrem with a range of 49 to 70 mrem. The annual doses based on measured exposure rates at or near ORR boundaries were typically within the range of the doses measured at the background location; slightly higher exposure rates were observed at ambient air monitoring Stations 11 and 46.

7.1.3. Current-Year Summary

A summary of the maximum EDs to individuals by exposure pathway is given in Table 7.7. In the unlikely event that any person was exposed to all those sources and pathways for the duration of 2022, that person could have received a total ED of about 3 mrem. Of that total, 0.2 mrem would have come from airborne emissions, approximately 0.9 mrem from waterborne emissions (0.1 mrem from drinking water, 0.7 mrem from consuming fish, 2×10^{-5} mrem from other water uses along the Clinch River, and 0.1 mrem from irrigation at CRK 16), and about 2 mrem from consumption of wildlife. Direct radiation measurements at six ORR ambient air monitoring stations were at or near background levels in 2022. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported.

7.1.4. Five-Year Trends

EDs associated with selected exposure pathways for 2018 through 2022 are given in Table 7.8. In 2022, the air pathway dose decreased but is similar to air pathway doses that have been estimated over the past 5 years. The increase in the 2019 fish consumption dose was due to a catfish sample collected at CRK 16, in which $^{239/240}$Pu was a primary dose contributor; however, the catfish sample collected at CRK 70, which is above ORR discharge locations, also contained $^{239/240}$Pu. Catfish and sunfish samples from both CRK 16 and CRK 70 were reanalyzed, and although results were generally lower, there was not a statistically significant difference, and the original results were used in dose calculations. The increase in fish consumption and drinking water doses in 2021 was due to the contribution of ^{241}Am detected in the second-quarter water sample taken at CRK 58. Recent direct radiation measurements indicate doses near background levels. Doses from consumption of wildlife have been similar for the last 5 years, although the dose from consumption of geese increased slightly in 2021.

7.1.5. Doses to Aquatic and Terrestrial Biota

The following sections summarize the results of assessments conducted to determine the potential effect of radionuclides originating from ORR on aquatic and terrestrial biota.

7.1.5.1. Aquatic Biota

DOE Order 458.1 (DOE 2020) sets an absorbed dose rate limit of 1 rad/day to native aquatic organisms from exposure to radioactive material in liquid wastes discharged to natural waterways (see Appendix E for definitions of *absorbed dose* and *rad*). To demonstrate compliance with this limit, the aquatic organism assessment was conducted using the RESRAD-Biota code (Version 1.8), a companion tool for implementing DOE technical standard *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019). The code serves as DOE's biota dose evaluation tool and uses the screening (i.e., biota concentration guides [BCGs]) and analysis methods in the technical standard. The BCG is the limiting concentration of a radionuclide in sediment or water that would not cause dose limits for protection of aquatic biota populations to be exceeded.

Table 7.7. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2022

Pathway	Dose to maximally exposed individual		Percentage of DOE mrem/year limit (%)	Estimated collective radiation dose[a]			
				Pathway		Background (person-rem)	Total Population
	mrem	mSv		person-rem	person-Sv		
			Airborne effluents				
All pathways	0.2	0.002	0.2	11.5	0.115		1,272,478[b]
			Liquid effluents				
Drinking water	0.1	0.001	0.1	10	0.1		456,282[c]
Eating fish	0.7	0.007	0.7	0.3	0.003		9,406[d]
Other activities	2×10^{-5}	2×10^{-7}	2×10^{-5}	0.07	0.007		3,359,287[d]
Irrigation	0.1	0.001	0.1				
			Other pathways				
Eating deer	*2*[e]	*0.02*[e]	2	*0.2*[e]	*0.002*[e]		
Eating geese	0.1[f]	0.001[f]	0.1	*g*	*g*		
Eating turkeys	*h*	*h*	*h*	*h*	*h*		
Direct radiation	NA[i]	NA					
			All pathways				
Total	3[j]	0.03	3	22	0.22	381,743	

[a] Estimated background collective dose is based on the roughly 300 mrem/year individual dose and the population within 80 km (50 mi) of ORR.
[b] Population is based on 2020 census data.
[c] Population estimates are based on community and noncommunity drinking water supply data from the Tennessee Department of Environment and Conservation Division of Water.

[d] Population estimates for fish are based on creel and commercial fishing data. Fractions of fish harvested from Melton Hill, Watts Bar, and Chickamauga Reservoirs are based on creel survey data. Melton Hill, Watts Bar, and Chickamauga recreational use information was obtained from the Tennessee Valley Authority (Stephens et al. 2006 and Poudyal et al. 2017). Other activities include swimming, boating, and shoreline use; the population estimates include individuals involved in more than one activity and visitors that may live outside the 80 km radius.

[e] Estimates for eating deer are based on consuming one hypothetical deer of the heaviest weight measured among the captured deer and with the highest ^{137}Cs concentration measured in the released deer on ORR; collective dose is based on number of harvested deer.

[f] Estimates for eating geese are based on consuming two hypothetical geese, each with the heaviest weight measured among the captured geese and with the highest measured concentration of ^{137}Cs in the released geese.

[g] Collective doses were not estimated for the consumption of geese because no geese were harvested for consumption during the goose roundup.

[h] No turkeys were harvested on ORR during 2022 because of the COVID-19 pandemic.

[i] Current exposure rate measurements at perimeter air monitoring stations are at or near background levels.

[j] Dose estimates have been rounded.

Acronyms:

DOE = US Department of Energy

ORR = Oak Ridge Reservation

Table 7.8. Trends in effective dose from ORR activities, 2018–2022 (mrem)[a]

Pathway	2018	2019	2020	2021	2022
Airborne Effluents—all pathways	0.2	0.4	0.4	0.5	0.2
Fish consumption (Clinch River)	0.09	4	2	3	0.4
Drinking water (Kingston)	0.03	0.01	0.02	3	.03
Deer	2	2	*b*	*b*	2
Geese	0.1	0.1	0.07	0.2	0.1
Turkeys	0.05	0.04	*b*	*b*	*b*

[a] 1 mrem = 0.01 mSv

[b] Wild turkey hunts scheduled on ORR for 2020 through 2022, and deer hunts for 2020 and 2021, were canceled because of the COVID-19 pandemic.

***Acronym:** ORR = Oak Ridge Reservation*

The intent of the graded approach is to protect populations of aquatic organisms from the effects of exposure to anthropogenic ionizing radiation. Certain organisms are more sensitive to ionizing radiation than others. Therefore, protecting the more sensitive organisms is generally assumed to adequately protect other, less sensitive organisms. Depending on the radionuclide, either aquatic organisms (e.g., crustaceans) or riparian organisms (e.g., raccoons) may be more sensitive and are typically the limiting organisms for the general screening phase of the graded approach for aquatic system evaluations.

At ORNL, doses to aquatic organisms are based on surface water concentrations at the following instream sampling locations:

- Melton Branch (X13) and Melton Branch Weir
- WOC headwaters (WOC 6.8), WOC (X14), and White Oak Dam (WOD) (X15)
- WOC 7500 Bridge
- First Creek
- Fifth Creek
- Northwest Tributary
- Raccoon Creek

- Solid Waste Storage Area 4 SW1(tributary to WOC)
- Waste Area Grouping 6 Monitoring Station 3 (tributary to WOC at WOD)
- CRK 16, 32, 58, and 66

Based on the results of the general screening phase, in which the maximum concentrations of radionuclides in water are compared with default BCGs, the absorbed dose rates to aquatic organisms at all ORNL locations were below the DOE aquatic dose limit of 1 rad/day.

At Y-12, doses to aquatic organisms were estimated from surface water concentrations and sediment concentrations (at Station 9422-1 and S24) at the following instream sampling locations:

- Surface Water Hydrological Information Support System Station 9422-1 (also known as Station 17)
- Bear Creek at Bear Creek kilometer 9.2
- Discharge Point S24
- Discharge Point S17 (unnamed tributary to the Clinch River)
- Discharge Point S19 (Rogers Quarry)
- Outfall 200 on EFPC

Absorbed dose rates to aquatic organisms at the Y-12 locations were below the DOE aquatic dose limit of 1 rad/day based on general screenings or second-level screenings at the Surface Water Hydrological Information Support System Station 9422-1 and Outfall 200.

At ETTP, doses to aquatic organisms were estimated from surface water concentrations at the following instream sampling locations:

- Mitchell Branch at K1700
- Mitchell Branch kilometers 0.45, 0.59, 0.71, and 1.4 (upstream location)
- Poplar Creek at K-716 (downstream)
- K1007-B and K-1710 (upstream location)
- K-702A and K901-A (downstream of ETTP operations)
- CRK 16 and 23

Absorbed dose rates to aquatic organisms were below the DOE aquatic dose limit of 1 rad/day at the ETTP sampling locations based on general screening results.

7.1.5.2. Terrestrial Biota

A terrestrial organism assessment was conducted to evaluate impacts on biota in accordance with requirements in DOE Order 458.1 (DOE 2020). An absorbed dose rate of 0.1 rad/day is recommended as the limit for terrestrial animal exposure to radioactive material in soils. RESRAD-Biota code (Version 1.8), a companion tool for implementing DOE technical standard *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019), was used for the terrestrial organism assessment to demonstrate compliance with this limit. As is the case with aquatic and riparian biota, certain terrestrial organisms are more sensitive to ionizing radiation than others, and it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms.

Initial soil sampling for terrestrial dose assessment was initiated in 2007 and was reassessed in 2014 and 2021. Additionally, biota sampling in the WOC floodplain was conducted in 2009. White-footed mice (*Peromyscus leucopus*), deer mice (*Peromyscus maniculatus*), and hispid cotton rats (*Sigmodon hispidus)* were selected for sampling because they live and forage in these areas, are food for other mammals, and have relatively small home ranges. The biota sampling locations were at the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake. ORR site-specific bioaccumulation factors were calculated using 2007 and 2014 maximum soil concentrations and radionuclide concentrations in tissue for biota inhabiting the WOC floodplain.

In 2007, 2014, and 2021, soil sampling focused on unremediated areas, such as floodplains and some upland areas. Floodplains are often downstream of contaminant source areas and are dynamic systems where soils are eroding in some places and being deposited in others. This biota sampling strategy was developed using guidance provided in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019) and existing radiological information on the concentrations and distribution of radiological contaminants on ORR. In 2021, soil samples were collected from the same general locations as those collected in 2007 and 2014. Soil sampling locations are identified as follows:

- **WOC floodplain.** Analytes detected in soil samples at this location in 2021 include ^{241}Am, ^{137}Cs, ^{60}Co, $^{243/244}$Cm, ^{238}Pu, $^{239/240}$Pu, ^{40}K, $^{89/90}$Sr, $^{233/234}$U, ^{235}U, and ^{238}U.
- **Mitchell Branch floodplain.** Analytes detected in soil samples at this location in 2021 include ^{241}Am, $^{239/240}$Pu, ^{99}Tc, $^{233/234}$U, and ^{238}U.
- **Bear Creek Valley floodplain.** Analytes detected in soil samples at this location in 2021 include ^{241}Am, $^{243/244}$Cm, $^{233/234}$U, ^{235}U, and ^{238}U.
- **EFPC floodplain.** Analytes detected in soil samples at this location in 2021 include $^{233/234}$U, ^{235}U, and ^{238}U.
- **Background locations.** Soils were also sampled in 2021 near Gum Hollow Branch, which represents Conasauga group geologic formations, and near Bearden Creek, which represents Chickamauga group geologic formations. Analytes detected in soil samples at the background locations in 2021 include ^{241}Am, ^{137}Cs, $^{239/240}$Pu, ^{40}K, $^{89/90}$Sr, $^{233/234}$U, ^{235}U, and ^{238}U.

In 2021, all soil samples except for those collected on the WOC floodplain upstream of WOD passed the initial-level screening (a comparison of maximum radionuclide soil concentrations to default BCGs). Cesium-137 was the primary dose contributor to terrestrial biota on the WOC floodplain and was also the primary dose contributor in 2007 and 2014. Strontium-90 also contributed significantly to wildlife dose on the WOC floodplain in 2021 but to a lesser extent than ^{137}Cs. Because of measured concentrations in soil on the WOC floodplain and results of second-level screening (comparison of average radionuclide soil concentrations to default BCGs), further evaluation was completed using ORR site-specific bioaccumulation factors and average radionuclide soil concentrations. The results of additional screening evaluation indicated that absorbed dose rates to terrestrial organisms on the WOC floodplain were less than the DOE limit of 0.1 rad/day.

Future evaluations of exposure to terrestrial organisms will be conducted within the next 5 years or sooner if an abnormal event occurs that could have adverse impacts on terrestrial organisms.

7.2. Chemical Dose

Chemicals released because of ORR operations can move through the environment to off-site locations, resulting in potential exposure of the public. The following sections summarize the results of risk assessments for chemicals found in drinking water and fish on or near ORR.

7.2.1. Drinking Water Consumption

Surface water and groundwater are both potential sources of drinking water for populations in areas adjacent to ORR. Samples of surface water and groundwater are collected from water sources near ORR and are analyzed for their chemical content to determine the presence and concentration of chemicals that could pose a health risk for the local population.

7.2.1.1. Surface Water

To evaluate the drinking water exposure pathway, hazard quotients (HQs) and risks were estimated downstream of ORNL and downstream of ORR discharge points to the Clinch River (Table 7.9).

The HQ is a ratio that compares the estimated exposure dose or intake to the reference dose for noncarcinogens. HQs of less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects. Likewise, risks are evaluated from estimated exposure dose or intake and cancer slope factors. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000) (see Appendix F). Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, the drinking water consumption rate for the MEI is assumed to be 730 L/year (2 L/day). This is the same drinking water consumption rate used in the estimation of the maximum exposed radiological dose from consumption of drinking water. Chemical analytes were measured in surface water samples collected at CRK 66, CRK 32, CRK 23, and CRK 16.

Nearly all calculated HQs and risk levels for carcinogens (Table 7.9) for CRK 16 and CRK 23 are based on water concentration values reported as the detection limit of the instrumentation and analysis method used except for chromium at CRK 23; nickel at CRK 16; and copper, mercury, and uranium at CRK 16 and CRK 23. At all locations, HQs were less than 1 for chemical analytes in water for which there are reference doses or maximum contaminant levels (Table 7.9). In 2022, mercury concentrations were measured at CRK 66, CRK 32, and CRK 16 using a more sensitive analysis method with a lower reporting limit than was used in previous years. HQs were 2×10^{-4} for CRK 66 and 1×10^{-4} for CRK 32 in 2022. For carcinogens, risk values greater than 10^{-6} were calculated for the hypothetical intake of drinking water containing chromium (as Cr^{+6}), arsenic, and vinyl chloride at locations CRK 23 and 16. The estimated risk values are within the EPA's acceptable risk range of 10^{-4} to 10^{-6}. CRK 16, located downstream of all ORR discharge points, is not a source of drinking water, but data from that location were used as surrogates to evaluate potential exposure to drinking water from the Clinch River.

Table 7.9. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 23 and 16, 2022

Analyte	Hazard quotient	
	CRK 23[a]	CRK 16[b]
Metals		
Antimony	4×10^{-2}	4×10^{-2}
Arsenic	1×10^{-1}	1×10^{-1}
Cadmium	7×10^{-3}	7×10^{-3}
Chromium	9×10^{-3}	8×10^{-3}
Copper	4×10^{-4}	4×10^{-4}
Lead	9×10^{-2}	9×10^{-2}
Mercury	3×10^{-5}	1×10^{-3}
Nickel	6×10^{-4}	6×10^{-4}
Selenium	7×10^{-3}	7×10^{-3}
Silver	1×10^{-3}	1×10^{-3}
Thallium	3×10^{-1}	3×10^{-1}
Uranium	3×10^{-2}	3×10^{-2}
Zinc	2×10^{-4}	2×10^{-4}
Volatile organics		
1,1,1-Trichloroethane	4×10^{-6}	4×10^{-6}
Acetone	c	3×10^{-4}
cis-1,2-Dichloroethene	4×10^{-3}	4×10^{-3}
Trichloroethene	2×10^{-2}	2×10^{-2}
Vinyl chloride	3×10^{-3}	3×10^{-3}
Risks for carcinogens		
Arsenic	2×10^{-5}	2×10^{-5}
Chromium	5×10^{-6}	4×10^{-6}
Lead	4×10^{-8}	4×10^{-8}
Trichloroethene	1×10^{-7}	1×10^{-7}
Vinyl chloride	4×10^{-6}	4×10^{-6}

[a] CRK 23 is no longer a water intake location.
[b] CRK 16 is downstream of all DOE inputs to the Clinch River and not a water intake location.
[c] The parameter was undetected.
Acronym:
CRK = Clinch River kilometer

7.2.1.2. Groundwater

During FY 2022, OREM continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley (see Section 6.5). Currently, no water is consumed from these off-site groundwater wells.

7.2.2. Fish Consumption

Chemicals in water can be accumulated by aquatic organisms that may be consumed by humans. To evaluate the potential health effects from the fish consumption pathway, HQs were estimated for the consumption of noncarcinogens, and risk values were estimated for the consumption of carcinogens detected in sunfish and catfish collected both upstream and downstream of ORR discharge points. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, avid fish consumers were assumed to have eaten 27 kg (60 lb) of fish during 2022. This fish consumption rate of 74 g/day (27 kg/year) is assumed for estimating exposure to both the noncarcinogenic and carcinogenic chemicals. This is the same fish consumption rate used in the estimation of the radiological dose from consumption of fish.

For consumption of sunfish and catfish, HQs of less than 1 were calculated for all detected analytes except for Aroclor-1254 (CRK 16) and Aroclor-1260 (CRK 32 and CRK 16) in catfish (Table 7.10). For carcinogens, risk values at or greater than 10^{-6} were calculated for the intake of Aroclor-1254 (CRK 16) and Aroclor-1260 (CRK 32 and CRK 16) in catfish. The Tennessee Department of Environment and Conservation (TDEC) has issued a fish advisory that states that catfish should not be consumed from Melton Hill Reservoir (in its entirety) or the Tennessee River portion of Watts Bar Reservoir because of PCB contamination (TDEC 2022). TDEC has also issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TDEC 2022).

Table 7.10. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on ORR, 2022[a]

	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
			Hazard quotients for metals			
Barium			0.002			
Copper	0.003	0.002	0.002	0.003	0.007	
Iron					0.008	
Manganese	0.001	0.002	0.02	0.002	0.002	0.001
Mercury					0.6	
Selenium	0.1	0.08	0.06			
Strontium			0.007			
Zinc	0.03	0.01	0.03	0.009	0.03	0.01
			Hazard quotients for Aroclors			
Aroclor-1254						9
Aroclor-1260					3	11
			Risks for carcinogens			
Aroclor-1254						1×10^{-4}
Aroclor-1260					4×10^{-5}	2×10^{-4}
PCBs (mixed)[e]					4×10^{-5}	3×10^{-4}

[a] Blank space for a location indicates that the parameter was undetected.
[b] Melton Hill Reservoir, reference location above the City of Oak Ridge water plant.
[c] Clinch River downstream of Oak Ridge National Laboratory.
[d] Clinch River downstream of all US Department of Energy inputs.
[e] Mixed PCBs comprise the summation of Aroclors detected or estimated.

Acronyms:
CRK = Clinch River kilometer
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl

7.3. References

40 CFR 61, Subpart H. "Subpart H—National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." *US Code of Federal Regulations*. https://www.ecfr.gov/cgi-bin/text-idx?SID=eff89c419f5d1ed63e14b4d1765f4bf9&mc=true&node=pt40.10.61&rgn=div5#sp40.10.61.h (accessed February 25, 2021).

Census 2020. 2020 Census Results. US Census Bureau, Washington, DC. https://www.census.gov/programs-surveys/decennial-census/decade/2020/2020-census-results.html.

DOE 2019. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. DOE-STD-1153-2019. US Department of Energy, Washington, DC.

DOE 2020. *Radiation Protection of the Public and the Environment*. DOE Order 458.1, Ltd. Chg. 4. Approved February 11, 2011 (Ltd. Chg. 4 dated September 15, 2020). US Department of Energy, Washington, DC.

DOE 2021. *Derived Concentration Technical Standard*. DOE-STD-1196-2021. US Department of Energy, Washington, DC.

EP&WSD 2010. *Radiological Monitoring and Dose Report for Selected Wildlife Populations Oak Ridge Reservation*. EPWSD-EPS-TP-01. Oak Ridge National Laboratory, Environmental Protection and Waste Services Division, Oak Ridge, Tennessee.

EPA 2011. *Exposure Factors Handbook.* EPA/600/R-090/052F. US Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment.

EPA 2015. *CAP-88 & CAP-88 PC*. US Environmental Protection Agency, November 2015. https://www.epa.gov/radiation/cap-88-cap-88-pc (accessed February 25, 2021).

Hamby 1991. Hamby, D.M., "LADTAP XL: An Improved Electronic Spreadsheet Version of LADTAP II." DE93003179. Westinghouse Savannah River Company, Aiken, South Carolina.

NCRP 2009. *Ionizing Radiation Exposure of the Population of the United States.* NCRP Report No. 160. National Council on Radiation Protection and Measurements, Bethesda, Maryland.

NRC 1977. *Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I.* US Nuclear Regulatory Commission, Washington, DC.

ORNL 2011. *Deer Hunt Radiation Monitoring Guidelines.* CSD-AM-RML-RA01. Oak Ridge National Laboratory, Chemical Sciences Division, Oak Ridge, Tennessee.

ORNL 2020. *Wildlife Monitoring at the TWRA Monitoring Station.* CSD-AM-RML-RA01. Oak Ridge National Laboratory, Chemical Sciences Division, Oak Ridge, Tennessee.

Poudyal et al. 2017. Poudyal, N. C., H. Gotwald, B. English, K. Jensen, J. Menard, C. Caplenor, C. Maldonado, and D. Watkins, "Results from Visitor and Property Owner Surveys on Chickamauga, Norris, and Watts Bar Reservoir in Summer 2016." University of Tennessee Institute of Agriculture, March 24.

Stephens 2006. Stephens, B. et al. *Recreation Use on Melton Hill Reservoir*. Human Dimensions Research Lab, University of Tennessee Agriculture Institute.

TDEC 2022. *Posted Streams, Rivers, and Reservoirs in Tennessee*. Tennessee Department of Environment and Conservation, Division of Water Resources, Nashville, Tennessee. https://www.tn.gov/content/dam/tn/environment/water/watershed-planning/wr_wq_fish-advisories.pdf (accessed March 1, 2023).

TWRA 2010. *Tennessee Waterfowl Report 2010–2011*, Tennessee Wildlife Resources Agency Technical Report No. 11-04, 2011.

TWRA 2019. *Final Report, Report No. 19-06, Tennessee Statewide Creel Survey, 2018 Results*, Fisheries Management Division, Tennessee Wildlife Resources Agency.

TWRA 2021. *Final Report, Report No. 21-06, Tennessee Statewide Creel Survey, 2020 Results*, Fisheries Management Division, Tennessee Wildlife Resources Agency.

TWRA 2022*, Tennessee's Commercial Fish and Mussel Report, Report No. 22-03,* Fisheries Management Division, Tennessee Wildlife Resources Agency.

A

Appendix A Glossary

accuracy—The closeness of the result of a measurement to the true value of the quantity.

aliquot—The quantity of a sample being used for analysis.

alkalinity—The capacity of an aqueous solution to neutralize an acid. Alkalinity measurements are important in determining the sensitivity of a body of water to acid inputs such as acidic pollution from rainfall or wastewater.

alpha particle—A positively charged particle emitted from the nucleus of an atom; it has the same charge and mass as that of a helium nucleus (two protons and two neutrons).

ambient air—The surrounding atmosphere as it exists around people, plants, and structures.

analyte—A constituent or parameter that is being analyzed.

analytical detection limit—The lowest reasonably accurate concentration of an analyte that can be detected; this value varies depending on the method, instrument, and dilution used.

anion—A negatively charged ion.

anthropogenic—Of, relating to, or resulting from the influence of human beings on nature.

aquifer—A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

aquitard—A geologic unit that inhibits the flow of water.

background radiation—Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material), and global fallout as it exists in the environment from the testing of nuclear explosive devices.

beta particle—A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.

biota—The animal and plant life of a particular region considered as a total ecological entity.

blank—A control sample that is identical in principle to the sample of interest, except the substance being analyzed is absent. In such cases, the measured value or signal for the substance being analyzed is believed to be a result of artifacts. Under certain circumstances, that value may be subtracted from the measured value to give a net result reflecting the amount of the substance in the sample. EPA does not permit the subtraction of blank results in EPA-regulated analyses.

calibration—Determination of variance from a standard of accuracy of a measuring instrument to ascertain necessary correction factors.

CERCLA Off-site Rule—Requires that CERCLA wastes be placed only in a facility operating in compliance with the Resource Conservation and Recovery act or other applicable federal or state requirements. The regulatory citation is 40 *CFR* 300.440.

CERCLA-reportable release—A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

chemical oxygen demand—Indicates the quantity of oxidizable materials present in water and varies with water composition, concentrations of reagent, temperature, period of contact, and other factors.

closure—Specifically, closure of a hazardous waste management facility under Resource Conservation and Recovery Act (RCRA) requirements.

compliance—Fulfillment of applicable requirements of a plan or schedule ordered or approved by government authority.

concentration—The amount of a substance contained in a unit volume or mass of a sample.

conductivity—A measure of water's capacity to convey an electric current. This property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made.

confluence—The point at which two or more streams meet; the point where a tributary joins the main stream.

contamination—Deposition of unwanted material on the surfaces of structures, areas, objects, or personnel.

cosmic radiation—Ionizing radiation with very high energies, originating outside the earth's atmosphere.

count—A measure of the radiation from an object or device; the signal that announces an ionization event within a counter.

curie (Ci)—A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are commonly used:

- **kilocurie (kCi)**—10^3 Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
- **millicurie (mCi)**—10^{-3} Ci, one-thousandth of a curie; 3.7×10^7 disintegrations per second.
- **microcurie (µCi)**—10^{-6} Ci, one-millionth of a curie; 3.7×10^4 disintegrations per second.
- **picocurie (pCi)**—10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.

daughter—A nuclide formed by the radioactive decay of a parent nuclide.

decay, radioactive—The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.

dense nonaqueous phase liquid (DNAPL)—The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

derived concentration standard (DCS)—Quantities used in the design and conduct of radiological environmental protection programs at US Department of Energy facilities and sites. These quantities represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving a 1 mSv (100 mrem) effective dose following continuous exposure for 1 year for each of the following pathways: ingestion of water, submersion in air, and inhalation.

disintegration, nuclear—A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dissolved oxygen—A measurement of the amount of gaseous oxygen in an aqueous solution. Adequate dissolved oxygen is necessary for good water quality.

dose—A general term for absorbed dose, equivalent dose, or effective dose.

- absorbed dose—The average energy imparted by ionizing radiation to the matter in a volume element per unit mass of irradiated material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
- collective dose/collective effective dose—The sum of the total effective dose to all persons in a specified population received in a specified period of time. It can be approximated by the sum of the average effective dose for a given subgroup i, and Ni is the number of individuals in this subgroup. Collective dose is expressed in units of person-rem (or person-sievert).
- effective dose (E or ED)—The summation of the products of the equivalent dose (HT) received by specified tissues or organs of the body and the appropriate tissue weighting factor (wT). It includes the dose from radiation sources internal and/or external to the body. The effective dose is expressed in units of rems (or sieverts).
- equivalent dose (HT)—The product of average absorbed dose (DT,R) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (wR).

dosimetry—Measurement and calculation of radiation doses from exposure to ionizing radiation.

drinking water standard (DWS)—Federal primary drinking water standards, both proposed and final, as set forth by the US Environmental Protection Agency.

duplicate samples—Two or more samples collected simultaneously into separate containers.

effluent—A liquid or gaseous waste discharge to the environment.

effluent monitoring—The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures of members of the public, and demonstrating compliance with applicable standards.

energy intensity—Energy consumption per square foot of building space, including industrial or laboratory facilities [EO 13514, Section 19(f)].

Environmental Management—A US Department of Energy program that directs the assessment and cleanup (remediation) of its sites and facilities contaminated with waste as a result of nuclear-related activities.

exposure (radiation)—The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that takes place during a person's working hours. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation—Exposure to ionizing radiation when the radiation source is located outside the body.

flux—A flow or discharge of a substance (in units of mass, radioactivity, etc.) per unit of time.

gamma ray—High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an excited atom. Gamma rays are identical to x-rays except for the source of the emission.

grab sample—A sample collected instantaneously with a glass or plastic bottle placed below the water surface to collect surface water samples (also called dip samples).

greenhouse gas (GHG)—Gas that traps heat in the atmosphere. The four major greenhouses gases are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

groundwater—The water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

hardness—Water hardness is caused by polyvalent metallic ions dissolved in water. In fresh water, these are mainly calcium and magnesium, although other metals such as iron, strontium, and manganese may contribute to hardness.

hectare—A metric unit of area equal to 10,000 square meters or 2.47 acres.

hydrology—The science dealing with the properties, distribution, and circulation of natural water systems.

internal radiation—Internal radiation occurs when radionuclides enter the body by ingestion of foods, milk, and water, and by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

ion—An atom or compound that carries an electrical charge.

irradiation—Exposure to radiation.

isotopes—Forms of an element having the same number of protons in their nuclei but differing in the number of neutrons.

Leadership in Energy and Environmental Design (LEED)—A suite of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods. LEED is intended to help building owners and operators find and implement ways to be environmentally responsible and resource-efficient.

maximally exposed individual (MEI)—A hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation from a given event or process.

microbes—Microscopic organisms.

migration—The transfer or movement of a material through the air, soil, or groundwater.

millirem (mrem)—The dose equivalent that is one one-thousandth of a rem.

milliroentgen (mR)—A measure of x-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable activity (MDA)—The smallest activity of a radionuclide that can be distinguished in a sample by a given measurement system at a preselected counting time and at a given confidence level.

monitoring—A process whereby the quantity and quality of factors that can affect the environment and/or human health are measured periodically to regulate and control potential impacts.

natural radiation—Radiation arising from cosmic and other naturally occurring radionuclide sources (such as radon) present in the environment.

nuclide—An atom specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

outfall—The point of conveyance (e.g., drain or pipe) of wastewater or other effluents into a ditch, pond, or river.

ozone—A gas made up of three oxygen atoms that occurs both in earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for human health and the environment, depending on its location in the atmosphere. Ozone acts as a protective layer high above the earth, but it can be harmful to breathe.

parts per billion (ppb)—A unit measure of concentration equivalent to the weight/volume ratio expressed as micrograms per liter or nanograms per milliliter.

parts per million (ppm)—A unit measure of concentration equivalent to the weight/volume ratio expressed as milligrams per liter or milligrams per kilogram.

person-rem—Collective dose to a population group. For example, a dose of 1 rem to 10 individuals results in a collective dose of 10 person-rem.

pH—A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 through < 7, basic solutions have a pH > 7, and neutral solutions have a pH = 7.

precision—The degree to which repeated measurements under unchanged conditions show the same results (also called reproducibility or repeatability).

quality assurance (QA)—Any action in environmental monitoring to ensure the reliability of monitoring and measurement data.

quality control (QC)—The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes.

rad—The unit of absorbed dose deposited in a volume of material.

radioactivity—The spontaneous emission of radiation, generally alpha or beta particles or gamma rays, from the nucleus of an unstable isotope.

radioisotopes—Radioactive isotopes.

radionuclide—An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reclamation—Recovery of wasteland, desert, etc. by ditching, filling, draining, or planting.

reference material—A material or substance with one or more properties that is sufficiently well established and is used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

release—Any discharge to the environment. "Environment" is broadly defined as any water, land, or ambient air.

rem—The unit of dose equivalent (absorbed dose in rads × the radiation quality factor). Dose equivalent is frequently reported in units of millirem (mrem), which is one one-thousandth of a rem.

remediation—The correction of a problem. On the Oak Ridge Reservation remediation efforts focus on the safe cleanup of the environmental legacy resulting from research activities and weapons production over the past 5 decades.

roentgen—A unit of radiation exposure equal to the quantity of ionizing radiation that will produce one electrostatic unit of electricity in one cubic centimeter of dry air at 0°C and standard atmospheric pressure. One roentgen equals 2.58×10^{-4} coulombs per kilogram of air. (Note: A coulomb is a unit of electric charge—the SI [International System of Units] unit of electric charge equal to the amount of charge transported by a current of one ampere in one second.)

sensitivity—The capability of a methodology or an instrument to discriminate among samples with differing concentrations or containing varying amounts of analyte.

sievert (Sv)—The SI (International System of Units) unit of dose equivalent; 1 Sv = 100 rem.

spike—The addition of a known amount of reference material containing the analyte of interest to a blank sample.

spiked sample—A sample to which a known amount of some substance has been added.

stable—Not radioactive or not easily decomposed or otherwise modified chemically.

stack—A vertical pipe or flue designed to exhaust airborne gases and suspended particulate matter.

standard reference material (SRM)—A reference material distributed and certified by the National Institute of Standards and Technology.

storm water runoff—Rainfall that flows over the ground surface.

stratospheric ozone—The stratosphere or "good" ozone layer extends upward from about 6 to 30 miles above the earth's surface and protects the earth from the sun's harmful ultraviolet rays.

substrate—The substance, base, surface, or medium in which an organism lives and grows.

Superfund—The Superfund Amendments and Reauthorization Act amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1986. CERCLA, the federal program to clean up the nation's uncontrolled hazardous waste, is now known as Superfund.

surface water—All water on the surface of the earth, as distinguished from groundwater.

terrestrial radiation—Ionizing radiation emitted from radioactive materials, primarily potassium-40, thorium, and uranium, in the earth's soils.

total dissolved solids—Dissolved solids and total dissolved solids (generally associated with freshwater systems) consist of inorganic salts, small amounts of organic matter, and dissolved materials.

transect—A line across an area being studied. The line is composed of points where specific measurements or samples are taken.

transuranic (or transuranium)—Of or relating to elements with higher atomic weights than uranium; all 13 known transuranic elements are radioactive and are produced artificially.

transuranic waste—Solid radioactive waste containing primarily alpha-emitting elements heavier than uranium.

trip blank—A sample container of deionized water that is transported to a sampling location, treated as a sample, and sent to the laboratory for analysis; trip blanks are used to check for contamination resulting from transport, shipping, and site conditions.

turbidity—A measure of the concentration of sediment or suspended particles in solution.

volatile organic compounds—Organic chemicals that have a high vapor pressure at ordinary conditions. They include both human-produced and naturally occurring chemical compounds and are used in many industrial processes. Common examples include trichloroethane, tetrachloroethene, and trichloroethene.

watershed—The region draining into a river, river system, or body of water. Large watersheds may be subdivided into smaller units called **subwatersheds**, which collectively flow together to form larger sub-basins and river basins.

wetlands—Lowland areas, such as a marshes or swamps, sufficiently inundated or saturated by surface water or groundwater to support aquatic vegetation or plants adapted for life in saturated soils. Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas.

wind rose—A diagram that summarizes statistical information concerning wind direction and speed at a specific location.

B

Appendix B Climate Overview of the Oak Ridge Area

B.1. Regional Climate

The climate of the Oak Ridge area and its surroundings may be broadly classified as humid subtropical. The term *humid* indicates that the region receives an overall surplus of precipitation compared with the level of evaporation and transpiration normally experienced throughout the year. The *subtropical* designation indicates that the region experiences a wide range of seasonal temperatures. Subtropical areas are typified by significant differences in temperature between summer and winter. Also, in humid subtropical climates, at least 4 months have an average temperature above 10°C (50°F). Monthly precipitation does not differ significantly throughout the year, but the types of precipitation may vary.

Oak Ridge winters are characterized by synoptic midlatitude cyclones that produce significant precipitation events roughly every 3 to 5 days. These wet periods are occasionally followed by arctic air outbreaks. Although snow and ice are not associated with many of these systems, occasional snowfall does result. Winter cloud cover tends to be enhanced by the regional terrain due to cold air wedging and moisture trapping.

Severe thunderstorms, which can occur at any time of the year, are most frequent during spring and rarely occur in winter. The Cumberland Mountains and Cumberland Plateau frequently inhibit the intensity of severe systems that traverse the region to the east, particularly those moving from west to east, because of the downward momentum created as the storms move off higher terrain into the Great Valley. Summers are characterized by very warm, humid conditions. Occasional frontal systems may produce organized lines of thunderstorms and rare damaging tornados.

More frequently, however, summer precipitation results from air mass thundershowers that form as a consequence of daytime heating, rising humid air, and local terrain features. Although fall precipitation is usually adequate, August through October often are the driest months of the year. Precipitation during the fall tends to be less cyclical than in other seasons, but it is occasionally enhanced by decaying tropical cyclones moving north from the Gulf of Mexico. In November, midlatitude cyclones again begin to dominate the weather and typically continue to do so until May.

Decadal-scale climate changes regularly affect the East Tennessee region. Most of these changes appear related to the hemispheric temperature and precipitation effects caused by the frequency and phase of the El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). The ENSO and PDO patterns, with cycles of 3 to 7 years and about 60 years, respectively, affect Pacific Ocean sea surface temperature patterns. The AMO, with a cycle of 40 to 70 years, has an effect on Atlantic sea surface temperature that is similar to the PDO's effect on Pacific Ocean sea surface temperature. These medium- and long-range sea surface temperature patterns collectively modulate decadal-scale and longer regional temperature and precipitation trends in eastern Tennessee. The AMO shifted from a cold to a warm sea surface temperature phase in the mid-1990s which may continue in for another decade or so. The PDO entered an either cool or transitional sea surface temperature phase around 2000. Although the ENSO pattern had frequently caused warmer Eastern Pacific sea surface temperatures during the 1990s, that warming had subsided somewhat in the 2000s. The El Niño returned to prominence during the 2010s. A very strong El Niño occurred in 2015–2016, causing above-normal temperatures both locally and across much of the globe by 2016. Additionally, evidence exists that human-induced climate change may be affecting local temperatures via well-mixed greenhouse gases, land cover change, carbon soot, aerosols, and other first-order influences. Solar influences on the jet stream via changes to the stratospheric temperature gradient over the 11-year solar cycle also contribute to interannual climate variability (Ineson et al. 2011). Perhaps in part because of the effects of the AMO and ENSO, the Oak Ridge climate warmed about 1.2°C from the 1970s to the 1990s, and through the 2010s it remained within 0.2°C of the value observed in the 1990s. The late 20th-century warming appears to have lengthened the growing season (i.e., the period with temperatures above 0°C, or 32°F) by about 2 to 3 weeks over the past 30 years, primarily by increasing minimum temperatures. This effect is presumably related to changes in the interaction of the surface boundary layer with greenhouse gases and/or aerosol concentration changes. The effects of greenhouse gases on the nocturnal inversion layer (and thus on minimum temperatures) represent a redistribution of heat in the lower portion of the surface atmospheric layer. Temperature averages for individual years may vary significantly, as observed in the more than 1°C difference between the average temperatures for 2014 (14.8°C) and 2015 (16.0°C), largely the result of the recent strong El Niño. During the post–El Niño years of 2017 and 2018, the annual average temperature at ORNL returned to approximately the same level as in 2014 (i.e., 14.5°C in 2018), but rose again in 2019 under the influence of weak El Niño conditions (15.2°C). Temperatures declined in 2020 to 14.7°C with the onset of La Niña conditions, which persisted into 2022 with an average temperature of 14.0°C.

B.2. Winds

Five major terrain-related wind regimes regularly affect the Great Valley of eastern Tennessee:

- Pressure-driven channeling
- Downward-momentum transport or vertically coupled flow
- Forced channeling
- Along-valley and mountain-valley thermal circulations
- Down sloping

Pressure-driven channeling and vertically coupled flow affect winds on scales comparable to that of the Great Valley (hundreds of kilometers). Forced channeling occurs on similar scales but is also quite important at small spatial scales, such as those characterizing the ridge-and-valley terrain within ORR (Birdwell 2011). Along-valley and mountain-valley circulations are thermally driven and occur within a broad range of spatial scales. Thermally driven flows are more prevalent under conditions of clear skies and low humidity, favoring summer and especially fall months. Down sloping frequently is responsible for a slight temperature elevation when the Cumberland Mountains are on the windward side of ORR. Such windward flow also favors reduced wind speeds.

Forced channeling is defined as the direct deflection of wind by terrain. Because it necessitates some degree of vertical motion transfer, forced channeling is less pronounced during strong temperature-inversion conditions. Although it may result from interactions between large valleys and mountain ranges (such as the Great Valley and the surrounding mountains), forced channeling is especially important in narrow, small valleys such as those within ORR and the Great Valley (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley is the dominant large-scale wind mechanism, influencing 50 to 60 percent of all winds observed in the area. For up-valley (southwest to northeast) flow cases, these winds are frequently associated with large wind shifts (45°–90°) when they initiate or terminate. At small scales, ridge-and-valley terrain produces forced-channeled local flow in more than 90 percent of cases.

Large-scale forced channeling occurs regularly within the Great Valley when northwest-to-north winds (perpendicular to the axis of the Central Great Valley) coincide with vertically coupled flow. This sometimes results in a split-flow pattern, with winds southwest of Knoxville moving down valley, and those east of Knoxville moving up valley. The causes of such a flow pattern may include the shape characteristics of the Great Valley (Kossman and Sturman 2002) but also may be associated with the specific location of the Cumberland and Smoky Mountains relative to upper-level wind flow (Eckman 1998). A northwest wind flow through the convex shape of the Great Valley may lead to a divergent wind flow pattern in the Knoxville area, resulting in downward air motion. Horizontal flow is also reduced by the windward mountain range, the Cumberland Mountains, which increases buoyancy and Coriolis effects (also known as Froude and Rossby ratios). Consequently, the leeward mountain range, the Smoky Mountains, becomes more effective at blocking or redirecting the winds.

Vertically coupled winds tend to occur when the atmosphere is unstably or neutrally buoyant. When a strong horizontal wind component is present, as in conditions behind a winter cold front or during strong regional cold-air advection, winds tend to override the terrain, flowing roughly in the same direction as the winds aloft. This is a consequence of the horizontal transport and momentum aloft being transferred to the surface. However, Coriolis effects may turn the winds to the left by up to 40° (Birdwell 1996).

In the Central Valley, vertically coupled winds dominate about 25 to 35 percent of the time; however, most such winds are turned toward an up-valley or down-valley direction when small-scale ridge-and-valley terrain is factored in. Wintertime vertically coupled flow is typically dominated by strong, large-scale pressure forces, whereas summertime cases tend to be associated with a deep mixing depth (greater than 500 m). Most vertically coupled flows are associated with major wind shifts (90°–135°) when they begin or terminate (Birdwell 2011).

Another wind mechanism, pressure-driven channeling, is the redirection of synoptically induced wind flow through a valley channel. The direction of wind flow through the valley is determined by the axis of the pressure gradient superimposed on the valley axis (Whiteman 2000). The process is affected by Coriolis forces, a leftward deflection of winds in the Northern Hemisphere. Eckman (1998) suggested that pressure-driven channeling plays a significant role in the Great Valley. Winds driven purely by pressure-driven channeling shift from up-valley to down-valley flow or in the opposite direction if large-scale pressure systems induce reversals in air pressure gradients across the axis of the Great Valley. Because the processes involved in pressure-driven flow primarily affect the horizontal motion of air, the presence of a temperature inversion enhances this pattern significantly. Weak vertical air motion and momentum associated with such inversions allow different layers of air to slide over one another with varied directions of movement (Monti et al. 2002).

Within the Central Great Valley, and especially within ORR, winds dominated by down-valley pressure-driven channeling range in frequency from 2 to 10 percent, with the lowest values in summer and the highest in winter. Up-valley pressure-driven channeling usually does not dominate winds in the Central Great Valley but co-occurs with forced-channeled winds 50 percent of the time. Winds dominated by pressure-driven channeling often result in large wind shifts (90°–180°) before and after the occurrence of the wind pattern. These wind shifts occur about twice as frequently within and near ORR than in other parts of the Great Valley (Birdwell 2011). Most pressure-driven channeled winds occur in association with moderate (0.006–0.016 mb/km) synoptic pressure gradients.

Thermally driven winds are common in areas of complex terrain. These winds occur because of pressure and temperature differences caused by varied surface-air energy exchanges at similar altitudes along a valley's axis, sidewalls, or slopes. Thermal flows operate most effectively when synoptic winds are light and when thermal differences are exacerbated by clear skies and low humidity (Whiteman 2000). Ridge-and-valley terrain may be responsible for enhancing or inhibiting such flow, depending on ambient weather conditions. The frequency of large-scale thermally driven winds is highest during summer and especially fall, when surface heating and low humidity help drive flow patterns (Birdwell 2011).

Annual wind roses were compiled for 2022 for each of the eight DOE-managed ORR meteorological towers (towers MT2, MT3, MT4, MT6, MT9, MT11, MT12, and MT13). These, along with other annual wind rose data, may be viewed on the ORNL meteorology website **here**. The wind roses represent large-scale trends and should be used with discretion when estimating short-term variations.

A wind rose depicts the typical distribution of wind speed and direction for a given location. The winds are represented in terms of the direction from which they originate. The rays emanating from the center correspond to points of the compass, and the length of each ray shows how often winds blow from that direction. The concentric circles represent increasing frequencies from the center outward.

B.3. Temperature and Precipitation

Temperature and precipitation normals (1991–2020) and extremes (1948–2022) and their durations for the city of Oak Ridge and ORNL are summarized in Table B.1. Decadal temperature and precipitation averages for five decades (1970s–2010s) are provided in Table B.2. Hourly freeze data (1985–2022) are given in Table B.3. Overall, at ORNL, 2022 was 0.9°C cooler than normal compared with the 1991–2020 Oak Ridge base period, and precipitation was 4 percent above normal compared with the 1991–2020 mean.

B.3.1. Recent Climate Change with Respect to Temperature and Precipitation

Table B.2 presents a decadal analysis of temperature patterns from 1970 to 2019. In general, temperatures in the Oak Ridge area rose from the 1970s to the 1990s and have nearly stabilized since the 1990s. Based on these average decadal temperatures, temperatures have risen 1.2°C between the 1970s and the 1990s, from 13.8°C to 15.0°C (56.8°F to 59.0°F). The warmest decade of the last five was the 2000s at 15.2°C (59.4°F), although temperatures in the 2010s were virtually the same (15.2°C or 59.4°F). More detailed analysis reveals that these temperature changes have been neither linear nor equal with respect to the seasons.

From the 1970s to the 1990s, January and February average temperatures increased by about 2.5°C and then declined by just over 1°C since the 1990s. The observed peak in the 1990s may be associated with the effects of the AMO, although this climate response may include both natural and anthropogenic effects. The Arctic has seen the largest increase in temperatures anywhere in the Northern Hemisphere over the past 30 years, and this increase has a corresponding effect on Oak Ridge temperatures in winter because of the influx of Arctic air masses during that season.

During the winter months of January, and February, much of the air entering eastern Tennessee comes from the Arctic. As a result, Oak Ridge temperatures have warmed more dramatically during these months. However, changes to average December temperatures have not been as dramatic as those in January and February. December averages were relatively warm in the 1970s (4.6°C), bottomed out in the 1980s (3.1°C), returned to approximately 1970s levels in the 1990s and 2000s, and finally warmed (to about 6.0°C) by the 2010s.

Compared with the 1970s, temperatures have warmed 1.0°C, 1.5°C, and 2.1°C during the climatological spring months of March, April, and May, respectively. However, most of the warming in March and April did not occur until the 2000s. The tendency toward warmer springs has slightly lengthened the growing season.

Summer months (June, July, and August) were 1.8°C, 1.3°C, and 0.9°C warmer on average, respectively, in the 2010s than in the 1970s; however, most observed warming during summer can be attributed to a rise in minimum temperatures. In fact, August maximum temperatures have declined about 1.0°C since the 2000s. Warming for June and July has virtually stopped since the 2000s.

Climatological fall months (September, October, and November) generally had the smallest average temperature increases (of 0.9°C, 1.3°C, and 0.1°C, respectively) since the 1970s. In fact, average temperatures in September and October have remained fairly constant since the 1990s, and November has not shown a clear trend across the decades since the 1970s.

The mean annual temperature increased by 1.4°C between the 1970s and the 2000s and then remained about the same in the 2010s (1.3°C warmer than the 1970s). About 90 percent of the observed increase occurred between the 1980s and 1990s. Mean annual decadal-averaged temperatures have varied by only 0.2°C since the 1990s. Beginning with the 2020 ASER, the base period used to determine the mean annual temperature was updated from 1981 to 2010 to 1991 to 2020. The mean annual temperature increased by about 0.6°C, mainly because the cooler 1980s values were eliminated.

Decadal precipitation averages suggest some important changes in precipitation patterns in Oak Ridge from the 1970s to 2010s. Although overall decadal precipitation averages have remained between about 48 and 60 in. annually, some decadal shifts were observed in monthly and seasonal patterns of rainfall. During winter (December, January, and February), precipitation remained fairly constant after the 1970s. However, February precipitation in the 2010s (and for winter overall after the 2000s) increased significantly. Spring precipitation (March, April, and May) declined about 20 percent after the 1970s. Summer (June, July, and August) precipitation changes are mixed. June values changed little between the 1970s and the 2010s, but July values increased by about 20 percent, and August values declined by about 20 percent. Similar patterns were observed for the fall months. During the 2010s, September precipitation values increased by about 10 percent compared with the 1970s, whereas October values decreased by about 10 percent. Little change occurred in precipitation for November. Overall, annual average precipitation in the 2010s was only about 3 percent less than it was in the 1970s (59.68 vs. 58.18 in.). Also, precipitation values in the 1980s and 2000s were 10 to 20 percent less than those in the 2010s, and precipitation levels in the 1990s were similar to levels observed in the 2010s.

The increase in winter temperatures since the 1970s has affected monthly and annual snowfall amounts. During the 1970s and 1980s, snowfall averaged about 25.4 to 28 cm (10 to 11 in.) annually in Oak Ridge. However, during the most recent two decades (2000s and 2010s), snowfall has averaged only 9.8 cm (3.9 in.) per year. This decrease seems to have occurred largely since the mid-1990s. January and February temperatures cooled slightly in the 2010s compared with the 2000s, which seems to have reversed the decrease in snowfall slightly, with annual averages of 13.2 cm (5.2 in.). Concurrent with the overall decrease in snowfall, the annual number of hours of subfreezing weather generally declined after the 1980s (see Table B.3). However, the number of subfreezing hours during 2010 (1,123 h) was the highest recorded since 1988. January 2014 was the coldest January since 1985, with 371 subfreezing hours, and February 2015 was the coldest February since 1978, also with 371 subfreezing hours.

Selected wind roses for ORR towers that show wind direction for hours with precipitation and other relevant meteorological parameters were compiled for 2022 and may be reviewed on the ORNL meteorology website **here**.

Table B.3 presents the number of hours of subfreezing temperatures in Oak Ridge for each year from 1985 to 2022. During the mid- to late 1980s, a typical year experienced about 900 to 1,000 h of subfreezing temperatures. In recent years, the value has fallen to about 600 to 700 h, although higher values have occurred relatively recently (e.g., 1,123 h in 2010). However, in some years in the 2010s, only 350 to 500 h of subfreezing weather were observed. Other statistics on winter precipitation may be found **here**.

B.4. Moisture

ORR's humid environment results in frequent saturation of the surface layer, especially at night. Average annual humidity at ORNL (Tower MT2) is 75.4 percent (2015–2021) at 2 m above ground level and 72.9 percent at 15 m above the ground. In terms of absolute humidity, the average annual humidity for the same location is 10.3 g/m^3 at both 2 and 15 m above ground level. This value varies greatly throughout the annual cycle, ranging from a monthly minimum of about 4.7 g/m^3 during winter to a maximum of about 16.9 g/m^3 during summer. Data for absolute and relative humidity and dew point are summarized on the ORNL meteorology website **here**.

Table B.1. Climate normals (1991–2020) and extremes (1948–2022) for ORNL

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C													
30-year average max	8.8	11.4	16.5	21.9	26.2	29.8	31.4	31.2	28.1	22.2	15.4	10.3	21.1
2022 average max	7.7	13.4	18.9	21.2	26.7	31.2	31.5	30.2	26.6	20.3	16.2	9.3	21.2
74-year record max	25	27	30	33	35	41	41	39	39	35	28	26	41
30-year average min	-1.5	0.2	3.9	5.8	13.4	17.8	20.1	19.5	15.9	9.1	3.0	0.3	9.0
2022 average min	-2.8	-1.4	3.5	6.3	14.1	17.6	20.6	18.8	13.7	4.5	2.5	-1.6	8.0
74-year record min	-27	-25	-17	-7	-1	4	9	10	1	-6	-16	-22	-27
30-year average	3.5	5.8	10.2	13.2	19.7	23.7	25.6	25.2	21.8	15.5	9.1	5.2	14.9
2022 average	1.9	5.6	11.0	13.8	20.3	24.0	25.1	23.4	19.3	11.8	8.8	3.4	14.0
2022 departure from average	-1.6	-0.2	0.8	0.6	0.6	0.3	-0.4	-1.8	-2.5	-3.7	-0.3	-1.8	-0.9
30-year average heating degree days, °C													
	451	351	252	110	31	1	0	0	9	101	270	399	1974
30-year average cooling degree days, °C													
	0	0	7	18	80	170	235	221	120	22	1	0	874
Precipitation, mm													
30-year average	132.4	138.7	129.8	131.6	106.5	113.1	141.5	84.6	100.4	80.0	120.7	138.5	1417.8
2022 totals	158.0	205.5	81.5	109.5	109.2	40.9	281.2	103.6	73.9	28.5	106.4	193.8	1,482.0
2022 departure from average	25.6	66.8	-48.3	-22.1	9.1	-90.2	139.7	19.0	-26.5	-51.6	-14.3	55.3	74.2
74-year max monthly	337.2	384.7	311.0	356.5	271.9	283	489.6	265.8	257.6	203.8	310.5	321.2	1,939.4
74-year max 24 h	108.0	131.6	120.4	158.5	112.0	94.0	124.8	190.1	160.1	67.6	130.1	130.1	190.1
74-year min monthly	23.6	21.3	54.1	46.2	20.3	13.5	31.3	13.7	Trace	Trace	34.8	17.0	911.4
Snowfall, in.													
30-year average	4.6	5.1	2	0	0	0	0	0	0	0	2.5	2.5	14.5
2022 totals	3.4	Trace	3.8	0	0	0	0	0	0	0	0	0.9	8.1
74-year max monthly	24.4	43.7	53.4	15	Trace	0	0	0	0	Trace	16.5	53.4	105.2
74-year max 24 h	21.1	28.7	30.5	13.7	Trace	0	0	0	0	Trace	16.5	30.5	30.5

Table B.1. Climate normals (1991–2020) and extremes (1948–2022) for ORNL (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Days w/temp													
30-year max ≥ 32°C	0	0	0	0.1	1.5	7.7	14.4	12.7	4.9	0.1	0	0	41.4
2022 max ≥ 32°C	0	0	0	0	0	12	14	5	1	0	0	0	32
30-year min ≤ 0°C	19.8	15.4	8.7	1.8	0.1	0	0	0	0	0.9	10.3	16.5	73.5
2022 min ≤ 0°C	27	19	7	2	0	0	0	0	0	4	13	18	90
30-year max ≤ 0 °C	2.6	0.8	0.1	0	0	0	0	0	0	0	0	0.8	4.3
2022 max ≤ 0°C	4	0	0	0	0	0	0	0	0	0	0	3	7
Days w/precipitation													
30-year avg ≥ 0.01 in.	11.8	11.6	12.4	11.1	11.5	11.4	12.3	9.8	8.1	8.3	9.2	12.2	129.7
2022 days ≥ 0.01 in.	11	12	11	13	14	9	17	12	8	8	12	18	134
30-year avg ≥ 1.00 in.	1.7	1.4	1.4	1.5	1.1	1.2	1.6	0.9	1.2	1	1.7	1.7	16.4
2022 days ≥ 1.00 in.	3	3	0	1	2	0	5	1	1	0	2	3	21

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/ORNL, with 2022 comparisons

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C													
1970–1979 avg max	6.6	9.7	15.6	21.4	24.8	28.5	30.0	29.7	26.8	20.8	14.5	10.0	19.9
1980–1989 avg max	6.9	10.2	15.9	21.0	25.6	29.8	31.6	30.7	27.1	21.3	15.6	8.6	20.3
1990–1999 avg max	9.4	12.3	16.2	21.9	26.2	29.7	32.1	31.4	28.4	22.6	15.2	10.4	21.3
2000–2009 avg max	8.8	11.2	17.0	21.4	25.8	29.8	30.8	31.4	27.6	21.8	15.9	9.8	21.0
2010–2019 avg max	8.1	11.2	16.3	22.6	26.8	30.2	31.2	30.8	28.5	22.3	15.1	11.4	21.2
1980s vs. 2010s	1.2	1.0	0.3	1.6	1.2	0.4	-0.2	0.0	1.4	1.0	-0.5	2.3	0.8
2000s vs. 2010s	-0.7	0.0	-0.8	1.2	1.0	0.4	0.5	-0.6	0.9	0.5	-0.8	1.1	0.2
2022 avg max	7.7	13.4	18.9	21.2	26.7	31.2	31.5	30.2	26.6	20.3	16.2	9.3	21.2
1970–1979 avg min	-3.4	-2.4	3.0	6.7	11.6	15.7	18.3	18.1	15.5	7.5	2.6	-0.8	7.7
1980–1989 avg min	-4.1	-2.1	1.7	6.0	11.4	16.2	19.0	18.4	14.4	7.5	3.1	-2.3	7.4
1990–1999 avg min	-0.9	0.0	2.9	7.2	12.5	17.2	20.0	18.9	15.1	8.2	2.2	0.1	8.6
2000–2009 avg min	-1.4	0.0	4.4	8.6	13.6	18.0	20.0	20.0	16.1	9.5	3.9	-0.4	9.4
2010–2019 avg min	-2.0	0.6	4.2	8.8	14.1	18.2	20.3	19.5	16.4	9.4	2.7	1.2	9.5
1980s vs. 2010s	2.0	2.6	2.5	2.7	2.7	2.1	1.3	1.1	2.0	2.0	-0.4	3.6	2.1

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/ORNL, with 2022 comparisons (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
2000s vs. 2010s	-0.6	0.6	-0.2	0.1	0.5	0.4	0.3	-0.5	0.3	-0.1	-1.2	1.6	0.1
2022 avg min	-2.8	-1.4	3.5	6.3	14.1	17.6	20.6	18.8	13.7	4.5	2.5	-1.6	8.0
1970–1979 avg	1.6	3.7	9.3	14.1	18.1	22.1	24.1	23.9	21.1	14.2	8.6	4.6	13.8
1980–1989 avg	1.4	4.1	8.8	13.5	18.5	23.0	25.3	24.6	20.8	14.4	9.4	3.1	13.9
1990–1999 avg	4.2	6.2	9.6	14.5	19.4	23.5	26.0	25.2	21.9	15.5	8.8	5.3	15.0
2000–2009 avg	3.7	5.6	10.7	15.3	19.7	23.9	25.4	25.7	21.9	15.6	9.9	4.7	15.2
2010–2019 avg	3.0	5.3	10.3	15.7	20.3	24.0	25.4	24.6	21.9	15.4	8.7	6.4	15.1
1980s vs. 2010s	1.5	1.8	1.5	2.1	1.8	0.9	0.1	0.2	1.2	1.1	-0.7	2.8	1.2
2000s vs. 2010s	-0.7	0.2	-0.4	0.3	0.6	0.0	0.0	-1.0	0.1	-0.2	-1.2	1.2	-0.1
2022 avg	1.9	5.6	11.0	13.8	20.3	24.0	25.1	23.4	19.3	11.8	8.8	3.4	14.0
Precipitation, mm													
1970–1979 avg	143.4	94.6	169.4	118.3	149.8	120.5	130.4	109.8	107.2	99.8	129.6	145.3	1,516.4
1980–1989 avg	100.4	109.1	112.6	88.8	110.6	84.1	120.4	82.6	108.9	79.8	128.0	107.6	1,236.2
1990–1999 avg	141.4	136.5	149.0	126.3	113.4	110.0	134.8	83.6	71.9	67.3	109.8	161.0	1,429.4
2000–2009 avg	116.9	121.8	115.6	125.0	117.8	95.2	138.9	78.4	108.8	74.0	121.4	124.4	1,333.4
2010–2019 avg	130.1	146.6	117.4	131.9	93.8	132.4	156.8	92.5	114.1	91.0	128.0	151.7	1,478.2
1980s vs. 2010s	29.5	37.6	4.6	42.9	-16.8	15.2	36.3	9.9	5.3	11.2	0.0	44.3	239.3
2000s vs. 2010s	13.2	24.9	1.7	6.9	24.1	13.5	17.8	14.0	5.3	17.0	6.7	27.2	146.9
2022 totals	158.0	205.5	81.5	109.5	109.2	40.9	281.2	103.6	73.9	28.4	106.4	193.8	1,482.0
Snowfall, cm													
1970–1979 avg	11.1	12.5	4.2	0.2	0	0	0	0	0	0	0.5	4.4	35.1
1980–1989 avg	11.4	8.8	2.2	2.2	0	0	0	0	0	0	0	7.5	32.8
1990–1999 avg	6.9	7.8	8.1	Trace	0	0	0	0	0	0	0.3	3.1	10.9
2000–2009 avg	2.1	4.5	Trace	Trace	0	0	0	0	0	0	Trace	1.7	8.3
2010–2019 avg	5.3	6.4	0.3	Trace	0	0	0	0	0	0	0.3	1.4	13.2
1980s vs. 2010s	-5.2	-1.8	-1.0	0.0	0	0	0	0	0	0	0.3	-2.8	-12.4
2000s vs. 2010s	3.6	2.8	0.3	0.0	0	0	0	0	0	0	0.3	0.3	6.6
2022 totals	86.4	Trace	96.5	0	0	0	0	0	0	0	0	22.9	205.8

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, 1985–2022[a] *(Hours at or below 0°C, −5°C, −10°C, and −15°C)*

Year	January				February				March			April		May		October		November			December				Annual			
	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15	≤0	<-5	<-10	≤0	<-5	≤0	<-5	≤0	<-5	≤0	<-5	<-10	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15
1985	467	195	103	39	331	127	26	0	105	6	0	43	3	0	0	0	0	22	0	0	431	201	66	2	1,399	532	195	41
1986	308	125	38	10	161	29	3	0	124	28	0	17	0	0	0	0	0	32	10	0	232	34	0	0	874	226	41	10
1987	302	53	7	0	111	19	3	0	95	0	0	55	4	0	0	36	0	103	18	0	151	16	0	0	853	110	10	0
1988	385	182	43	0	294	102	19	0	97	9	0	6	0	0	0	45	0	62	3	0	301	55	0	0	1,190	351	62	0
1989	163	27	0	0	190	66	10	0	35	0	0	18	0	3	0	7	0	125	14	0	421	188	71	30	962	295	81	30
1990	142	13	0	0	115	5	0	0	35	0	0	35	0	0	0	19	0	62	1	0	172	43	5	0	580	62	5	0
1991	186	44	0	0	158	47	15	0	49	0	0	0	0	0	0	4	0	148	16	0	192	38	0	0	737	145	15	0
1992	230	65	8	0	116	22	0	0	116	4	0	27	2	0	0	7	0	100	0	0	166	9	0	0	762	102	8	0
1993	125	11	0	0	245	47	8	0	124	32	9	3	0	0	0	0	0	152	2	0	223	44	0	0	872	136	17	0
1994	337	191	85	26	196	46	3	0	66	0	0	18	0	0	0	0	0	53	1	0	142	0	0	0	812	238	88	26
1995	240	45	6	0	217	84	18	0	37	0	0	0	0	0	0	0	0	142	3	0	288	84	10	0	924	216	34	0
1996	301	91	0	0	225	110	62	27	182	49	6	23	0	0	0	3	0	101	0	0	194	40	4	0	1,029	290	72	27
1997	254	101	24	0	67	0	0	0	25	0	0	6	0	0	0	6	0	96	10	0	232	14	0	0	686	125	24	0
1998	97	10	7	0	25	0	0	0	74	20	0	0	0	0	0	0	0	38	0	0	132	4	0	0	366	34	7	0
1999	181	68	0	0	113	14	0	0	62	0	0	0	0	0	0	4	0	41	0	0	177	23	0	0	578	105	0	0
2000	273	62	5	0	127	30	0	0	18	0	0	8	0	0	0	11	0	94	11	0	345	124	7	0	876	227	12	0
2001	281	60	5	0	79	9	0	0	53	0	0	2	0	0	0	18	0	28	0	0	137	35	0	0	598	104	5	0
2002	185	28	0	0	121	16	0	0	91	17	0	2	0	0	0	0	0	41	0	0	82	6	0	0	522	67	0	0
2003	345	123	26	0	117	12	0	0	19	0	0	0	0	0	0	0	0	37	0	0	102	9	0	0	620	144	26	0
2004	285	50	2	0	76	0	0	0	18	0	0	0	0	0	0	0	0	9	0	0	247	41	4	0	635	91	6	0
2005	151	65	6	0	52	1	0	0	81	1	0	0	0	0	0	1	0	55	0	0	176	28	0	0	516	95	6	0
2006	70	0	0	0	169	19	0	0	44	0	0	0	0	0	0	15	0	37	0	0	126	41	1	0	461	60	1	0
2007	189	30	5	0	283	70	0	0	29	0	0	32	0	0	0	0	0	60	0	0	83	8	0	0	673	111	5	0
2008	242	86	11	0	114	7	0	0	69	6	0	0	0	0	0	15	0	89	18	0	157	34	5	0	686	151	16	0
2009	238	93	29	0	178	64	5	0	55	15	0	5	0	0	0	0	0	8	0	0	178	22	0	0	662	194	34	0
2010	384	181	14	0	289	32	0	0	40	2	0	0	0	0	0	0	0	46	0	0	364	109	11	0	1,123	324	25	0
2011	300	61	0	0	108	14	0	0	2	0	0	0	0	0	0	5	0	29	0	0	91	0	0	0	535	75	0	0
2012	169	27	0	0	78	19	0	0	9	0	0	1	0	0	0	0	0	46	0	0	76	0	0	0	379	46	0	0
2013	245	49	0	0	120	12	0	0	95	7	0	0	0	0	0	11	0	121	0	0	173	6	0	0	765	74	0	0
2014	371	208	76	12	109	5	0	0	68	0	0	5	0	0	0	0	0	122	10	0	94	1	0	0	769	224	76	12

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, 1985–2022 (continued)[a] *(Hours at or below 0°C, −5°C, −10°C, and −15°C)*

Year	January				February				March			April		May		October		November			December				Annual			
	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15	≤0	<-5	<-10	≤0	<-5	≤0	<-5	≤0	<-5	≤0	<-5	<-10	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15
2015	228	52	16	0	371	120	31	6	52	16	0	0	0	0	0	0	0	11	0	0	41	0	0	0	703	188	47	6
2016[a]	333	82	12	0	211	17	0	0	35	0	0	9	0	0	0	0	0	44	3	0	163	32	0	0	795	134	12	0
2017	130	47	11	1	64	5	0	0	82	8	0	0	0	0	0	8	0	67	0	0	252	20	0	0	603	44	10	0
2018	362	199	86	4	67	7	0	0	49	2	0	11	0	0	0	0	0	89	6	0	102	11	0	0	680	225	86	4
2019	146	46	1	0	46	0	0	0	80	9	0	5	0	0	0	0	0	93	11	0	90	0	0	0	466	66	1	0
2020	124	14	0	0	102	11	0	0	20	1	0	12	0	4	0	0	0	30	0	0	210	49	11	0	502	75	11	0
2021	151	1	0	0	144	33	0	0	34	0	0	31	0	0	0	0	0	121	0	0	70	0	0	0	551	34	0	0
2022	271	45	0	0	126	3	0	0	37	11	0	3	0	0	0	8	0	59	3	0	170	75	36	13	674	137	36	13
Avg.	241	75	17	2	151	33	6	1	61	6	0	10	0	0	0	6	0	69	4	0	184	37	5	1	723	156	28	4

[a] *Source: 1985–2014 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2015–2022 ORNL, Tower "D"*

B.5. Severe Weather

On average, thunderstorms and associated lightning occur in the Oak Ridge area at a rate of 48 days per year, with a monthly maximum of about 11 days occurring in July. About 40 of these thunderstorm days occur during the 7-month period from April through October, with the remainder spread evenly throughout the late fall and winter. The highest number of thunderstorm days at ORNL (65) was observed during 2012; the lowest (34) was observed during 2007. There were 40 total thunderstorm days in 2022. Monthly and annual average numbers of thunderstorm days for ORNL and the Knoxville McGhee-Tyson Airport, respectively, during 2001 to 2022 can be viewed on the ORNL meteorology website **here**.

Hailstorms are infrequent on ORR and typically occur in association with severe thunderstorms. Hailstorms are usually caused by high-altitude thunderstorm updrafts, which propel water droplets above the freezing level. Some hail events have been known to occur in association with nonthunder rain showers and low freezing levels (particularly during winter or spring). Most hailstorm occurrences (77 percent) do not produce hailstones larger than 2 cm (about 0.75 in.). From 1961 through 1990, about six hail events (with hailstones larger than about 2 cm) were documented at locations within 40 km (25 mi.) of ORNL. Nearly all of these events occurred during the summer and fall seasons. During the 2011 significant tornado outbreak in East Tennessee, large hail (greater than 2 cm) was observed in Farragut, Tennessee, about 15 km (9 mi.) southeast of ORNL.

A tornado outbreak occurs in East Tennessee about once every 3 to 6 years on average. Tornadoes occur more frequently in Middle and West Tennessee. Tornado indices from the National Weather Service in Morristown, Tennessee, show that since 1950, three tornadoes have been documented within 10 km (6 mi.) of ORNL, represented by two F0 (Fujita Scale) tornadoes and one F3 tornado. A moderately strong F3 tornado occurred in February 1993 and moved through Bear Creek Valley near the Y-12 National Security Complex, with winds damaging the roofs of several buildings along Union Valley Road. To date, the February 1993 tornado is the only documented tornado that has occurred within ORR.

Nine additional tornadoes have been documented since 1950 within 20 km (12 mi.) of ORNL, ranging in intensity from F0/EF0 (Enhanced Fujita Scale) to F2/EF2. The most recent of these were three EF0–EF1 tornadoes that occurred during the April 27, 2011, tornado outbreak and an EF0 tornado near Kingston, Tennessee, on June 10, 2014. The storm system that produced the latter tornado brought a squall line through ORNL that produced high winds and some minor damage. The remaining tornadoes within 20 km (12 mi.) of ORNL affected eastern Roane County to the south and the Edgemoor Road area to the northeast of ORR. Another 10 tornadoes, ranging from F0/EF0 to F3/EF3 in intensity, have occurred within 35 km (22 mi.) of ORNL since 1950. Most of them occurred to the east and south of ORR in Knox and Roane Counties; however, a few occurred in the Rocky Top and Norris areas. Tornado statistics relevant to ORR are provided on the ORNL meteorology website **here** for Anderson, Knox, Loudon, and Roane Counties.

The annual probability that a tornado will strike any location in a grid square may be estimated by multiplying the number of tornadoes per year per square kilometer in that particular grid square by the path area of a tornado. The result of this calculation is greatly affected by the assumed path area of a tornado. In total, about 22 tornadoes have been documented within 35 km (22 mi.) of ORNL since 1950. The paths of these tornadoes had a total surface area of 3,848 km^2 (1,485 $mi.^2$), yielding a probability of about 0.006 tornadoes per square kilometer per 50-year period.

B.6. Stability

The local ridge-and-valley terrain plays a role in the development of stable surface air under certain conditions and influences the dynamics of airflow. Although ridge-and-valley terrain creates identifiable patterns of association during unstable conditions as well, strong vertical mixing and momentum tend to reduce these effects. *Stability* describes the tendency of the atmosphere to mix (especially vertically) or overturn. Consequently, dispersion parameters are influenced by the stability characteristics of the atmosphere. Stability classes range from A (very unstable) to G (very stable), with D being a neutral state.

The suppression of vertical motions during stable conditions increases the effect of local terrain on air motion. Conversely, stable conditions isolate wind flows within the ridge-and-valley terrain from the effects of more distant terrain features and from winds aloft. These effects are particularly significant with respect to mountain waves. Deep, stable layers of air tend to reduce the vertical space available for oscillating vertical air motions caused by local mountain ranges (Smith et al. 2002). This effect on mountain wave formation may be important to the impact that the nearby Cumberland Mountains may have on local airflow.

A second factor that may decouple large-scale wind flow effects from local ones (and thus produce stable surface layers) occurs with overcast sky conditions. Clouds overlying the Great Valley may warm because of direct insolation on the cloud tops. Warming may also occur within the clouds as latent energy, which is released because of the condensation of moisture. Surface air underlying the clouds may remain relatively cool because the layer remains cut off from direct exposure to the sun. Consequently, the vertical temperature gradient associated with the air mass becomes more stable (Lewellen and Lewellen 2002). Long-wave cooling of fog decks has also been observed to help modify stability in the surface layer (Whiteman et al. 2001).

Stable boundary layers typically form as a result of radiational cooling processes near the ground (Van De Weil et al. 2002); however, they are also influenced by the mechanical energy supplied by horizontal wind motion, which is in turn influenced by the synoptic-scale weather-related pressure gradient. Ridge-and-valley terrain may have significant ability to block such winds and their associated mechanical energy (Carlson and Stull 1986). Consequently, radiational cooling at the surface is enhanced because less wind energy is available to remove chilled air.

Stable boundary layers also exhibit intermittent turbulence, which is associated with the above factors. The process results from interactions between the effects of friction and radiational cooling. As a stable surface layer intensifies via a radiational cooling process, it tends to decouple from air aloft, thereby reducing the effects of surface friction. The upper air layer responds with an acceleration in wind speed. Increased wind speed aloft increases mechanical turbulence and wind shear at the boundary with the stable surface layer. Eventually, the turbulence works into the surface layer and weakens it. As the inversion weakens, friction again increases, reducing wind speeds aloft. The reduced wind speeds aloft allow enhanced radiation cooling at the surface, which reintensifies the inversion and allows the process to start again. Van De Weil et al. (2002) have shown that cyclical temperature oscillations up to 4°C (7°F) may result from these processes. Because these intermittent processes are driven primarily by large-scale horizontal wind flow and radiational cooling of the surface, ridge-and-valley terrain significantly affects the intensity of these oscillations.

Wind roses for stability and mixing depth were compiled for all ORR tower sites for 2022. They may be viewed on the ORNL meteorology website here. The wind roses reveal that unstable conditions and deep mixing depths are associated with less channeling of winds and that stable conditions and shallow mixing depths tend to promote channeled flow.

B.7. References

Birdwell 1996. Birdwell, K. R., "A Climatology of Winds over a Ridge and Valley Terrain within the Great Valley of Eastern Tennessee." Master's Thesis, Department of Geosciences, Murray State University, Murray, Kentucky.

Birdwell 2011. Birdwell, K. R., "Wind Regimes in Complex Terrain of the Great Valley of Eastern Tennessee." Doctoral Dissertation, Department of Geography, University of Tennessee, Knoxville, Tennessee.

Carlson and Stull 1986. Carlson, M. A., and R. B. Stull, "Subsidence in the Nocturnal Boundary Layer." *Journal of Climate and Applied Meteorology* **25**, 1088–99.

Eckman 1998. Eckman, R. M., "Observations and Numerical Simulations of Winds within a Broad Forested Valley." *Journal of Applied Meteorology* **37**, 206–19.

Ineson et al. 2011. Ineson, S., A. A. Scaife, J. R. Knight, J. C. Manners, N. J. Dunstone, L. J. Grey, and J. D. Haigh, "Solar Forcing of Winter Climate Variability in the Northern Hemisphere." *Nature Geoscience* **4,** 753–57.

Kossman and Sturman 2002. Kossman, M., and A. P. Sturman, "Pressure Driven Channeling Effects in Bent Valleys." *Journal of Applied Meteorology* **42**, 151–58.

Lewellen and Lewellen 2002. Lewellen, D. C., and W. S. Lewellen, "Entrainment and Decoupling Relations for Cloudy Boundary Layers." *Journal of the Atmospheric Sciences* **59**, 2966-86.

Monti et al. 2002. Monti, P., H. J. S. Fernando, M. Princevac, W. C. Chan, T. A. Kowalewski, and E. R. Pardyjak, "Observations of Flow and Turbulence in the Nocturnal Boundary Layer over a Slope." *Journal of the Atmospheric Sciences* **59**, 2513–34.

Smith et al. 2002. Smith, R. B., S. Skubis, J. D. Doyle, A. S. Broad, C. Kiemle, and H. Volkert, "Mountain Waves over Mount Blanc: Influence of a Stagnant Boundary Layer." *Journal of the Atmospheric Sciences* **59**, 2073–92.

Van De Weil et al. 2002. Van De Weil, B. J. H., A. F. Moene, R. J. Ronda, H. A. R. De Bruin, and A. A. M. Holtslag, "Intermittent Turbulence and Oscillations in the Stable Boundary Layer over Land. Part II: A System Dynamics Approach." *Journal of the Atmospheric Sciences* **59**, 2567-81.

Whiteman 2000. Whiteman, C. D., *Mountain Meteorology: Fundamentals and Applications*. Oxford University Press, New York.

Whiteman et al. 2001. Whiteman, C. D., S. Zhong, W. J. Shaw, J. M. Hubbe, and X. Bian, "Cold Pools in the Columbia River Basin." *Weather and Forecasting* **16**, 432-47.

C

Appendix C Reference Standards and Data for Water

Table C.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{241}Am		740
^{214}Bi		1,000,000
^{109}Cd		42,000
^{143}Ce		210,000
^{60}Co		14,000
^{51}Cr		3,800,000
^{137}Cs		4,100
^{155}Eu		1,000,000
Alpha particles[d,e]	15	
Beta particles and photon emitters (mrem/year)[e]	4	
^{3}H Tritated Water		2,600,000
^{3}H Organic Bound Tritium		1,000,000
^{131}I		2,800
^{40}K		16,000
^{237}Np		1,400
^{234}Pa		300,000
^{238}Pu		430
$^{239/240}$Pu		400
^{226}Ra		280
^{228}Ra		73
^{226}Ra and ^{228}Ra combined[e]	5	
^{106}Ru		19,000
^{90}Sr		1,700
^{99}Tc		390,000
^{228}Th		830
^{230}Th		720
^{232}Th		620
^{234}Th		84,000
^{234}U		1,200
^{235}U		1,300

Table C.1. Reference standards for radionuclides in water (continued)

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{236}U		1,300
^{238}U		1,400
Uranium, total (ug/L)[e]	30	

[a] *Only the radionuclides included in the Oak Ridge Reservation monitoring programs are listed. Unless labeled otherwise, units are pCi/L.*
[b] *40 Code of Federal Regulations Part 141, National Primary Drinking Water Regulations, Subparts B and G. The drinking water standards are presented strictly for reference purposes and have regulatory applicability only for public water supplies.*
[c] *DOE. "Derived Concentration Technical Standard," DOE-STD-1196-2021, July 2021.*
[d] *Excludes radon and uranium.*
[e] *Carcinogenic pollutant (EPA uses a 10^{-6} level to determine an increased risk of cancer)*

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Acenaphthene				670, 990
Acrolein		3.0	3.0	6, 9
Acrylonitrile (c)				0.51, 2.5
Alachlor	2 (E1, T)			
Aldicarb[c]	3 (E1)			
Aldicarb sulfone[c]	2 (E1)			
Aldicarb sulfoxide[c]	4 (E1)			
Aldrin (c)		3.0	–	0.00049, 0.00050
Aluminum	50 to 200 (E2)			
Anthracene				8,300, 40,000
Antimony	6 (E1, T)			5.6, 640
Arsenic (c)	10 (E1, T)			10.0, 10.0
Arsenic(III)		340[d]	150[d]	
Asbestos	7 million fibers/L (MFL) (E1)			
Atrazine	3 (E1, T)			
Barium	2,000 (E1, T)			
Benzene (c)	5 (E1, T)			22, 510
Benzidine (c)				0.00086, 0.0020
Benzo(a)anthracene (c)				0.038, 0.18
Benzo(a)pyrene (c)	0.2 (E1, T)			0.038, 0.18
Benzo(b)fluoranthene (c)				0.038, 0.18
Benzo(k)fluoranthene (c)				0.038, 0.18
Beryllium	4 (E1, T)			
a-BHC (c)				0.026, 0.049
b-BHC (c)				0.091, 0.17
g-BHC (Lindane) (b)	0.2 (E1, T)	0.95	–	0.98, 1.8
Bis(2-chloroethyl) ether (c)				0.30, 5.3

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (μg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Bis(2-chloro-isopropyl) ether				1,400, 65,000
Bis(2-ethylhexyl) phthalate (Di (2-ethylhexyl) phthalate) (c)	6 (E1, T)			12, 22
Bis (Chloromethyl) ether (c)				0.0010, 0.0029
Bromate	10 (E1)			
Bromoform (c)				43, 1,400
Butylbenzyl phthalate (c)				1,500, 1,900
Cadmium	5 (E1, T)	1.8[e]	0.72[e]	
Carbaryl		2.1	2.1	
Carbofuran	40 (E1, T)			
Carbon tetrachloride (c)	5 (E1, T)			2.3, 16
Chlordane (b) (c)	2 (E1, T)	2.4	0.0043	0.0080, 0.0081
Chloride	250,000 (E2)			
Chlorine (TRC)	4,000 (E1)	19	11	
Chlorine dioxide (as Cl_2)	800 (E1)			
Chlorite	1,000 (E1)			
Chloramines (as Cl_2)	4,000 (E1)			
Chlorobenzene (Monochlorobenzene)	100 (E1, T)			130, 1,600
Chlorodibromomethane (c)				4.0, 130
Chloroform (c)				57, 4,700
2-Chloronaphthalene				1,000, 1,600
2-Chlorophenol				81, 150
Chlorpyrifos		0.083	0.041	
Chromium (total)	100 (E1, T)			
Chromium(III)		570[e]	74[e]	
Chromium(VI)		16[d]	11[d]	
Chrysene (c)				0.038, 0.18
Coliforms	630/100 mL (geometric mean) (T); no more than 5% of samples per month can be positive for total coliforms (E1)	630/100 mL, *E. coli* (geometric mean); 2880/100 mL, maximum, *E. coli* (single sample) 630/100 mL, *E. coli* (geometric mean); 2880/100 mL, maximum, *E. coli* (single sample)		126/100 mL (geometric mean), *E. coli*; 487/100 mL, maximum lakes/ reservoirs/state scenic river/Exceptional Tennessee Water/ Outstanding Natural Resource Water, *E. coli*; 941/100 mL, maximum, other water bodies, *E. coli*
Color	15 color units (E2)			
Copper	1,300 (E1 "Action Level") 1,000 (E2)	13[e]	9.0[e]	
Cyanide (as free cyanide)	200 (E1, T)	22[f]	5.2[f]	140, 140

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
2,4-D (Dichlorophenoxyacetic acid)	70 (E1, T)			
4,4'-DDD (b) (c)				0.0031, 0.0031
4,4'-DDE (b) (c)				0.0022, 0.0022
4,4'-DDT (b) (c)		1.1	0.001	0.0022, 0.0022
Dalapon	200 (E1, T)			
Demeton			0.1	
Diazinon		0.17	0.17	
Dibenz(a,h)anthracene (c)				0.038, 0.18
1,2-dibromo-3-chloropropane (DBCP) (c)	0.2 (E1, T)			
1,2-Dichlorobenzene (*ortho-*)	600 (E1, T)			420, 1,300
1,3-Dichlorobenzene (*meta-*)				320, 960
1,4-Dichlorobenzene (*para-*)	75 (E1, T)			63, 190
3,3-Dichlorobenzidine (c)				0.21, 0.28
Dichlorobromomethane (c)				5.5, 170
1,2-Dichloroethane (c)	5 (E1, T)			3.8, 370
1,1-Dichloroethylene	7 (E1, T)			330, 7,100
Cis-1,2-Dichloroethylene	70 (E1, T)			
trans 1,2-Dichloroethylene	100 (E1, T)			140, 10,000
2,4-Dichlorophenol				77, 290
1,2-Dichloropropane (c)	5 (E1, T)			5.0, 150
1,3-Dichloropropene (c)				3.4, 210
Dieldrin (b)(c)		0.24	0.056	0.00052, 0.00054
Diethyl phthalate				17,000, 44,000
Di (2-ethylhexyl) adipate	400 (E1, T)			
Dinoseb	7 (E1, T)			
Dimethyl phthalate				270,000, 1,100,000
Dimethylphenol				380, 850
Di-n-butyl phthalate				2,000, 4,500
2,4-Dinitrophenols				69, 5,300
2,4-Dinitrotoluene (c)				1.1, 34
Dioxin (2,3,7,8-TCDD) (b) (c)	3 E-5 (E1, T)			0.000001[g], 0.000001[g]
Diquat	20 (E1, T)			
1,2-Diphenylhydrazine (c)				0.36, 2.0
a-Endosulfan		0.22	0.056	62, 89
b-Endosulfan		0.22	0.056	62, 89
Endosulfan sulfate				62, 89
Endothall	100 (E1, T)			
Endrin	2 (E1, T)	0.086	0.036	0.059, 0.06
Endrin aldehyde				0.29, 0.30
Ethylbenzene	700 (E1)			530, 2,100
Ethylene dibromide	0.05 (E1, T)			
Fluoranthene				130, 140

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Fluorene				1,100, 5,300
Fluoride	4,000 (E1) 2,000 (E2)			
Foaming agents	500 (E2)			
Glyphosate	700 (E1, T)			
Guthion			0.01	
Haloacetic acids (HAA5) (c)	60 (E1)			
Heptachlor (c)	0.4 (E1, T)	0.52	0.0038	0.00079, 0.00079
Heptachlor epoxide (c)	0.2 (E1, T)	0.52	0.0038	0.00039, 0.00039
Hexachlorobenzene (b)(c)	1 (E1, T)			0.0028, 0.0029
Hexachlorobutadiene (b)(c)				4.4, 180
Hexachlorocyclohexane-Technical (b)(c)				0.123, 0.414
Hexachlorocyclopentadiene	50 (E1, T)			40, 1,100
Hexachloroethane (c)				14, 33
Ideno(1,2,3-cd)pyrene (c)				0.038, 0.18
Iron	300 (E2)			
Isophorone (c)				350, 9,600
Lead	5 (T) 15 (E1 “Action Level”)	65[e]	2.5[e]	
Malathion			0.1	
Manganese	50 (E2)			
Mercury (b)	2 (T) 2 (E1 inorganic)	1.4[d]	0.77[d]	0.05, 0.051
Methoxychlor	40 (E1, T)		0.001	
Methyl bromide				47, 1,500
2-Methyl-4,6-dinitrophenol				13, 280
Methylene chloride (Dichloromethane) (c)	5 (E1, T)			46, 5,900
Nickel	100 (T)	470[e]	52[e]	610, 4,600
Nitrate as N	10,000 (E1,T)			
Nitrite as N	1,000 (E1, T)			
Nitrobenzene				17, 690
Nitrosamines				0.0008, 1.24
Nitrosodibutylamine (c)				0.063, 2.2
Nitrosodiethylamine (c)				0.008, 2.4
Nitrosopyrrolidine (c)				0.16, 340
N-Nitrosodimethylamine (c)				0.0069, 30
N-Nitrosodi-n-propylamine (c)				0.05, 5.1
N-Nitrosodiphenylamine (c)				33, 60
Nonylphenol		28.0	6.6	
Odor	3 Threshold Odor Numbers (E2)[h]			
Oxamyl (Vydate)	200 (E1, T)			

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Parathion		0.065	0.013	
Pentachlorobenzene (b)				1.4, 1.5
Pentachlorophenol (c)	1 (E1, T)	19[i]	15[i]	2.7, 30
pH	6.5 to 8.5 units (E2) 6.0 to 9.0 units (T)	6.0 to 9.0 units for wadeable streams; 6.5 to 9.0 units for larger rivers, lakes, reservoirs, and wetlands		6.0 to 9.0 units
Phenol				10,000, 860,000
Picloram	500 (E1,T)			
Polychlorinated biphenyls (PCBs), total (b)(c)	0.5 (E1, T)	–	0.014	0.00064, 0.00064
Pyrene				830, 4,000
Selenium	50 (E1, T)			170, 4,200
Selenium (lentic)[j]		20	1.5[k]	
Selenium (lotic)[l]		20	3.1[k]	
Silver	100 (E2)	3.2[e]	–	
Simazine	4 (E1, T)			
Styrene	100 (E1, T)			
Sulfate	250,000 (E2)			
1,2,4,5-Tetrachlorobenzene (b)				0.97, 1.1
1,1,2,2-Tetrachloroethane (c)				1.7, 40
Tetrachloroethylene (c)	5 (E1, T)			6.9, 33
Thallium	2 (E1, T)			0.24, 0.47
Toluene	1,000 (E1, T)			1,300, 15,000
Total dissolved solids	500,000 (E2, T)			
Toxaphene (b)(c)	3 (E1, T)	0.73	0.0002	0.0028, 0.0028
Tributyltin (TBT)		0.46	0.072	
1,2,4-Trichlorobenzene	70 (E1, T)			35, 70
1,1,1-Trichloroethane	200 (E1, T)			
1,1,2-Trichloroethane (c)	5 (E1, T)			5.9, 160
Trichloroethylene (c)	5 (E1, T)			25, 300
2,4,5-Trichlorophenol				1,800, 3,600
2,4,6-Trichlorophenol (c)				14, 24
2,4,5 Trichlorophenoxyprioponic acid (2,4,5-TP, Silvex)	50 (E1, T)			
Trihalomethanes (total) (THMs) (c)	80 (E1)			
Vinyl chloride (c)	2 (E1, T)			0.25, 24
Xylenes (total)	10,000 (E1, T)			
Zinc	5,000 (E2)	120[e]	120[e]	7,400, 26,000

[a] E1 = EPA Primary Drinking Water Standards; E2 = EPA Secondary Drinking Water Standards; T = TDEC domestic water supply criteria.

[b] For each parameter, the first recreational criterion is for "water and organisms" and is applicable on the Oak Ridge Reservation (ORR) only to the Clinch River, because it is the only stream on ORR classified for both domestic water supply and for recreation. The second criterion is for "organisms only" and is applicable to the other streams on ORR. TDEC uses a 10^{-5} risk level for recreational criteria for all carcinogenic pollutants (designated as (c) under the "Chemical" column). Recreational criteria for noncarcinogenic chemicals are set using a 10^{-6} risk level. (Note: All federal recreational criteria are set at a 10^{-6} risk level.)

[c] Administrative stay of the effective date.

[d] Criteria are expressed as dissolved.

[e] Criteria are expressed as dissolved and are a function of total hardness (mg/L). Criteria displayed correspond to a total hardness of 100 mg/L.

[f] Criteria may be applied as free cyanide if Standard Methods 4500-CN, 4500-CN G, or OIA-1677 are used.

[g] Total dioxin in the sum of the concentrations of all dioxin and dibenzofuran isomers after multiplication by Toxic Equivalent Factors.

[h] Threshold Odor Numbers (TON) are whole numbers that indicate how many dilutions it takes to produce odor-free water.

[i] Criteria are expressed as a function of pH; values shown correspond to a pH of 7.8.

[j] Lentic – Still water aquatic ecosystems such as ponds, lakes, or reservoirs.

[k] The numeric water criteria are applicable for all purposes, but for water quality assessment, fish tissue values may be used to confirm or refute impacts to aquatic life in accordance with and using values from EPA's Final Criterion: Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater (June 30, 2016).

[l] Lotic – Flowing water aquatic ecosystems such as streams and rivers.

Acronyms and other definitions:

EPA = US Environmental Protection Agency

TDEC = Tennessee Department of Environment and Conservation

(b) = bioaccumuative parameter (TDEC)

(c) = carcinogenic pollutant (TDEC uses a 10^{-5} risk level and EPA uses a 10^{-6} level to determine an increased risk of cancer)

D

Appendix D National Pollutant Discharge Elimination System Noncompliance Summaries for 2022

D.1. East Tennessee Technology Park

The East Tennessee Technology Park program was 100 percent compliant with the numerical permit limits during 2022. The previous ETTP NPDES permit in effect during the first months of 2022 became effective on April 1, 2015, and expired on March 31, 2020, but the expired permit continued in effect until the new permit was issued by the State of Tennessee. The new permit was issued on February 4, 2022, and became effective on April 1, 2022.

D.2. Y-12 National Security Complex

The Y-12 National Security Complex was 100 percent compliant with the NPDES permit limits in 2022. Approximately 3,400 data points were obtained from sampling required by the NPDES permit. Y-12's NPDES permit in effect during part of 2022 (TN0002968) was issued on October 31, 2011, and became effective on December 1, 2011. A modification was effective in May 2014. It expired on November 30, 2016. A new permit was issued on August 5, 2022, and became effective on October 1, 2022.

D.3. Oak Ridge National Laboratory

In 2022, compliance with the Oak Ridge National Laboratory NPDES permit was determined by approximately 1,736 laboratory analyses and field measurements. ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 100 percent in 2022. In October 2022, water from a potable water line break in the 7000 Area was released into White Oak Creek and caused aquatic species mortality (a total of 141 fish, 11 salamanders, and 13 aquatic worms). This incident was reported as a noncompliance with narrative criteria in the permit. ORNL had received a renewed NPDES permit in May 2019. Several conditions in the permit were appealed and were addressed in a reissued permit in December 2022.

E

Appendix E Radiation

This appendix presents basic information about radiation. The information is intended to serve as a basis for understanding the potential doses associated with releases of radionuclides from the Oak Ridge Reservation, not as a comprehensive discussion of radiation and its effects on the environment and on biological systems.

Radiation comes from natural and human sources. People are constantly exposed to naturally occurring radiation. For example, cosmic radiation, radon in air, potassium in food and water, and uranium, thorium, and radium in the earth's crust are all sources of radiation. The following discussion describes important aspects of radiation and its types, sources, and pathways, as well as radiation measurement and dose information.

E.1. Atoms and Isotopes

All matter is made up of atoms. An atom is "a unit of matter consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (Alter 1986). The number of protons in the nucleus determines an element's atomic number or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the neutrons may vary in number among atoms of the same element. The number of neutrons and protons determines the atomic weight. Atoms of the same element that have different numbers of neutrons are called isotopes. In other words, isotopes have the same chemical properties but different atomic weights, as illustrated in Figure E.1.

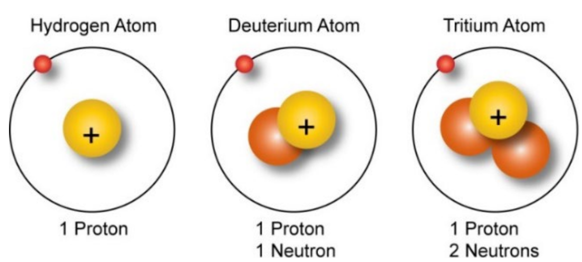


Figure E.1. The hydrogen atom and its isotopes

For example, the element uranium has 92 protons. All isotopes of uranium, therefore, have 92 protons. However, each uranium isotope has a different number of neutrons:

- Uranium-238 has 92 protons and 146 neutrons
- Uranium-235 has 92 protons and 143 neutrons
- Uranium-234 has 92 protons and 142 neutrons

Some isotopes are stable, or nonradioactive, and some are radioactive. Radioactive isotopes are called radionuclides or radioisotopes. In an attempt to become stable, radionuclides emit rays or particles. This emission of rays and particles is known as radioactive decay. Each radioisotope has a radioactive half-life, which is the average time required for half of a specified number of atoms to decay. Half-lives can be very short (fractions of a second) or very long (millions of years), depending on the isotope. Table E.1 shows the half-lives of selected radionuclides.

Table E.1. Selected radionuclide half-lives

Radionuclide	Symbol	Half-life (in years unless otherwise noted)	Radionuclide	Symbol	Half-life (in years unless otherwise noted)
Americium-241	^{241}Am	432.2	Plutonium-238	^{238}Pu	87.74
Americium-243	^{243}Am	7.37E+3	Plutonium-239	^{239}Pu	2.411E+4
Argon-41	^{41}Ar	1.827 hours	Plutonium-240	^{240}Pu	6.564E+3
Beryllium-7	^{7}Be	53.22 days	Potassium-40	^{40}K	1.251E+9
Californium-252	^{252}Cf	2.645	Radium-226	^{226}Ra	1.6E+3
Carbon-11	^{11}C	20.39 minutes	Radium-228	^{228}Ra	5.75
Carbon-14	^{14}C	5.70E+3	Ruthenium-103	^{103}Ru	39.26 days
Cerium-141	^{141}Ce	32.508 days	Samarium-153	^{153}Sm	46.5 hours
Cerium-144	^{144}Ce	284.91 days	Strontium-89	^{89}Sr	50.53 days
Cesium-134	^{134}Cs	2.0648	Strontium-90	^{90}Sr	28.79
Cesium-137	^{137}Cs	30.167	Technetium-99	^{99}Tc	2.111E+5
Cesium-138	^{138}Cs	32.41 minutes	Thorium-228	^{228}Th	1.9116
Cobalt-58	^{58}Co	70.86 days	Thorium-230	^{230}Th	7.538E+4
Cobalt-60	^{60}Co	5.271	Thorium-232	^{232}Th	1.405E+10
Curium-242	^{242}Cm	162.8 days	Thorium-234	^{234}Th	24.1 days
Curium-244	^{244}Cm	18.1	Tritium	^{3}H	12.32
Iodine-129	^{129}I	157E+7	Uranium-234	^{234}U	2.455E+5
Iodine-131	^{131}I	8.02 days	Uranium-235	^{235}U	7.04E+8
Krypton-85	^{85}Kr	10.756	Uranium-236	^{236}U	2.342E+7
Krypton-88	^{88}Kr	2.84 hours	Uranium-238	^{238}U	4.468E+9
Lead-212	^{212}Pb	10.64 hours	Xenon-133	^{133}Xe	5.243 days
Manganese-54	^{54}Mn	312.12 days	Xenon-135	^{135}Xe	9.14 hours
Neptunium-237	^{237}Np	2.144E+6	Yttrium-90	^{90}Y	64.1 hours
Niobium-95	^{95}Nb	34.991 days	Zirconium-95	^{95}Zr	64.032 days

Source: ICRP 2008

E.2. Radiation

Radiation, or radiant energy, is energy in the form of waves or particles moving through space. Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from sunlight, they are actually absorbing the radiant energy emitted by the sun.

Electromagnetic radiation is a form of energy that travels in waves. It comes from natural and man-made sources and includes gamma rays, x-rays, ultraviolet light, and radio waves. Particulate radiation consists of particles that have mass and energy, such as alpha and beta particles. Radiation also is characterized as ionizing or nonionizing by its energy and the way it interacts with matter.

Ionizing Radiation

Normally an atom has an equal number of protons (positively charged) and electrons (negatively charged), but atoms can lose or gain electrons in a process known as ionization. Ionizing radiation removes bound electrons from an electrically neutral atom, leaving the atom with a net positive charge. Examples of ionizing radiation include alpha and beta particles, gamma rays, and x-rays (World Health Organization 2016).

Ionizing radiation is capable of changing the chemical state of matter and subsequently causing biological damage. By this mechanism, it is potentially harmful to human health.

Nonionizing Radiation

Nonionizing radiation is described as a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light, and is lower in energy than ionizing radiation (Department of Labor 2023). It includes the spectrum of ultraviolet light, visible light, infrared radiation, microwaves, radio waves, and other extremely low frequency fields. Lasers commonly operate in the ultraviolet, visible, and infrared frequencies. Microwave radiation is absorbed near the skin, while radio frequency radiation may be absorbed throughout the body. At high enough intensities, both will damage tissue through heating. Excessive visible radiation can damage the eyes and skin (Department of Labor 2023).

In the discussion that follows, the term "radiation" is used to describe ionizing radiation.

E.3. Measuring Ionizing Radiation

To determine the possible effects of exposure to radiation on the health of the environment and the public, the radiation must be measured. By quantifying the levels of energy, its potential to cause damage may be estimated.

Activity

To determine the level of radiation in the environment, the rate of radioactive decay or activity is measured. The rate of decay varies widely among radioisotopes. For that reason, 1 gram of a radioactive substance may contain the same amount of activity as several tons of another material. This activity is expressed in a unit of measure known as a curie (Ci). More specifically, 1 Ci equals 3.7×10^{10} (37,000,000,000) atomic disintegrations per second (dps). In the International System of Units, 1 dps equals 1 becquerel (Bq).

Absorbed Dose

The total amount of energy absorbed per unit mass of an exposed material as a result of exposure to radiation is expressed in a unit of measure known as a rad, short for "radiation absorbed dose." The number of rads is used to estimate the effect of the absorbed energy and the potential biological damage that may occur. In the International System of Units, 100 rads equal 1 gray (Gy).

Effective Dose

The measure of potential biological damage to the body caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem, an abbreviation for "roentgen equivalent man." For radiation protection purposes, 1 rem of any type of radiation has the same damaging effect. Because a rem represents a fairly large dose, the measure is usually expressed as millirem (mrem), which is 1/1000 of a rem. In the International System of Units, 1 sievert (Sv) equals 100 rem; 1 millisievert (mSv) equals 100 mrem. The effective dose (ED) is the weighted sum of equivalent dose, which accounts for type of radiation absorbed via a radiation weighting factor, over specified tissues or organs. The ED is based on tissue-weighting factors for 12 specific tissues or organs plus a weighting factor for the remaining organs and tissues. In addition, the ED is based on the recently developed lung model, gastrointestinal absorption fractions, and biokinetic models used for selected elements. Specific types of EDs are defined as follows (ICRP 2007):

- Committed ED – the weighted sum of the committed organ or tissue equivalent doses in the human body during the 50-year period following intake (70 years for children)
- Collective ED – the product of the mean ED for a population and the number of persons exposed

E.4. Radiation Exposure Pathways

People can be exposed to radionuclides in the environment through a number of routes, as shown in Figure E.2. Potential routes for internal and external exposure are referred to as pathways. For example, radionuclides in air could be inhaled directly or could fall on grass in a pasture. If the grass were then consumed by cows, it would be possible for the radionuclides to impact the cow's milk, and subsequently the people drinking the milk. Similarly, radionuclides in water could be ingested by fish, and fishermen or other consumers could then ingest the radionuclides in the fish tissue. People swimming in the water also would be exposed. Exposure to ionizing radiation varies significantly with geographic location, diet, drinking water source, and building construction.

Figure E.2. Examples of radiation pathways

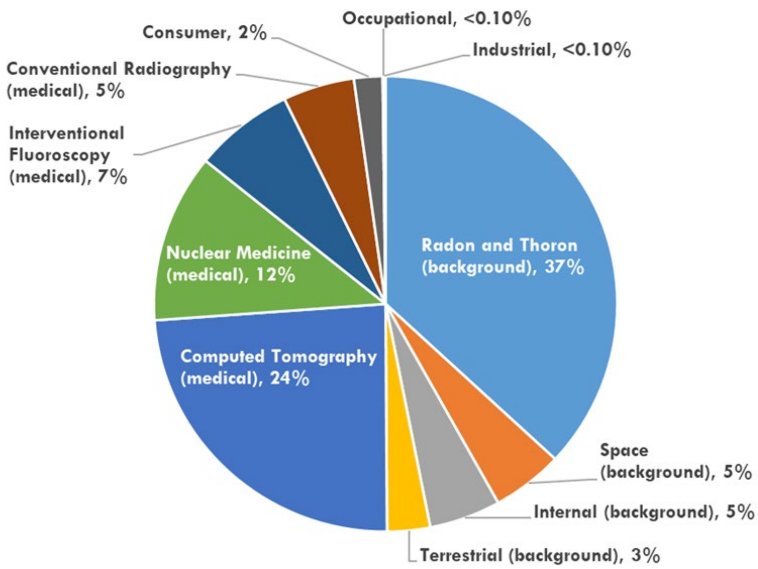
E.5. Radiation Sources and Doses

Basically, the process of radioactive decay generates radiant energy. People absorb some of the energy to which they are exposed, either from external radiation sources or internally deposited radionuclides. The amount of absorbed energy is reflected in an individual's dose. Whether radiation is natural or anthropogenic, it has the same effect on people.

There are five broad categories for radiation exposure to the US population (NCRP 2009):

- Exposure to ubiquitous background radiation, including radon in homes
- Exposure to patients from medical procedures
- Exposure from consumer products or activities involving radiation sources
- Exposure from industrial, security, medical, educational, and research radiation sources
- Exposure to workers that results from their occupations

Figure E.3 shows the percent contributions of various sources of exposure to the total collective dose for the US population in 2006. As shown, the major sources are radon and thoron (37 percent), computed tomography (24 percent), and nuclear medicine (12 percent) (NCRP 2009). Consumer, occupational, and industrial sources contribute about 2 percent to the total US collective dose.



Source: NCRP 2009

Figure E.3. All exposure categories for collective effective dose for 2006

E.5.1. Background Radiation

Naturally occurring radiation is the major source of radiation in the environment. Sources of background radiation exposure include the following:

- External exposure from space or cosmic radiation
- External exposure from terrestrial radiation
- Internal exposure from inhalation of radon, thoron, and their progeny
- Internal exposure from radionuclides in the body

E.5.1.1. External Exposures

Space or Cosmic Radiation

Energetically charged particles from outer space continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are called cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver is exposed to more cosmic radiation than a person in New Orleans.

The average annual effective dose to people in the United States from cosmic radiation is about 33 mrem, or 0.33 mSv (NCRP 2009). Effective dose rates from cosmic radiation depend on geomagnetic latitude and elevation above sea level.

Terrestrial Radiation

Terrestrial radiation refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn), radon progeny (the relatively short-lived decay products from the decay of the radon isotope ^{222}Rn), potassium (^{40}K), isotopes of thorium (Th), and isotopes of uranium (U) are the elements responsible for most terrestrial radiation.The average annual dose from terrestrial gamma radiation is about 21 mrem (0.21 mSv) in the United States, but it varies geographically across the country (NCRP 2009). Typical reported values are about 23 mrem (0.23 mSv) on the Atlantic and Gulf Coasts, about 90 mrem (0.9 mSv) on the Colorado Plateau, and about 46 mrem (0.46 mSv) elsewhere in the United States (EPA 2023).

E.5.1.2. Internal Exposures

Radionuclides in the environment enter the body with the air people breathe and the foods they eat. They can also enter through an open wound. Natural radionuclides that can be inhaled and ingested include isotopes of uranium and their progeny, especially radon (^{222}Rn) and its progeny, thoron (^{220}Rn) and its progeny, potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C). Radionuclides contained in the body are dominated by ^{40}K and polonium (^{210}Po); others include ^{87}Rb and ^{14}C (NCRP 1987).

Radon and Thoron and Decay Products

The major contributors to the annual effective dose from background radiation sources are radon and thoron and their short-lived decay products. As shown in Figure E.3, 37 percent of the dose from all exposure categories is from radon and thoron and their decay products, which contribute an average dose to an individual of about 228 mrem (2.28 mSv) per year (NCRP 2009). Radon is an inert gas and a small fraction is retained in the body; however, the dose to the lungs comes from the short-lived radon decay products. Radon levels vary widely across the United States. Elevated levels are most commonly found in the Appalachians, the upper Midwest, and the Rocky Mountain states (NCRP 2009).

Other Internal Radiation Sources

Other sources of internal radiation include ^{40}K, ^{232}Th, and the ^{238}U series. The primary source of ^{40}K in body tissues is food, primarily fruits and vegetables. Sources of radionuclides from the ^{232}Th and ^{238}U series are food and water (NCRP 2009). The average dose from these other internal radionuclides is about 29 mrem (0.29 mSv) per year. This dose is attributed predominantly to the naturally occurring radioactive isotope of potassium, ^{40}K.

E.5.2. Anthropogenic Radiation

In addition to background radiation, most people are exposed to anthropogenic, or human-made, sources of radiation such as consumer products, medical sources, industrial by-products, and fallout from atmospheric atomic bomb tests. No atmospheric testing of atomic weapons has occurred since 1980 (NCRP 1987).

Consumer Products

Some consumer products are sources of radiation. The radiation in these products—which includes smoke detectors, radioluminous products (e.g., self-illuminating exit signs in commercial buildings), and airport x-ray baggage inspection systems—is essential to the performance of the device. In other products, such as tobacco products and building materials, the radiation occurs incidentally to the product's function (NCRP 1987, NCRP 2009).

The US annual dose to an individual from consumer products and activities averages about 13 mrem (0.13 mSv), ranging between 0.1 and 40 mrem (0.001 and 0.4 mSv). Cigarette smoking accounts for about 35 percent of this dose. Other important sources are building materials (27 percent), commercial air travel (26 percent), mining and agriculture (6 percent), miscellaneous consumer-oriented products (3 percent), combustion of fossil fuels (2 percent), highway and road construction materials (0.6 percent), and glass and ceramics (less than 0.003 percent). Television and video, sewage sludge and ash, and self-illuminating signs contribute negligible doses (NCRP 2009).

Medical Sources

Radiation is an important tool in diagnostic medicine and treatment, which are the main sources of exposure to the public from anthropogenic radiation. Exposure is deliberate and is directly beneficial to the patients exposed. In general, medical exposures from diagnostic or therapeutic x-rays result from beams directed to specific areas of the body, so not all organs are uniformly irradiated. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Radiation and radioactive materials also are used in preparing medical instruments, including sterilizing heat-sensitive products such as plastic heart valves.

Nuclear medicine examinations, which internally administer radiopharmaceuticals, account for a significant portion of dose from anthropogenic sources. However, the radionuclides used for specific tests are not uniformly distributed throughout the body. In these cases, the concept of ED, which relates the significance of exposures of organs or body parts to the effect on the entire body, is useful in making comparisons. The average annual ED from medical examinations is roughly 300 mrem (3 mSv), including 147 mrem (1.47 mSv) from computed tomography scans, 77 mrem (0.77 mSv) from nuclear medicine procedures, 43 mrem (0.43 mSv) from interventional fluoroscopy, and 33 mrem (0.33 mSv) from conventional radiography and fluoroscopy (NCRP 2009). Not everyone receives such exams each year.

Other Sources

Other sources of radiation include emissions of radioactive materials from nuclear facilities such as uranium mines, fuel-processing plants, and nuclear power plants; transportation of radioactive materials; and emissions from mineral-extraction facilities. The dose to the general public from nuclear fuel cycle facilities, such as uranium mines, mills, fuel-processing plants, nuclear power plants, and transportation routes, has been estimated at less than 1 mrem (0.01 mSv) per year (NCRP 1987).

Small doses to individuals occur because of radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to an individual's average dose (NCRP 1987).

E.6. References

Alter 1986. Alter, H. *A Glossary of Terms in Nuclear Science and Technology*. American Nuclear Society, La Grange Park, Illinois.

Department of Labor 2023. *OSHA Safety and Health Topics: Non Ionizing Radiation.* https://www.osha.gov/non-ionizing-radiation. Retrieved May 14, 2023.

EPA 2023. *Calculate Your Radiation Dose.* US Environmental Protection Agency. https://www.epa.gov/radiation/calculate-your-radiation-dose. Retrieved May 14, 2023.

ICRP 2007. *The 2007 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 103. *Annals of the ICRP* 37 (2-4). International Commission on Radiological Protection, Ottawa, Canada.

ICRP 2008. *Nuclear Decay Data for Dosimetric Calculations.* ICRP Publication 107. *Annals of the ICRP* 38(3). International Commission on Radiological Protection, Ottawa, Canada.

NCRP 1987. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 93. National Council on Radiation Protection and Measurements, Bethesda, MD.

NCRP 2009. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 160, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

World Health Organization 2016. *Ionizing radiation, health effects and protective measures*. https://www.who.int/news-room/fact-sheets/detail/ionizing-radiation-health-effects-and-protective-measures. Retrieved May 14, 2023.

F

Appendix F Chemicals

This appendix presents basic information about chemical risk assessment for carcinogens and noncarcinogens. The information is intended to serve as a basis for understanding the toxicity associated with possible releases from the Oak Ridge Reservation (ORR) and is not a comprehensive discussion of chemicals and their effects on human health and the environment.

F.1. Perspective on Chemicals

The lives of modern humans have been greatly improved by the development of chemicals such as pharmaceuticals, building materials, housewares, pesticides, and industrial chemicals. Through the use of chemicals, we can increase food production, cure diseases, build more efficient houses, and send people into space. At the same time, we must be cautious to ensure uncontrolled and over-expanded use of chemicals does not endanger our own existence (Chan et al. 1982).

Just as all humans are exposed to radiation in their normal daily routines, humans are also exposed to chemicals. Some potentially hazardous chemicals exist in the natural environment. In many areas of the country, soils contain naturally elevated concentrations of metals such as selenium, arsenic, or molybdenum, which may be hazardous to humans or animals. Even some of the foods we eat contain natural toxins. Aflatoxins are found in chili peppers, corn, millet, peanuts, rice, sorghum, sunflower seeds, tree nuts, and wheat. Cyanide is found in apple seeds. However, exposure to many more hazardous chemicals results from direct or indirect human actions. Building materials used in home construction may contain chemicals such as formaldehyde (in some insulation materials), asbestos (formerly used in insulation and ceiling tiles), and lead (formerly used in paints and gasoline). Some chemicals are present as a result of applying pesticides and fertilizers to soil. Other chemicals may have been transported long distances through the atmosphere from industrial sources and then deposited on soil or water.

F.2. Pathways of Chemicals from the Oak Ridge Reservation to the Public

Pathways are the routes or ways through which a person can encounter a chemical substance. Chemicals may be released to the air, soil, or water. Chemicals may also be released as liquid wastes, called effluents, which can enter streams and rivers.

People are exposed to chemicals by inhalation (breathing air), ingestion (intake of food, soil, or water), or dermal contact (touching soil or swimming in water). For example, fish that live in a river containing effluents may take in some of the chemicals present in the water. People eating fish and drinking water from the river would then be exposed to the chemicals. The public is not normally exposed to chemicals on ORR because access to the reservation is limited. However, chemicals released as a result of ORR operations can move through the environment to off-site locations, resulting in potential exposure of the public.

F.3. Toxicity

Toxicity refers to an adverse effect of a chemical on human health. Health effects from chemical exposures vary based on the chemical's toxicity. The toxic effect can be acute (a short-term, possible severe health effect) or chronic (a longer-term, persistent health effect). Although we ingest chemicals in food, water, and medications every day, toxic chemicals are typically nontoxic or harmless below certain concentrations or thresholds.

Chemical health effects due to toxicity are divided into two broad categories: adverse or systemic effects from noncarcinogens and cancer from carcinogens. The potential health hazards of noncarcinogens range from mild (e.g., skin irritation) to severe (e.g., death). Carcinogens cause or increase the incidence of malignant neoplasms or cancers. A chemical can have both carcinogenic and noncarcinogenic effects. Toxic effects can result from short-term or long-term chemical exposures.

Concentration limits or advisories are set by government agencies for some chemicals that are known or suspected to have adverse effects on human health. These concentration limits are used to calculate chemical doses that would not be harmful to individuals who are particularly sensitive to a chemical. These chemical doses are converted to slope factors to address carcinogenic risk and to reference doses to address noncarcinogenic hazards.

F.3.1. Dose Terms for Carcinogens

A slope factor is a plausible upper-bound estimate of the probability of a response per daily dose of a chemical during a lifetime of exposure (70 years). The slope factor conservatively estimates the probability of cancer due to chemical exposure for an individual's lifetime to a particular concentration. Units are expressed as risk per dose in mg/kg-day.

A slope factor converts the estimated daily dose, averaged over a lifetime exposure, to the incremental risk of an individual developing cancer. Because it is unknown for most chemicals whether a threshold (an intake below which no adverse effect occurs) exists for carcinogens, units for carcinogens are set in terms of risk factors. The standard cancer benchmarks used by the US Environmental Protection Agency (EPA) range from 1 in 1,000,000 to 1 in 10,000 (i.e., 10^{-6} to 10^{-4}), depending on the subpopulation exposed. In other words, a certain chemical concentration in food or water could cause a risk of one additional cancer for every 1,000,000 (10^{-6} risk level) to 10,000 (10^{-4} risk level) exposed persons.

F.3.2. Dose Term for Noncarcinogens

A reference dose is an estimate of a daily chemical exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Units are expressed as milligrams of chemical per kilogram of body weight per day (mg/kg-day). Reference dose values are derived from chemical intakes that resulted in no adverse effect or the lowest dose that showed an adverse effect in humans or laboratory animals.

Uncertainty factors are typically used in deriving reference doses. Uncertainty adjustments may be made to account for (1) interspecies variability in response when extrapolating from animal studies to humans; (2) response variability in humans; (3) uncertainty in estimating a no-effect level from a dose where effects were observed; (4) extrapolation from shorter duration studies to a full life-time exposure; and (5) data deficiencies (Dankovic et al., 2015). The use of uncertainty factors in deriving reference doses is thought to help protect sensitive human subpopulations.

F.3.3. Toxicity Value Sources

The slope factors and reference doses used for ORR calculations are selected from a tiered hierarchy system devised by EPA (EPA 2003). Values in the Integrated Risk Information System database, a Tier 1 toxicity value source, are considered to be validated and have undergone rigorous peer review and an EPA consensus review process. The EPA's Provisional Peer-Reviewed Toxicity Value database is a Tier 2 toxicity value source with values primarily derived for use in EPA's Superfund Program. Provisional Peer-Reviewed Toxicity Values are derived from a review of the relevant scientific literature using EPA methods, sources of data and guidance for value derivation. Tier 2 values have undergone rigorous peer review, but an EPA consensus review has not been performed. Tier 3 toxicity value sources include other sources of information and are used when Tier 1 or 2 values are not available for a contaminant. Multiple Tier 3 toxicity value sources used on ORR including the Agency for Toxic Substances and Disease Registry Minimal Risk Levels, the EPA's Office of Pesticide Programs Human Health Benchmarks for Pesticides, EPA's Health Effects Summary Table, and other federal and state sources.

F.4. Measuring Chemicals

Environmental samples are collected in areas surrounding ORR and are analyzed for those chemical constituents most likely to be released from ORR. Chemical concentrations in liquids are typically expressed in milligrams or micrograms of chemical per liter of water (mg/L or µg/L, respectively); concentrations in solids, such as soil and fish tissue, are expressed in milligrams or micrograms of chemical per kilogram of sample material (e.g., mg/kg or µg/kg for soil or fish tissue).

The instruments used to measure chemical concentrations are sensitive; however, there are limits below which they cannot detect chemicals of interest. Concentrations below the reported analytical detection limits of the instruments are recorded by the laboratory as estimated values, which have a greater uncertainty than concentrations detected above the detection limits of the instruments. Concentrations that use these estimated values are indicated by the less-than symbol (<), which specifies that the value for a parameter could not be quantified at the analytical detection limit.

F.5. Risk Assessment Methodology

The methods for assessing the cancer risk and noncancer hazard resulting from exposure to a particular chemical are discussed in the following paragraphs.

Exposure Assessment

To estimate an individual's potential exposure via a specific exposure pathway, the daily dose of the chemical must be determined. For example, chemical dose (in units of mg of contaminant per kilogram of body weight per day) from drinking water and eating fish from the Clinch River is assessed in the following manner:

Clinch River surface water and fish tissue samples are analyzed to measure chemical contaminant concentrations. Estimated daily doses to the public are calculated by multiplying chemical concentrations measured in the samples by the surface water intake rate (liters/day) and fish ingestion rate (kg/day), respectively. The average daily intakes are then multiplied by the exposure duration (in years) and exposure frequency (days/year) and divided by an averaging time (365 days/year multiplied by a lifetime [70 years] for carcinogens or the exposure duration for noncarcinogens). The default exposure assumptions are conservative and, in many cases, may result in higher estimated daily doses than an individual would actually receive.

Calculation Method

Carcinogenic risk calculations use slope factors and daily doses averaged over a lifetime (70 years). To estimate the potential carcinogenic risk from ingestion of water and fish, the estimated average daily dose (mg/kg-day) is multiplied by the slope factor (risk per mg/kg-day), resulting in units of risk. As mentioned earlier, acceptable risk levels for carcinogens range from 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000) to 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000). Carcinogenic risks greater than 10^{-4} indicate a concern for adverse health effects or the need for further study.

Noncarcinogenic hazard calculations use reference doses and daily doses averaged over the exposure duration. To calculate the potential hazard from ingestion of water and fish, the estimated average daily dose (mg/kg-day) is divided by the RfD (mg/kg-day), resulting in a unitless value called a hazard quotient. Hazard quotient values less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects; hazard quotient values greater than 1 indicate a concern for adverse health effects or the need for further study.

F.6. References

Chan, P.K., G.P. O'Hara, and A.W. Hayes. 1982. "Principles and Methods for Acute and Subchronic Toxicity." *Principles and Methods of Toxicology*. Raven Press, New York.

Dankovic, B. D. Naumann, A. Maier, M. L. Dourson and L. S. Levy. 2015. "The Scientific Basis of Uncertainty Factors Used in Setting Occupational Exposure Limits." *Journal of Occupational and Environmental Hygiene*. 12:sup1, S55-S68.

EPA 2003. Human Health Toxicity Values in Superfund Risk Assessment. *OSWER Directive 9285.7-53*. December 5, 2003.

G

Appendix G Radiological Airborne Emissions at Oak Ridge National Laboratory

This appendix presents annual radioactive airborne emissions for ORNL in 2022. All data were determined to be statistically different from zero at the 95 percent confidence level. Any number not statistically different from zero was not included in the emission calculation. Because measuring a radionuclide requires counting random radioactive emissions from a sample, the same result may not be obtained if the sample is analyzed repeatedly. This deviation is referred to as the *counting uncertainty*. Statistical significance at the 95 percent confidence level means that there is a 5 percent chance that the results could be erroneous.

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a]

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{225}Ac	M	particulate									9.58E-08	9.58E-08
^{226}Ac	M	particulate									1.07E-09	1.07E-09
^{227}Ac	M	particulate									1.07E-08	1.07E-08
^{105}Ag	M	particulate									2.46E-28	2.46E-28
^{106m}Ag	M	particulate									5.24E-50	5.24E-50
^{108}Ag	B	unspecified									4.95E-18	4.95E-18
^{108m}Ag	M	particulate									2.76E-10	2.76E-10
^{110}Ag	B	unspecified									1.79E-11	1.79E-11
^{110m}Ag	M	particulate									3.65E-08	3.65E-08
^{111}Ag	M	particulate									4.23E-08	4.23E-08
^{112}Ag	M	particulate									5.62E-10	5.62E-10
^{26}Al	M	particulate									2.99E-09	2.99E-09
^{241}Am	M	particulate	4.19E-08	1.21E-06		1.54E-09			1.21E-09		2.79E-07	1.53E-06
^{241}Am	F	particulate			1.48E-07		1.42E-08	1.64E-07			9.84E-10	3.27E-07
^{242}Am	M	particulate									4.24E-11	4.24E-11
^{242m}Am	M	particulate									4.29E-11	4.29E-11
^{243}Am	M	particulate									4.05E-09	4.05E-09
^{37}Ar	B	unspecified									2.14E-07	2.14E-07
^{39}Ar	B	unspecified									3.7E-04	3.7E-04
^{41}Ar	B	unspecified							3.94E+02	1.04E+02		4.98E+02
^{73}As	M	particulate									1.67E-21	1.67E-21
^{74}As	M	particulate									1.75E-26	1.75E-26
^{195}Au	M	particulate									9.07E-21	9.07E-21
^{131}Ba	M	particulate									7.63E-31	7.63E-31
^{133}Ba	M	particulate									5.67E-15	5.67E-15
^{137m}Ba	B	unspecified									9.54E-07	9.54E-07
^{139}Ba	M	particulate							3.62E-01			3.62E-01
^{140}Ba	M	particulate							5.08E-04		1.85E-08	5.08E-04

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{7}Be	M	particulate	3.78E-07	4.81E-07							2.68E-06	3.54E-06
^{7}Be	S	particulate			3.75E-06		1.59E-07				7.03E-07	4.61E-06
^{10}Be	M	particulate									6.01E-16	6.01E-16
^{206}Bi	M	particulate									3.21E-09	3.21E-09
^{207}Bi	M	particulate									5.86E-17	5.86E-17
^{208}Bi	B	unspecified									8.67E-20	8.67E-20
^{210}Bi	M	particulate									3.38E-21	3.38E-21
^{210m}Bi	M	particulate									4.04E-20	4.04E-20
^{211}Bi	B	unspecified									4.14E-11	4.14E-11
^{212}Bi	M	particulate									1.89E-11	1.89E-11
^{245}Bk	M	particulate									2.5E-84	2.5E-84
^{247}Bk	M	particulate									1.77E-27	1.77E-27
^{249}Bk	M	particulate									1.23E-11	1.23E-11
^{82}Br	M	particulate									6.58E-10	6.58E-10
^{11}C	G	dioxide								1.3E+04		1.3E+04
^{14}C	M	particulate									2.26E-05	2.26E-05
^{41}Ca	M	particulate									7.05E-12	7.05E-12
^{45}Ca	M	particulate									2.58E-12	2.58E-12
^{47}Ca	M	particulate									2.94E-77	2.94E-77
^{109}Cd	M	particulate									1.28E-14	1.28E-14
^{113}Cd	M	particulate									3.46E-27	3.46E-27
^{113m}Cd	M	particulate									2.55E-10	2.55E-10
^{115}Cd	M	particulate									1.16E-08	1.16E-08
^{115m}Cd	M	particulate									5.86E-11	5.86E-11
^{134}Ce	M	particulate									3.4E-69	3.4E-69
^{139}Ce	M	particulate									1.58E-09	1.58E-09
^{141}Ce	M	particulate									3.48E-08	3.48E-08
^{143}Ce	M	particulate									8.44E-10	8.44E-10
^{144}Ce	M	particulate									1.53E-06	1.53E-06
^{248}Cf	M	particulate									1.01E-23	1.01E-23

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{249}Cf	M	particulate									5.56E-19	5.56E-19
^{250}Cf	M	particulate									7.07E-18	7.07E-18
^{251}Cf	M	particulate									3.36E-20	3.36E-20
^{252}Cf	M	particulate									3.45E-08	3.45E-08
^{252}Cf	F	particulate									6.87E-11	6.87E-11
^{253}Cf	M	particulate									1.2E-34	1.2E-34
^{254}Cf	M	particulate									9.2E-28	9.2E-28
^{36}Cl	M	particulate									4.08E-09	4.08E-09
^{240}Cm	M	particulate									3.24E-29	3.24E-29
^{241}Cm	M	particulate									5.7E-23	5.7E-23
^{242}Cm	M	particulate									6.59E-09	6.59E-09
^{243}Cm	M	particulate	1.03E-07	3.32E-08					2.06E-09		2.32E-10	1.38E-07
^{243}Cm	F	particulate			4.23E-09		3.1E-08	6.8E-09			2.41E-10	4.22E-08
^{244}Cm	M	particulate	1.03E-07	3.32E-08					2.06E-09		3.63E-06	3.77E-06
^{244}Cm	F	particulate			4.23E-09		3.1E-08	6.8E-09			2.41E-10	4.22E-08
^{245}Cm	M	particulate									3.5E-09	3.5E-09
^{246}Cm	M	particulate									6.06E-13	6.06E-13
^{247}Cm	M	particulate									1.2E-09	1.2E-09
^{248}Cm	M	particulate									1.45E-11	1.45E-11
^{250}Cm	M	particulate									4.18E-26	4.18E-26
^{56}Co	M	particulate									5.1E-14	5.1E-14
^{57}Co	M	particulate									7.02E-09	7.02E-09
^{58}Co	M	particulate									4.14E-08	4.14E-08
^{60}Co	M	particulate									3.94E-06	3.94E-06
^{51}Cr	M	particulate									3.96E-12	3.96E-12
^{131}Cs	F	particulate									9.2E-43	9.2E-43
^{132}Cs	F	particulate									1.11E-51	1.11E-51
^{134}Cs	F	particulate									7.03E-07	7.03E-07
^{135}Cs	F	particulate									3.2E-09	3.2E-09
^{136}Cs	F	particulate									4.06E-09	4.06E-09

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{137}Cs	F	particulate	3.19E-07	3.44E-06					4.26E-06		2.32E-04	2.4E-04
^{137}Cs	S	particulate			4.6E-05						1.26E-05	5.86E-05
^{138}Cs	F	particulate							1.11E+03			1.11E+03
^{159}Dy	M	particulate									2.78E-19	2.78E-19
^{166}Dy	M	particulate									2.38E-87	2.38E-87
^{169}Er	M	particulate									6.76E-41	6.76E-41
^{253}Es	M	particulate									4.4E-32	4.4E-32
^{254}Es	M	particulate									8.84E-25	8.84E-25
^{255}Es	B	unspecified									4.98E-30	4.98E-30
^{147}Eu	M	particulate									1.22E-34	1.22E-34
^{148}Eu	M	particulate									4.92E-97	4.92E-97
^{149}Eu	M	particulate									2.36E-23	2.36E-23
^{150}Eu	M	particulate									3.29E-18	3.29E-18
^{152}Eu	M	particulate									1.89E-07	1.89E-07
^{154}Eu	M	particulate									1.92E-07	1.92E-07
^{155}Eu	M	particulate									4.37E-08	4.37E-08
^{156}Eu	M	particulate									2.97E-11	2.97E-11
^{55}Fe	M	particulate									2.4E-07	2.4E-07
^{59}Fe	M	particulate									2.76E-10	2.76E-10
^{60}Fe	M	particulate									1.16E-15	1.16E-15
^{67}Ga	M	particulate									1.62E-101	1.62E-101
^{148}Gd	M	particulate									1.07E-10	1.07E-10
^{149}Gd	M	particulate									4.16E-52	4.16E-52
^{150}Gd	B	unspecified									3.18E-90	3.18E-90
^{151}Gd	M	particulate									2.13E-19	2.13E-19
^{152}Gd	M	particulate									2.16E-26	2.16E-26
^{153}Gd	M	particulate									3.39E-10	3.39E-10
^{68}Ge	M	particulate									3.1E-16	3.1E-16
^{71}Ge	M	particulate									3.14E-31	3.14E-31
^{3}H	V	vapor	3.18E-02		3.39E-01	2.99E-03	7.37E-01		7.93E+01	1.16E+03	9.32E-01	1.24E+03

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{172}Hf	M	particulate									6.47E-12	6.47E-12
^{175}Hf	M	particulate									6.93E-14	6.93E-14
^{178m}Hf	M	particulate									3.22E-11	3.22E-11
^{179m}Hf	M	particulate									5.64E-20	5.64E-20
^{181}Hf	M	particulate									1.62E-14	1.62E-14
^{182}Hf	M	particulate									2.77E-15	2.77E-15
^{203}Hg	M	inorganic									8.53E-24	8.53E-24
^{163}Ho	B	unspecified									1.49E-21	1.49E-21
^{166m}Ho	M	particulate									2.78E-13	2.78E-13
^{124}I	F	particulate									1.82E-82	1.82E-82
^{125}I	F	particulate									3.98E-23	3.98E-23
^{126}I	F	particulate			6.94E-03	4.97E-03					1.57E-09	1.19E-02
^{129}I	F	particulate									1.09E-05	1.09E-05
^{131}I	F	particulate	3.12E-08		8.43E-04	2.64E-02			4.22E-02		1.68E-08	6.94E-02
^{131}I	S	particulate						1.73E-06				1.73E-06
^{132}I	F	particulate				8.01E-03			4.36E-01			4.44E-01
^{133}I	F	particulate							2.32E-01			2.32E-01
^{134}I	F	particulate							3.94E-01			3.94E-01
^{135}I	F	particulate							7.75E-01			7.75E-01
^{111}In	M	particulate									8.78E-107	8.78E-107
^{114}In	B	unspecified									2.6E-17	2.6E-17
^{114m}In	M	particulate									1.8E-11	1.8E-11
^{115}In	M	particulate									8.88E-25	8.88E-25
^{192}Ir	M	particulate									1.47E-14	1.47E-14
^{192n}Ir	B	unspecified									2.33E-20	2.33E-20
^{194m}Ir	M	particulate									1.71E-14	1.71E-14
^{40}K	M	particulate									3.15E-07	3.15E-07
^{81}Kr	B	unspecified									1.09E-07	1.09E-07
^{83m}Kr	B	unspecified									4.E-08	4.E-08
^{85}Kr	B	unspecified							1.51E+02		2.53E+02	4.04E+02

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{85m}Kr	B	unspecified							1.21E+01	1.17E+02		1.29E+02
^{87}Kr	B	unspecified							5.77E+01	2.61E+02		3.19E+02
^{88}Kr	B	unspecified							5.33E+01	9.13E+01		1.45E+02
^{89}Kr	B	unspecified							2.88E+01			2.88E+01
^{137}La	M	particulate									3.42E-19	3.42E-19
^{138}La	M	particulate									1.94E-23	1.94E-23
^{140}La	M	particulate							5.12E-02		8.14E-09	5.12E-02
^{171}Lu	M	particulate									3.65E-17	3.65E-17
^{172}Lu	M	particulate									1.97E-18	1.97E-18
^{173}Lu	M	particulate									5.08E-13	5.08E-13
^{174}Lu	M	particulate									5.61E-12	5.61E-12
^{174m}Lu	M	particulate									1.16E-17	1.16E-17
^{176}Lu	M	particulate									3.29E-21	3.29E-21
^{177m}Lu	M	particulate									3.89E-11	3.89E-11
^{52}Mn	M	particulate									4.04E-65	4.04E-65
^{53}Mn	M	particulate									1.31E-15	1.31E-15
^{54}Mn	M	particulate									1.99E-07	1.99E-07
^{93}Mo	M	particulate									1.75E-09	1.75E-09
^{99}Mo	M	particulate									1.74E-08	1.74E-08
^{22}Na	M	particulate									2.3E-11	2.3E-11
^{91}Nb	B	unspecified									9.31E-11	9.31E-11
^{91m}Nb	B	unspecified									1.08E-15	1.08E-15
^{92}Nb	B	unspecified									4.48E-15	4.48E-15
^{92m}Nb	B	unspecified									9.14E-29	9.14E-29
^{93m}Nb	M	particulate									1.47E-09	1.47E-09
^{94}Nb	M	particulate									1.82E-08	1.82E-08
^{95}Nb	M	particulate									2.1E-08	2.1E-08
^{95m}Nb	M	particulate									6.62E-61	6.62E-61
^{96}Nb	M	particulate									9.67E-11	9.67E-11
^{97}Nb	M	particulate									5.95E-11	5.95E-11

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{140}Nd	B	unspecified									5.94E-95	5.94E-95
^{144}Nd	B	unspecified									1.25E-20	1.25E-20
^{147}Nd	M	particulate									1.13E-08	1.13E-08
^{56}Ni	M	particulate									1.08E-89	1.08E-89
^{59}Ni	M	particulate									3.03E-10	3.03E-10
^{63}Ni	M	particulate									1.37E-07	1.37E-07
^{234}Np	M	particulate									1.62E-79	1.62E-79
^{235}Np	M	particulate									7.29E-15	7.29E-15
^{236}Np	M	particulate									1.45E-18	1.45E-18
^{237}Np	M	particulate									9.12E-08	9.12E-08
^{238}Np	M	particulate									1.22E-101	1.22E-101
^{239}Np	M	particulate									1.37E-09	1.37E-09
^{185}Os	M	particulate									4.2E-19	4.2E-19
^{191}Os	M	particulate				1.06E-02						1.06E-02
^{194}Os	M	particulate									2.24E-13	2.24E-13
^{32}P	M	particulate									7.13E-17	7.13E-17
^{33}P	M	particulate									6.66E-18	6.66E-18
^{228}Pa	M	particulate									5.5E-11	5.5E-11
^{230}Pa	M	particulate									3.72E-09	3.72E-09
^{231}Pa	M	particulate									1.54E-16	1.54E-16
^{232}Pa	M	particulate									1.4E-10	1.4E-10
^{233}Pa	M	particulate									5.9E-08	5.9E-08
^{205}Pb	M	particulate									1.83E-20	1.83E-20
^{210}Pb	M	particulate									4.67E-21	4.67E-21
^{211}Pb	M	particulate									3.42E-11	3.42E-11
^{212}Pb	M	particulate	2.87E-01	3.5E-01		3.77E-02			3.22E-02		4.85E-08	7.07E-01
^{212}Pb	S	particulate			6.37E+00		1.15E+00				1.16E-01	7.64E+00
^{214}Pb	S	particulate			6.81E-01							6.81E-01
^{214}Pb	M	particulate				4.9E-03						4.9E-03
^{103}Pd	M	particulate									3.26E-28	3.26E-28

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{107}Pd	M	particulate									8.16E-13	8.16E-13
^{143}Pm	M	particulate									1.11E-23	1.11E-23
^{144}Pm	M	particulate									2.06E-21	2.06E-21
^{145}Pm	M	particulate									2.53E-11	2.53E-11
^{146}Pm	M	particulate									1.59E-11	1.59E-11
^{147}Pm	M	particulate									2.75E-06	2.75E-06
^{148}Pm	M	particulate									1.13E-08	1.13E-08
^{148m}Pm	M	particulate									1.04E-08	1.04E-08
^{208}Po	B	unspecified									3.8E-32	3.8E-32
^{209}Po	B	unspecified									1.95E-29	1.95E-29
^{210}Po	B	inorganic									5.31E-16	5.31E-16
^{143}Pr	M	particulate									1.63E-15	1.63E-15
^{144}Pr	M	particulate									1.25E-06	1.25E-06
^{193}Pt	M	particulate									3.4E-12	3.4E-12
^{236}Pu	M	particulate									1.43E-09	1.43E-09
^{237}Pu	M	particulate									3.54E-12	3.54E-12
^{238}Pu	M	particulate	1.23E-08	7.89E-08		3.01E-10			1.34E-08		7.09E-07	8.14E-07
^{238}Pu	F	particulate			8.32E-08		8.49E-09	1.21E-07			1.39E-09	2.14E-07
^{239}Pu	M	particulate	1.94E-08	5.35E-07		3.21E-10			3.37E-09		1.4E-06	1.96E-06
^{239}Pu	F	particulate			3.29E-07		9.5E-09	2.47E-08			1.29E-06	1.65E-06
^{240}Pu	M	particulate	1.94E-08	5.35E-07		3.21E-10			3.37E-09		1.96E-07	7.54E-07
^{240}Pu	F	particulate			3.29E-07		9.5E-09	2.47E-08			5.68E-10	3.64E-07
^{241}Pu	M	particulate									5.55E-07	5.55E-07
^{242}Pu	M	particulate									5.69E-10	5.69E-10
^{243}Pu	M	particulate									3.87E-20	3.87E-20
^{244}Pu	M	particulate									3.13E-10	3.13E-10
^{246}Pu	M	particulate									1.32E-43	1.32E-43
^{223}Ra	M	particulate									2.34E-08	2.34E-08
^{224}Ra	M	particulate									4.98E-09	4.98E-09
^{225}Ra	M	particulate									1.09E-09	1.09E-09

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{226}Ra	M	particulate									1.06E-08	1.06E-08
^{228}Ra	M	particulate									5.5E-14	5.5E-14
^{83}Rb	M	particulate									2.01E-16	2.01E-16
^{84}Rb	M	particulate									1.41E-21	1.41E-21
^{86}Rb	M	particulate									6.26E-23	6.26E-23
^{87}Rb	M	particulate									2.48E-16	2.48E-16
^{183}Re	B	unspecified									1.53E-25	1.53E-25
^{184}Re	M	particulate									5.45E-27	5.45E-27
^{184m}Re	M	particulate									5.74E-16	5.74E-16
^{186m}Re	M	particulate									2.48E-15	2.48E-15
^{187}Re	M	particulate									1.68E-21	1.68E-21
^{99}Rh	M	particulate									1.73E-39	1.73E-39
^{101}Rh	M	particulate									4.96E-19	4.96E-19
^{101m}Rh	M	particulate									2.56E-76	2.56E-76
^{102}Rh	M	particulate									5.31E-12	5.31E-12
^{102m}Rh	M	particulate									3.42E-15	3.42E-15
^{103m}Rh	M	particulate									1.4E-12	1.4E-12
^{105}Rh	M	particulate									5.57E-09	5.57E-09
^{106}Rh	B	unspecified									7.02E-07	7.02E-07
^{219}Rn	B	unspecified									5.43E-07	5.43E-07
^{222}Rn	B	unspecified									1.7E-05	1.7E-05
^{103}Ru	M	particulate									3.64E-08	3.64E-08
^{106}Ru	M	particulate									9.37E-07	9.37E-07
^{35}S	M	particulate									2.78E-13	2.78E-13
^{120m}Sb	M	particulate									1.46E-09	1.46E-09
^{122}Sb	M	particulate				1.81E-03					3.E-09	1.81E-03
^{124}Sb	M	particulate				4.33E-03					1.99E-09	4.33E-03
^{125}Sb	M	particulate				4.7E-04					5.35E-08	4.7E-04
^{126}Sb	M	particulate				8.25E-03					5.45E-09	8.25E-03
^{126m}Sb	M	particulate									2.4E-12	2.4E-12

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{127}Sb	M	particulate									4.54E-09	4.54E-09
^{46}Sc	M	particulate									1.16E-13	1.16E-13
^{47}Sc	M	particulate									1.05E-90	1.05E-90
^{72}Se	B	unspecified									4.02E-63	4.02E-63
^{75}Se	F	particulate				1.88E-07					3.51E-15	1.88E-07
^{79}Se	F	particulate									9.35E-13	9.35E-13
^{32}Si	M	particulate									1.81E-13	1.81E-13
^{145}Sm	M	particulate									5.56E-16	5.56E-16
^{146}Sm	M	particulate									9.79E-19	9.79E-19
^{147}Sm	M	particulate									2.61E-17	2.61E-17
^{148}Sm	B	unspecified									2.18E-24	2.18E-24
^{151}Sm	M	particulate									1.86E-09	1.86E-09
^{113}Sn	M	particulate									8.78E-09	8.78E-09
^{117m}Sn	M	particulate									1.58E-06	1.58E-06
^{119m}Sn	M	particulate									8.08E-10	8.08E-10
^{121}Sn	M	particulate									1.48E-12	1.48E-12
^{121m}Sn	M	particulate									1.11E-11	1.11E-11
^{123}Sn	M	particulate									1.59E-10	1.59E-10
^{125}Sn	M	particulate									3.63E-09	3.63E-09
^{126}Sn	M	particulate									2.42E-12	2.42E-12
^{82}Sr	M	particulate									1.49E-52	1.49E-52
^{85}Sr	M	particulate									5.87E-16	5.87E-16
^{89}Sr	S	particulate			5.15E-06		1.66E-08				9.35E-08	5.26E-06
^{89}Sr	M	particulate	5.1E-08	1.54E-06		1.38E-08			7.E-06		7.18E-07	9.32E-06
^{90}Sr	M	particulate	5.1E-08	1.54E-06		1.38E-08			7.E-06		9.92E-05	1.08E-04
^{90}Sr	S	particulate			5.15E-06		1.66E-08	1.38E-06			9.83E-08	6.64E-06
^{91}Sr	M	particulate									1.19E-13	1.19E-13
^{179}Ta	M	particulate									1.07E-11	1.07E-11
^{182}Ta	M	particulate									2.64E-05	2.64E-05
^{155}Tb	M	particulate									2.48E-67	2.48E-67

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{156}Tb	M	particulate									1.19E-65	1.19E-65
^{157}Tb	M	particulate									3.5E-19	3.5E-19
^{158}Tb	M	particulate									6.38E-16	6.38E-16
^{160}Tb	M	particulate									7.29E-13	7.29E-13
^{161}Tb	M	particulate									1.75E-47	1.75E-47
^{95m}Tc	M	particulate									5.92E-27	5.92E-27
^{96}Tc	M	particulate									1.97E-10	1.97E-10
^{97}Tc	M	particulate									4.75E-18	4.75E-18
^{97m}Tc	M	particulate									2.14E-16	2.14E-16
^{98}Tc	M	particulate									3.55E-17	3.55E-17
^{99}Tc	M	particulate									7.96E-10	7.96E-10
^{99}Tc	S	particulate						2.19E-06				2.19E-06
^{118}Te	B	unspecified									2.22E-72	2.22E-72
^{119m}Te	B	unspecified									5.82E-82	5.82E-82
^{121}Te	M	particulate									4.05E-10	4.05E-10
^{121m}Te	M	particulate									5.41E-11	5.41E-11
^{123m}Te	M	particulate									8.16E-07	8.16E-07
^{125m}Te	M	particulate									1.6E-07	1.6E-07
^{127}Te	M	particulate									1.08E-10	1.08E-10
^{127m}Te	M	particulate				3.22E-06					1.13E-10	3.22E-06
^{129}Te	M	particulate									1.84E-15	1.84E-15
^{129m}Te	M	particulate				3.71E-06					6.73E-08	3.78E-06
^{131m}Te	M	particulate									9.13E-10	9.13E-10
^{132}Te	M	particulate									3.03E-09	3.03E-09
^{227}Th	S	particulate									1.56E-08	1.56E-08
^{228}Th	S	particulate	6.32E-10	5.08E-08	2.85E-08	4.15E-09	5.04E-09		2.53E-08		7.07E-06	7.18E-06
^{229}Th	S	particulate									5.31E-10	5.31E-10
^{230}Th	S	particulate	1.43E-09	1.88E-09		4.77E-10			3.86E-09		3.4E-09	1.1E-08
^{230}Th	F	particulate			1.18E-08		4.34E-10				9.97E-10	1.32E-08
^{231}Th	S	particulate									3.58E-14	3.58E-14

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{232}Th	S	particulate	1.02E-09	1.12E-08		6.12E-10			6.81E-09		1.28E-08	3.24E-08
^{232}Th	F	particulate			2.14E-08		1.64E-09				1.53E-09	2.46E-08
^{234}Th	S	particulate									3.11E-13	3.11E-13
^{44}Ti	M	particulate									3.87E-12	3.87E-12
^{204}Tl	M	particulate									4.56E-18	4.56E-18
^{208}Tl	B	unspecified									7.02E-12	7.02E-12
^{167}Tm	M	particulate									1.56E-48	1.56E-48
^{168}Tm	B	unspecified									1.82E-21	1.82E-21
^{170}Tm	M	particulate									2.39E-14	2.39E-14
^{171}Tm	M	particulate									2.67E-09	2.67E-09
^{230}U	M	particulate									2.06E-31	2.06E-31
^{231}U	M	particulate									4.24E-79	4.24E-79
^{232}U	M	particulate									6.84E-14	6.84E-14
^{233}U	M	particulate	3.01E-08	4.5E-07		4.59E-10			5.4E-09		3.4E-07	8.25E-07
^{233}U	S	particulate			1.03E-06		9.52E-09				1.47E-08	1.05E-06
^{234}U	M	particulate	3.01E-08	4.5E-07		4.59E-10			5.4E-09		7.42E-05	7.47E-05
^{234}U	S	particulate			1.03E-06		9.52E-09				1.47E-08	1.05E-06
^{235}U	M	particulate		1.27E-08					5.45E-10		1.94E-05	1.94E-05
^{235}U	S	particulate			8.44E-09						8.92E-11	8.53E-09
^{236}U	M	particulate									2.77E-12	2.77E-12
^{237}U	M	particulate									1.38E-16	1.38E-16
^{238}U	M	particulate	3.E-09	5.82E-08		2.23E-09			1.42E-08		4.45E-04	4.45E-04
^{238}U	S	particulate			2.62E-08		1.94E-09				3.58E-09	3.17E-08
^{240}U	M	particulate									4.6E-19	4.6E-19
^{48}V	M	particulate									2.5E-23	2.5E-23
^{49}V	M	particulate									1.05E-11	1.05E-11
^{50}V	B	unspecified									7.84E-28	7.84E-28
^{181}W	M	particulate									2.15E-13	2.15E-13
^{185}W	M	particulate									1.77E-11	1.77E-11
^{188}W	M	particulate									7.41E-14	7.41E-14

Table G.1. Radiological airborne emissions from all sources at ORNL, 2022 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{123}Xe	B	unspecified								1.57E+02		1.57E+02
^{125}Xe	B	unspecified								9.13E+01		9.13E+01
^{127}Xe	B	unspecified								3.63E-03		3.63E-03
^{131m}Xe	B	unspecified							1.59E+02		1.64E-05	1.59E+02
^{133}Xe	B	unspecified				3.27E-02			8.43E+00		4.52E-09	8.46E+00
^{133m}Xe	B	unspecified							2.61E+01			2.61E+01
^{135}Xe	B	unspecified							6.17E+01			6.17E+01
^{135m}Xe	B	unspecified							4.5E+01			4.5E+01
^{137}Xe	B	unspecified							9.1E+01			9.1E+01
^{138}Xe	B	unspecified							2.16E+02			2.16E+02
^{87}Y	M	particulate									2.98E-93	2.98E-93
^{88}Y	M	particulate									1.E-10	1.E-10
^{90}Y	M	particulate									8.22E-07	8.22E-07
^{91}Y	M	particulate									2.91E-10	2.91E-10
^{169}Yb	M	particulate									2.77E-09	2.77E-09
^{65}Zn	M	particulate									1.31E-06	1.31E-06
^{88}Zr	M	particulate									2.1E-15	2.1E-15
^{89}Zr	M	particulate									2.9E-89	2.9E-89
^{93}Zr	M	particulate									2.28E-11	2.28E-11
^{95}Zr	M	particulate									1.52E-08	1.52E-08
^{97}Zr	M	particulate									3.72E-11	3.72E-11
Totals			**3.19E-01**	**3.50E-01**	**7.40E+00**	**1.43E-01**	**1.89E+00**	**5.65E-06**	**2.50E+03**	**1.50E+04**	**2.54E+02**	**1.77E+04**

[a] *Emissions given in curies (Ci). 1 Ci = 3.7E+10 Bq*

[b] *The designation of F, M, and S refers to the lung clearance type—fast (F), moderate (M), and slow (S) for the given radionuclide. G stands for gaseous, V stands for vapor, and B stands for blank (unspecified form).*