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.

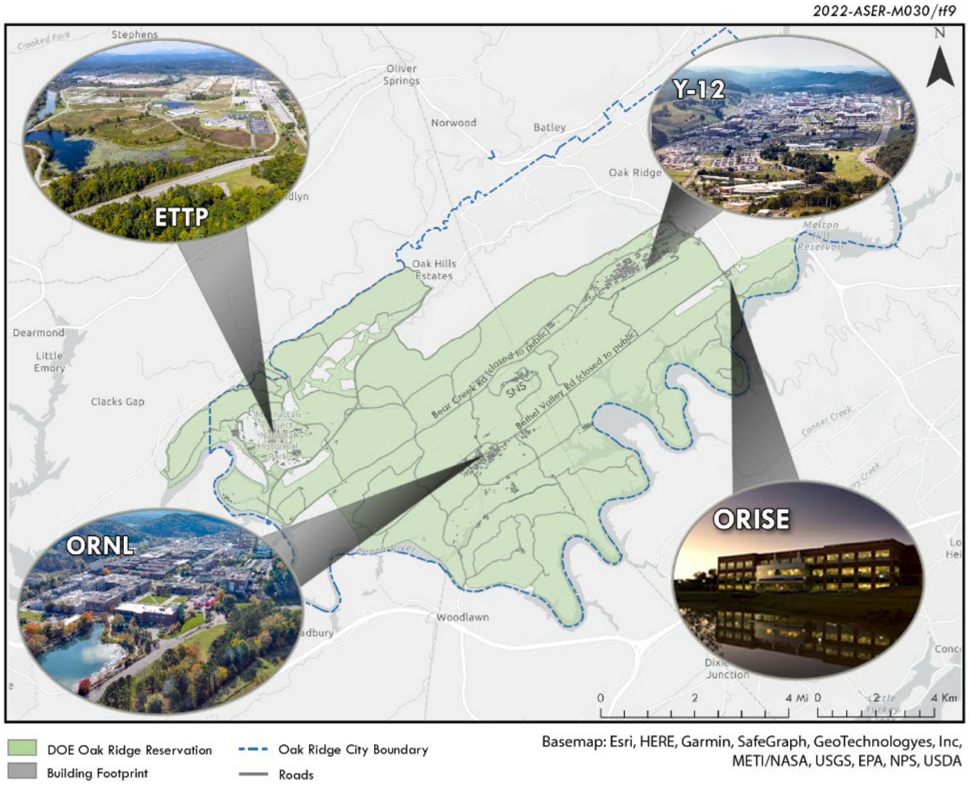
In March 2007, Isotek assumed responsibility for the Building 3019 Complex at ORNL, where the national repository of ^{233}U has been kept since 1962. In 2010, an Analysis of Alternatives was conducted to evaluate methods available for ^{233}U disposition, and in 2011, the recommendations in the *Final 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.

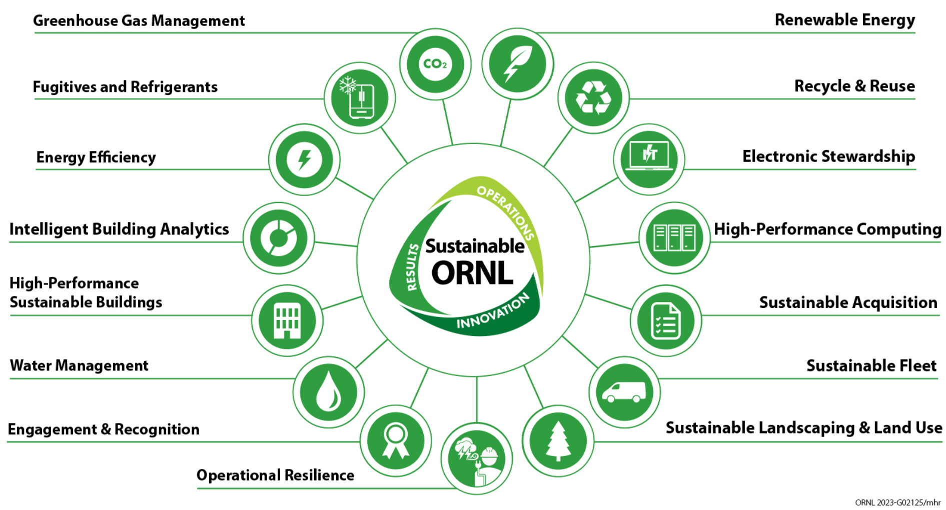


Figure 5.3. Sustainable ORNL focus areas (roadmaps)

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.

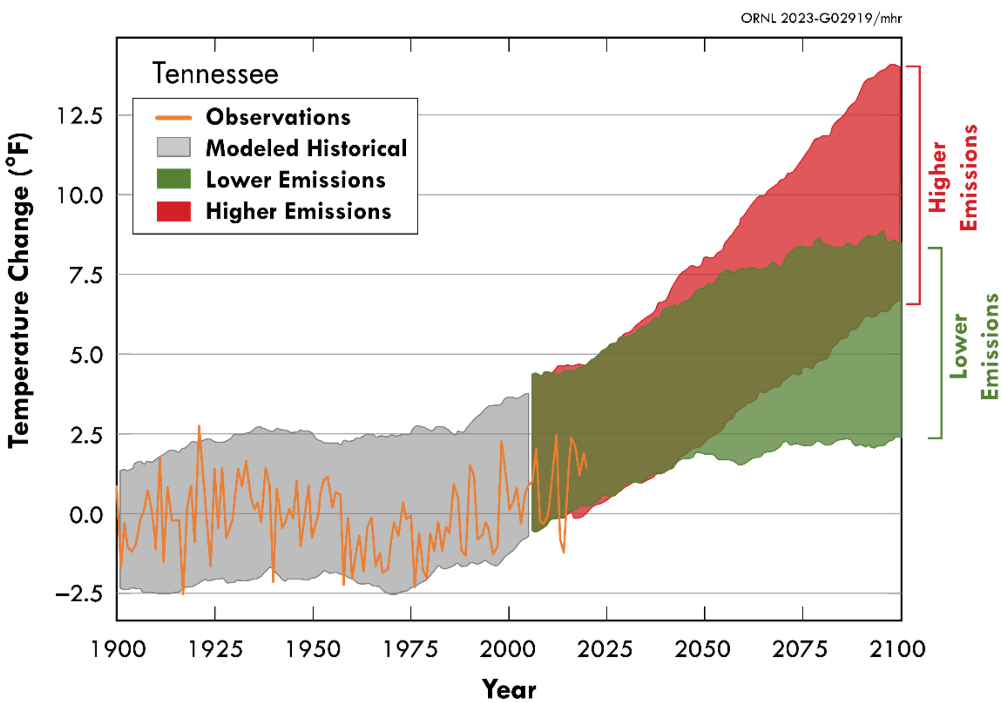


Figure 5.4. Tennessee observed and projected temperature change (Runkle et al. 2022)

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).

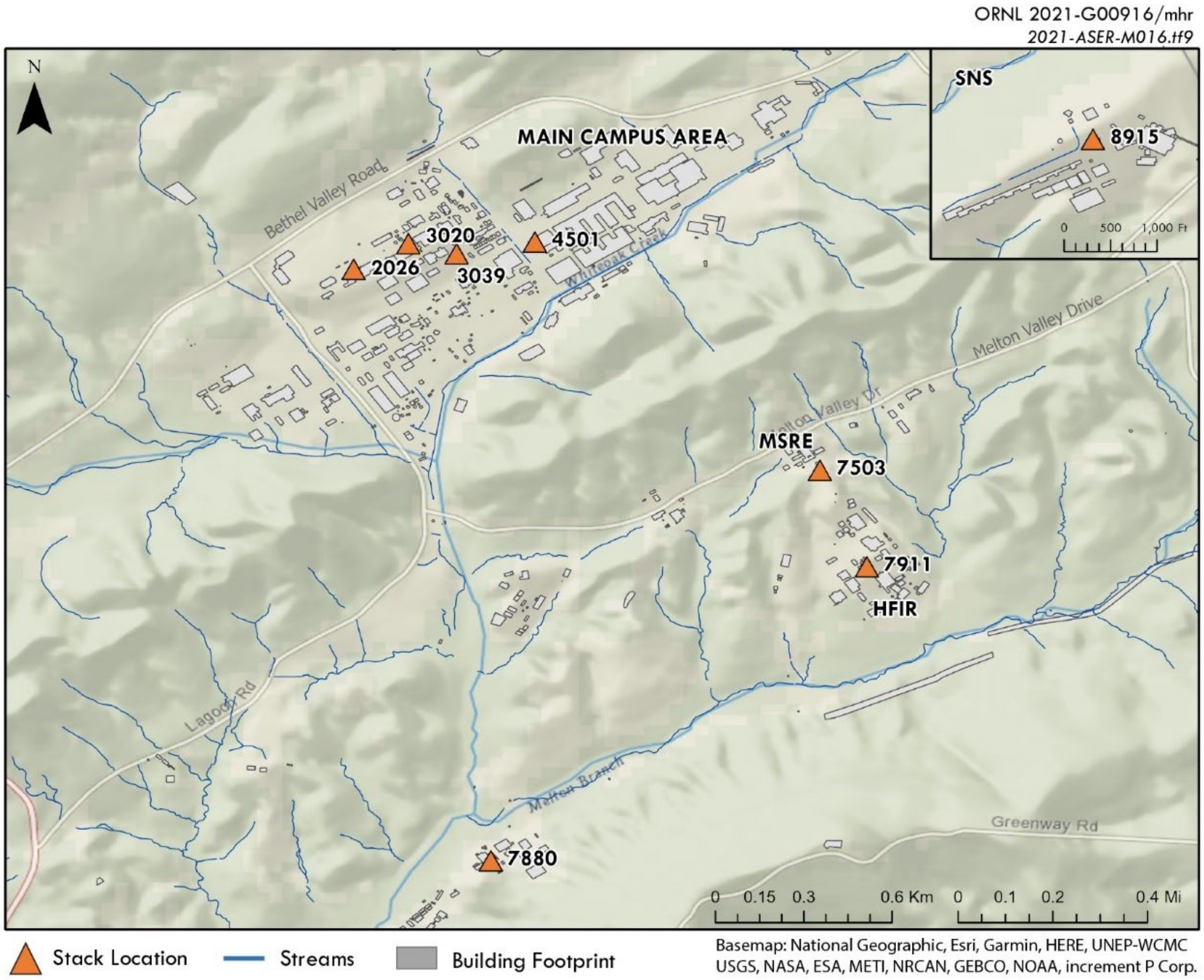
The major radiological emission point sources for ORNL consist of the following eight stacks. Seven are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.7):

- 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.

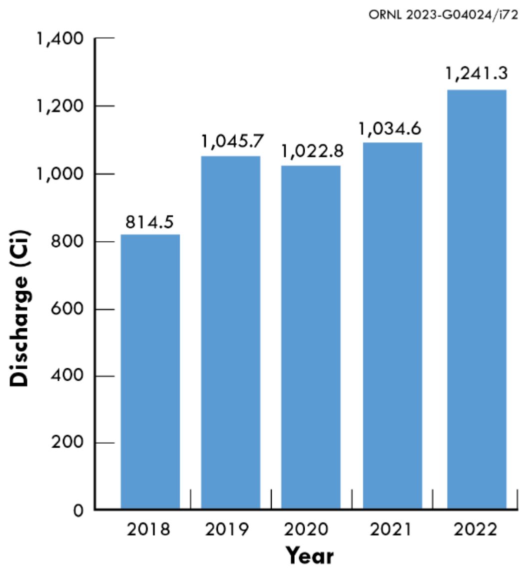


Figure 5.8. Total curies of ^{3}H discharged from ORNL to the atmosphere, 2018–2022

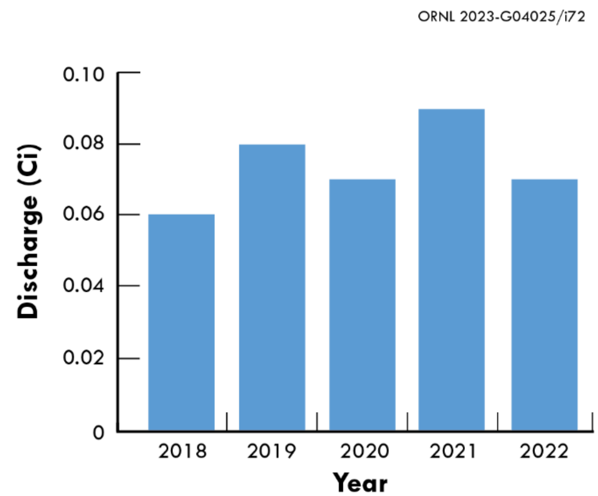


Figure 5.9. Total curies of ^{131}I discharged from ORNL to the atmosphere, 2018–2022

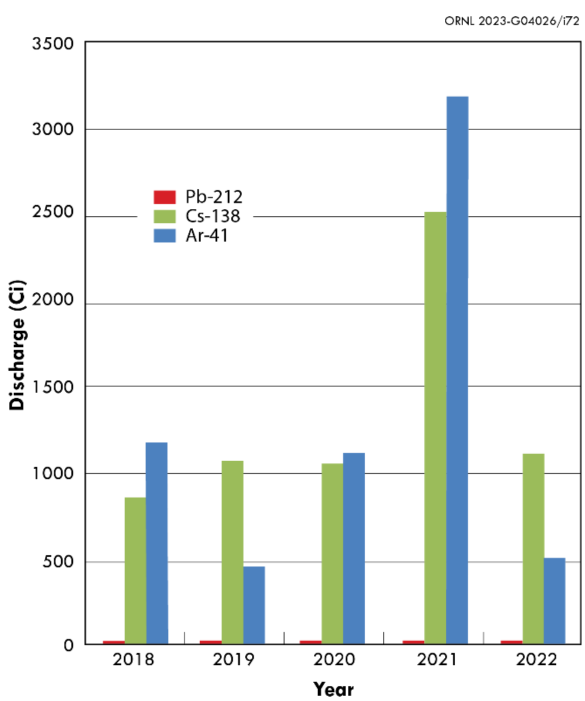


Figure 5.10. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from ORNL to the atmosphere, 2018–2022

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

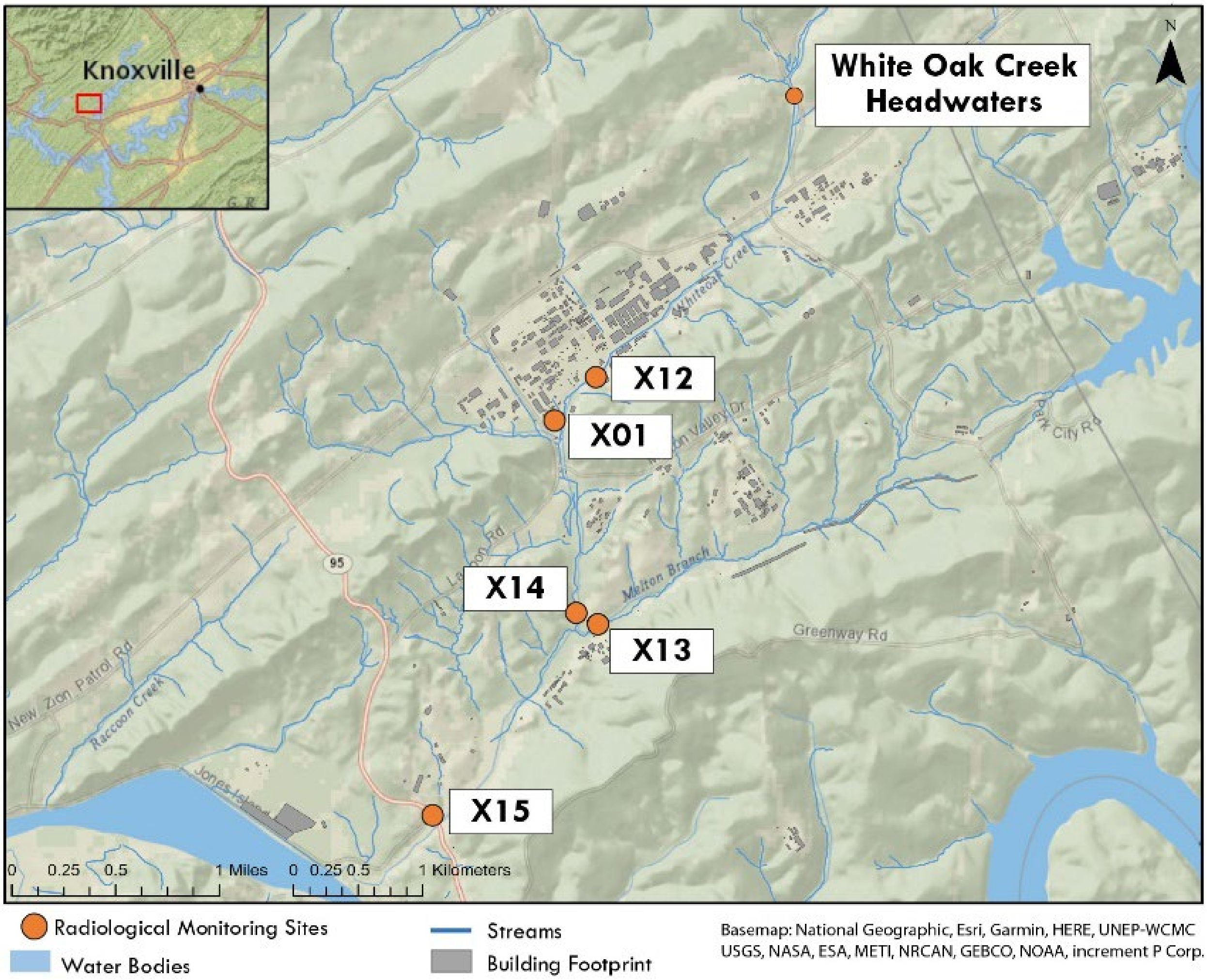


Figure 5.11. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at ORNL

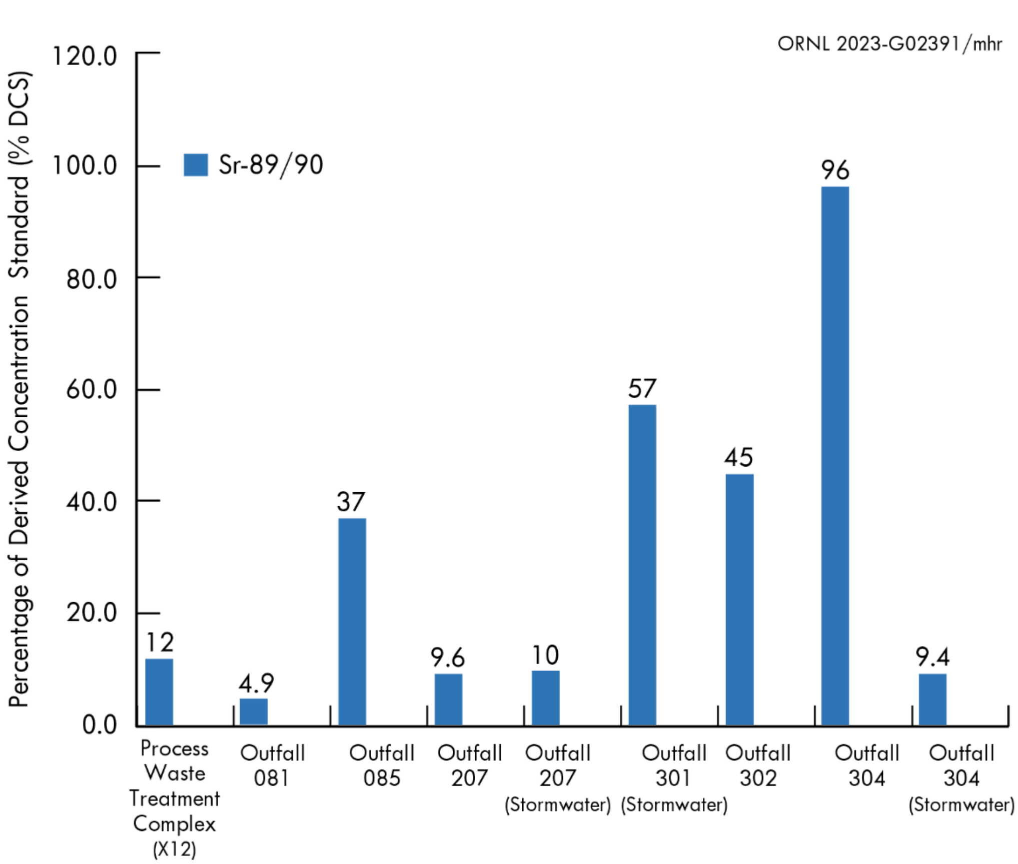


Figure 5.12. Outfalls and instream locations, including storm water outfalls at ORNL with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2022

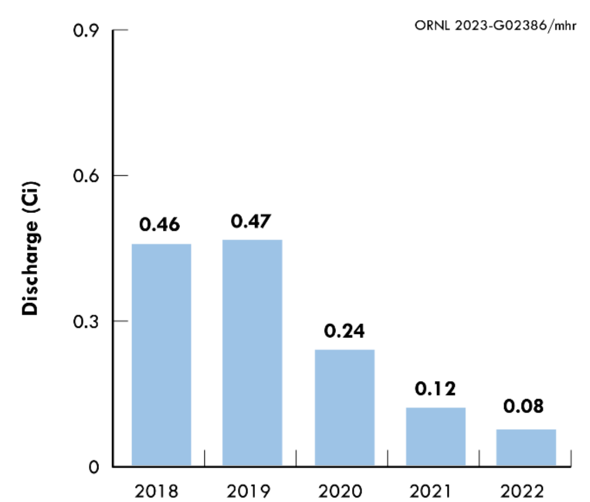


Figure 5.13. Cesium-137 discharges at White Oak Dam, 2018–2022

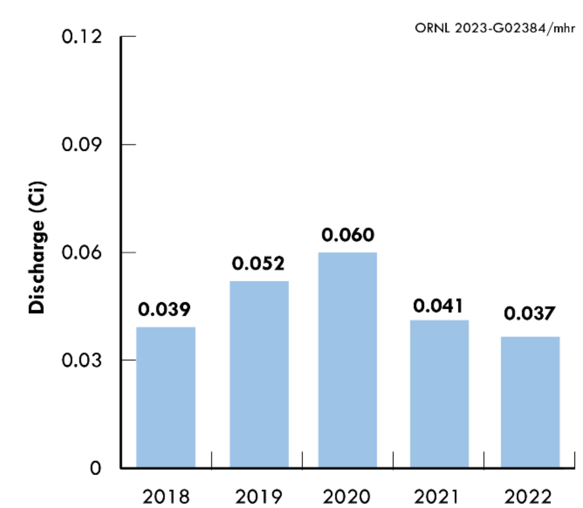


Figure 5.14. Gross alpha discharges at White Oak Dam, 2018–2022

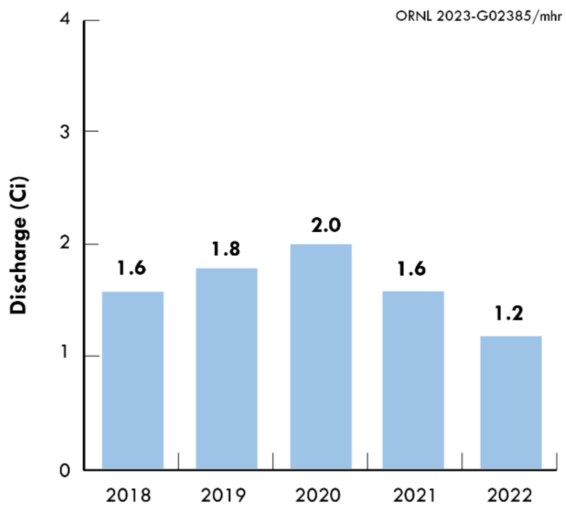


Figure 5.15. Gross beta discharges at White Oak Dam, 2018–2022

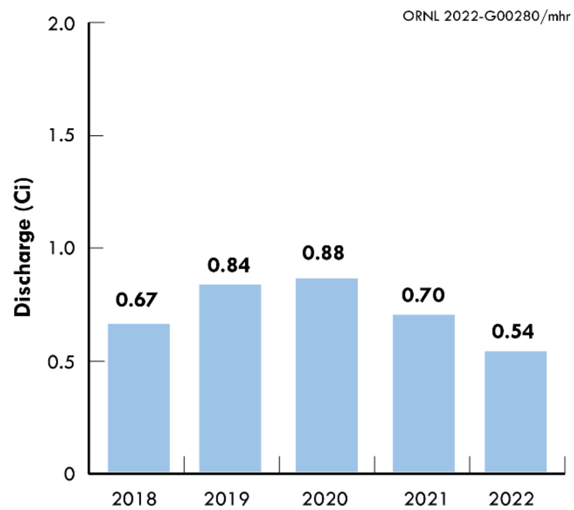


Figure 5.16. Total radioactive strontium discharges at White Oak Dam, 2018–2022

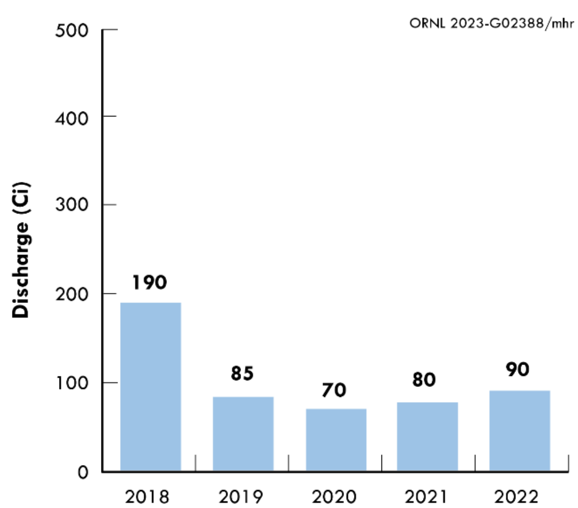


Figure 5.17. Tritium discharges at White Oak Dam, 2018–2022

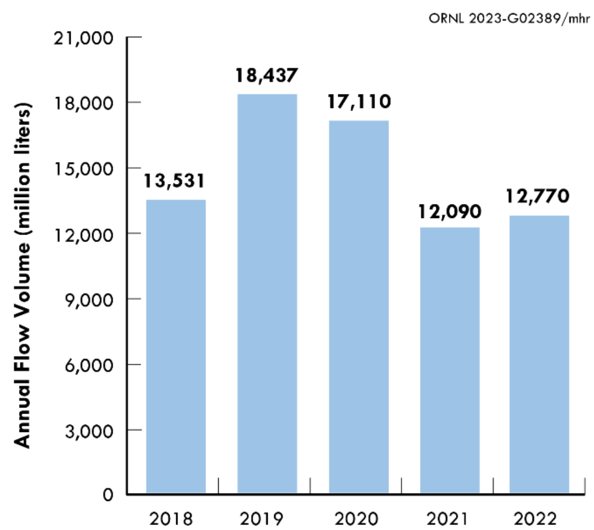


Figure 5.18. Annual flow volume at White Oak Dam 2018–2022

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.

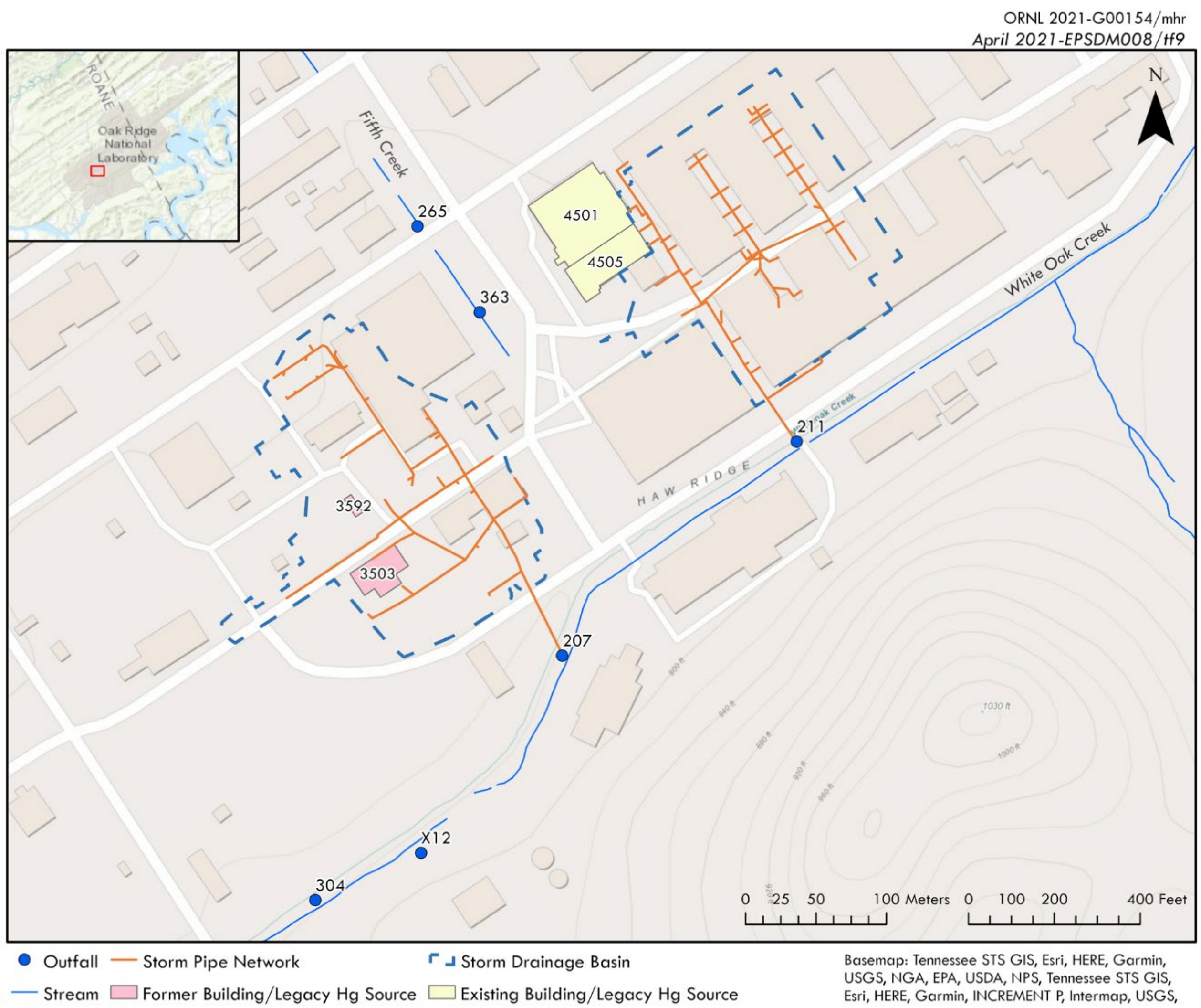


Figure 5.19. Outfalls 211 and 207 and associated storm drain connections that are potential mercury sources

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.

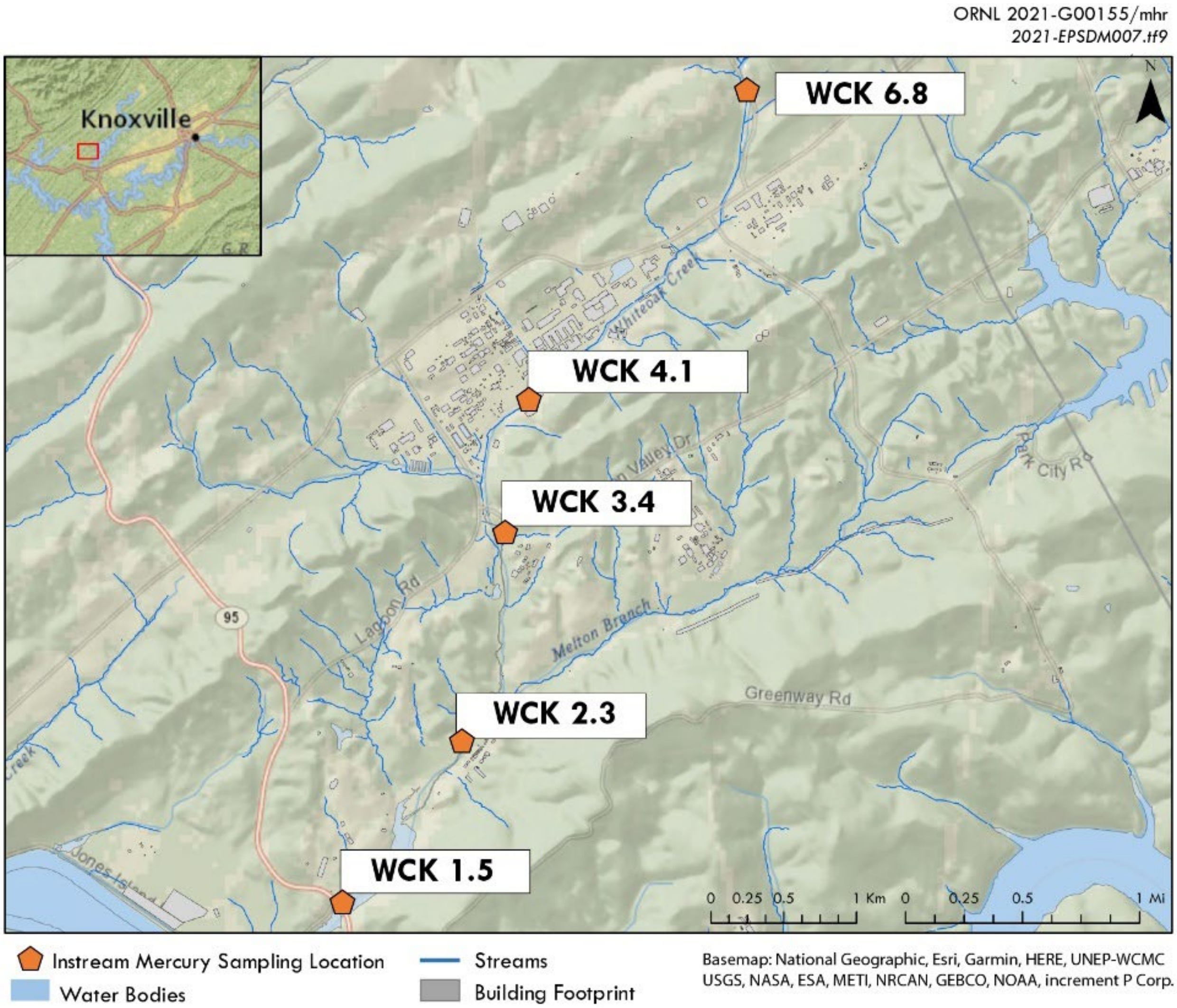
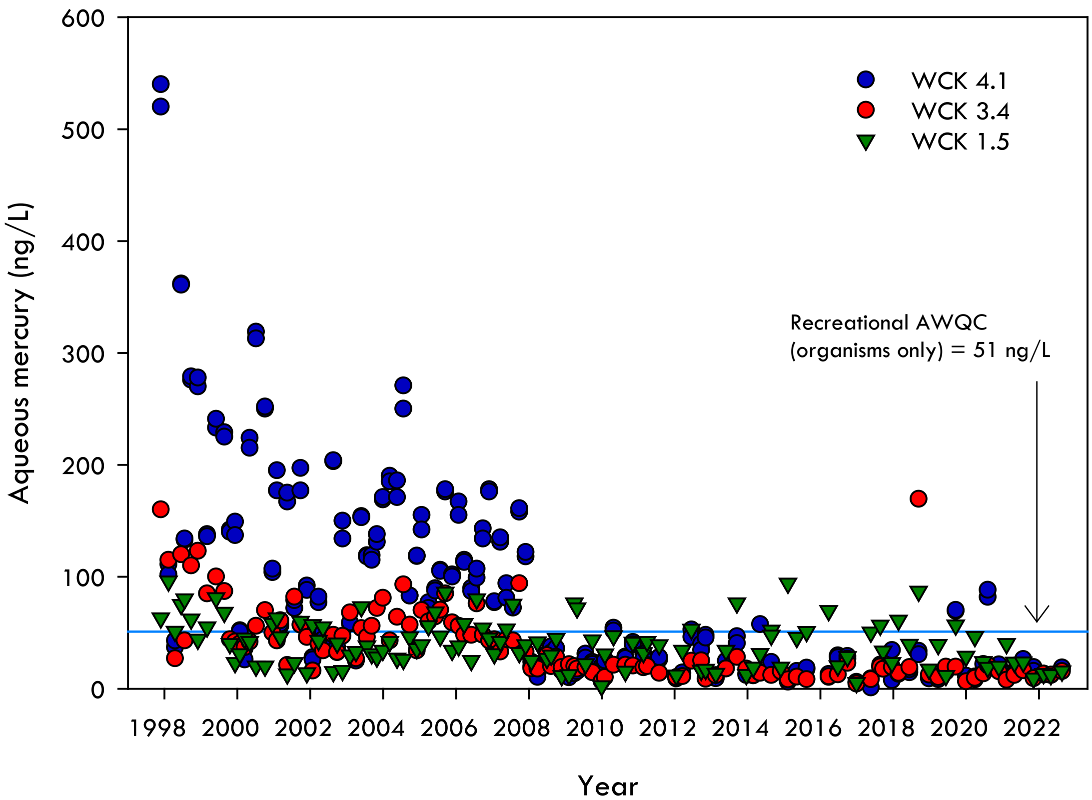


Figure 5.20. Instream mercury monitoring and data locations, 2022



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.

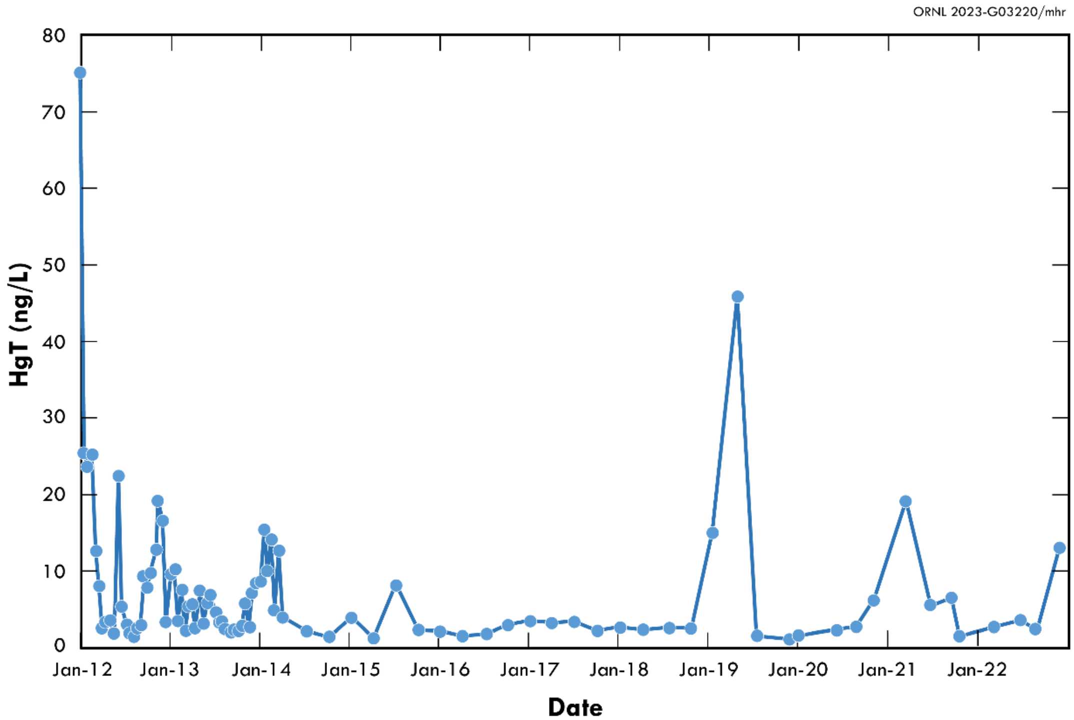
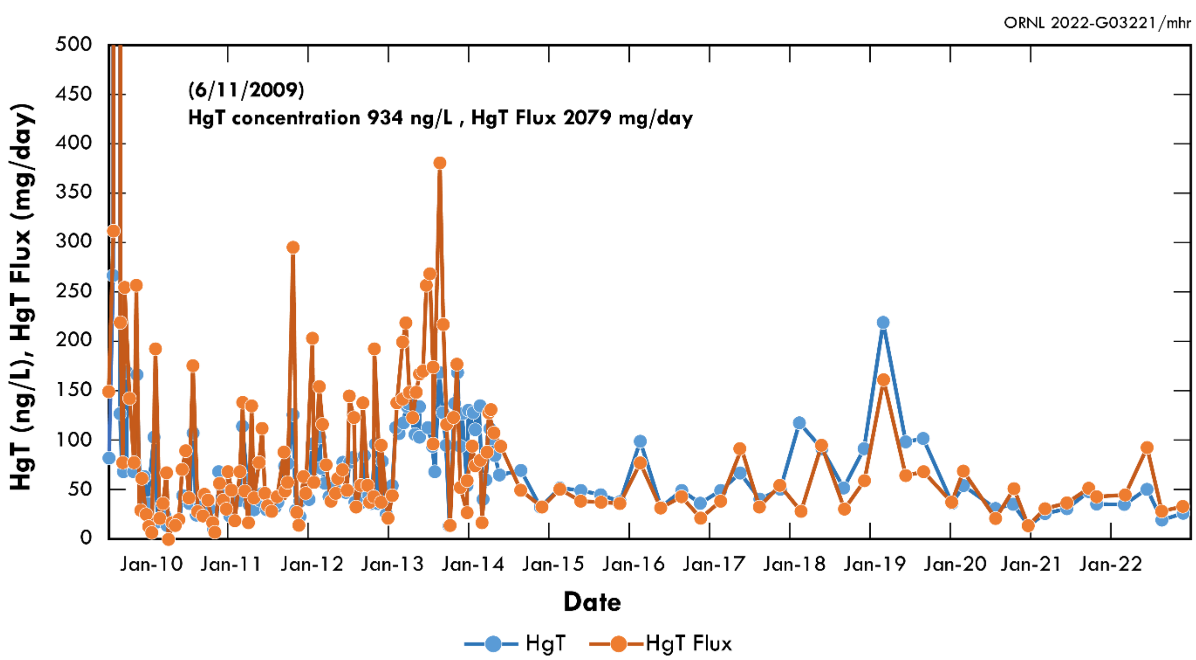


Figure 5.22. Total mercury concentration in discharges to outfall X01 from the Sewage Treatment Plant, 2010–2022



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

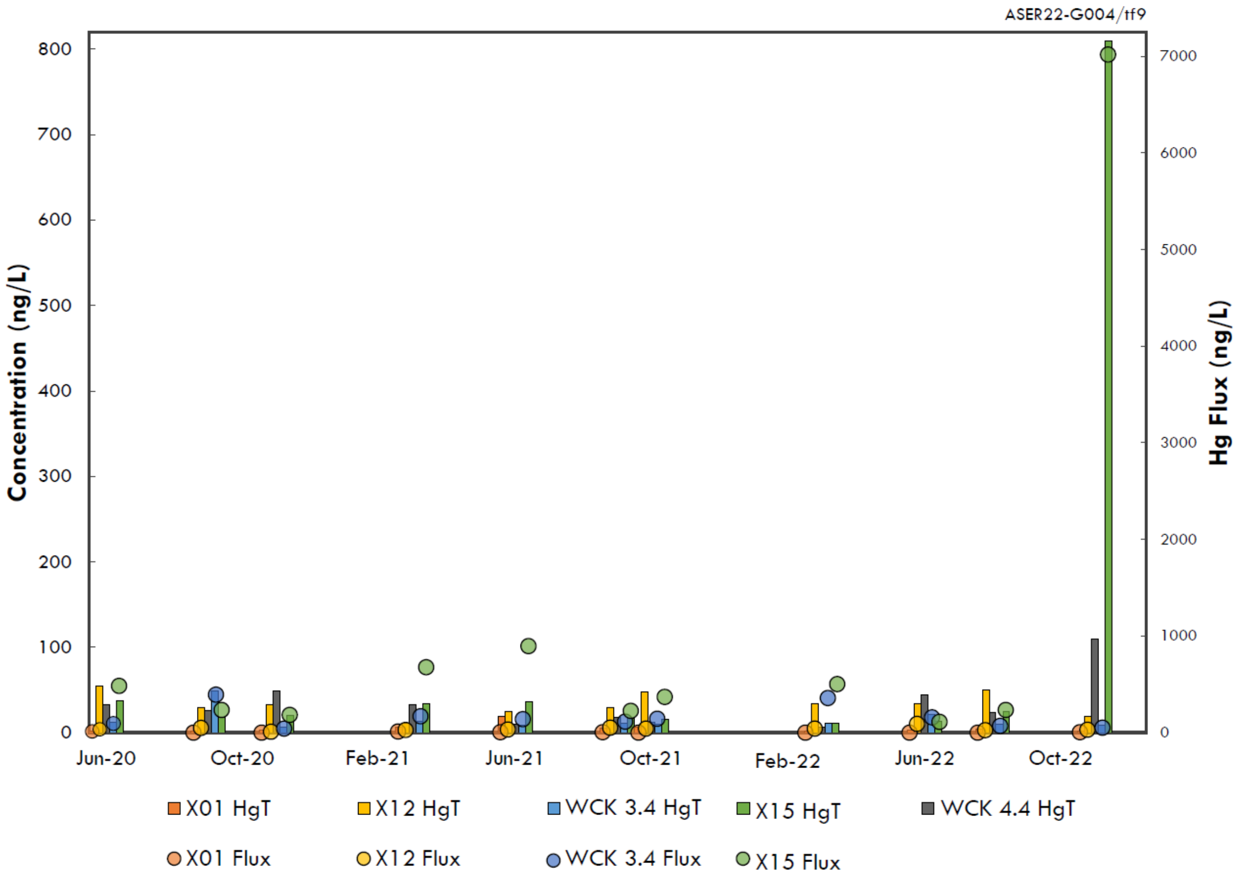
Instream
24 h composites
HgT (51 ng/L WQC)

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.

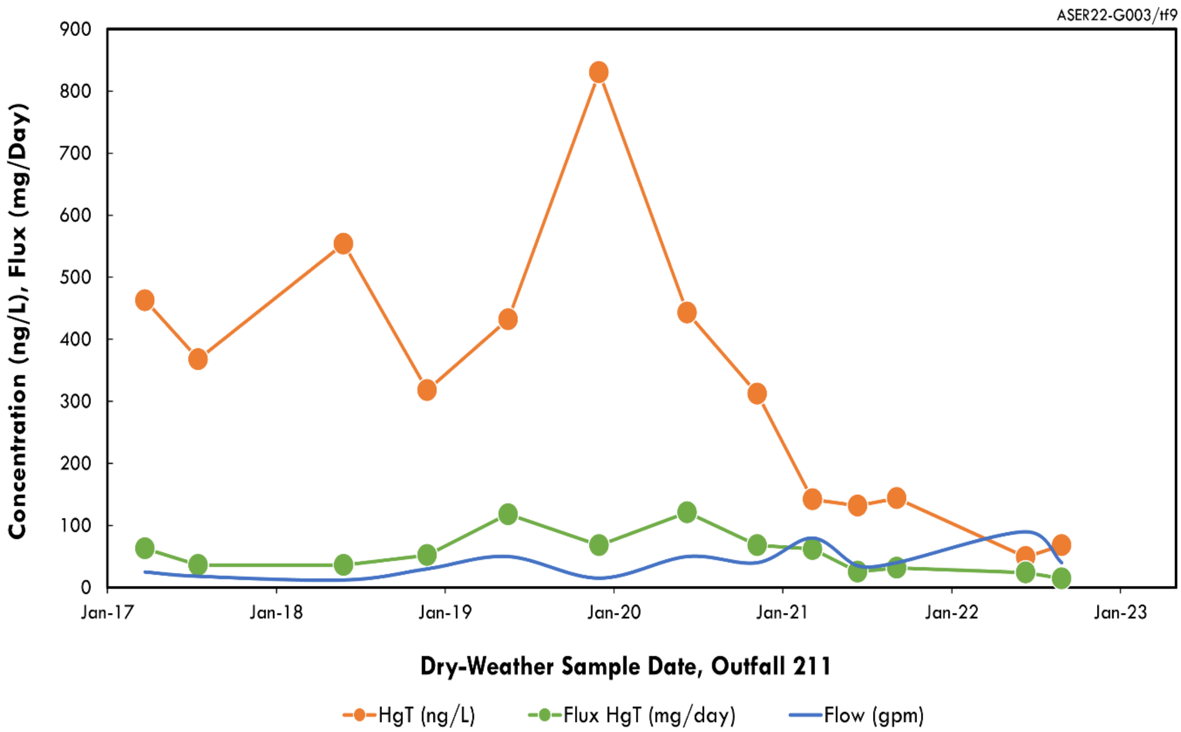


Figure 5.26. Outfall 211 dry-weather flow, concentration, and flux, 2017–2022

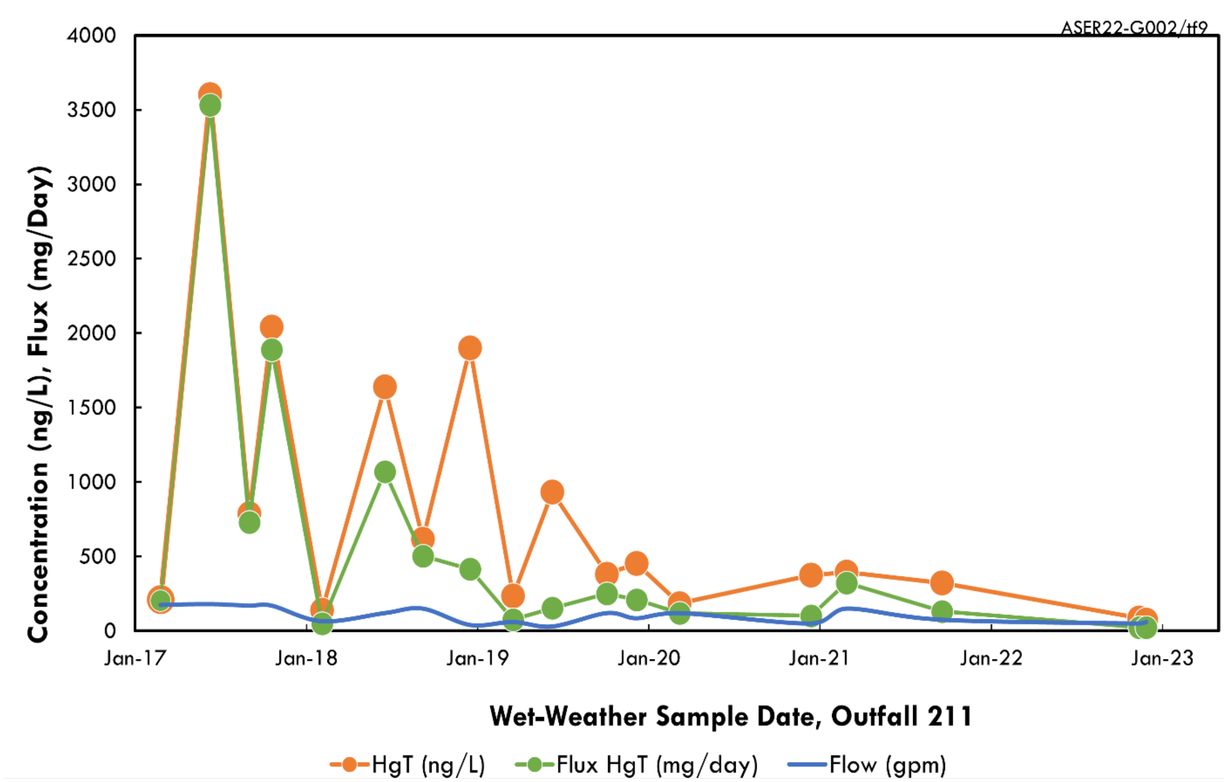


Figure 5.27. Outfall 211 storm flow, total mercury concentration and flux, 2017–2022

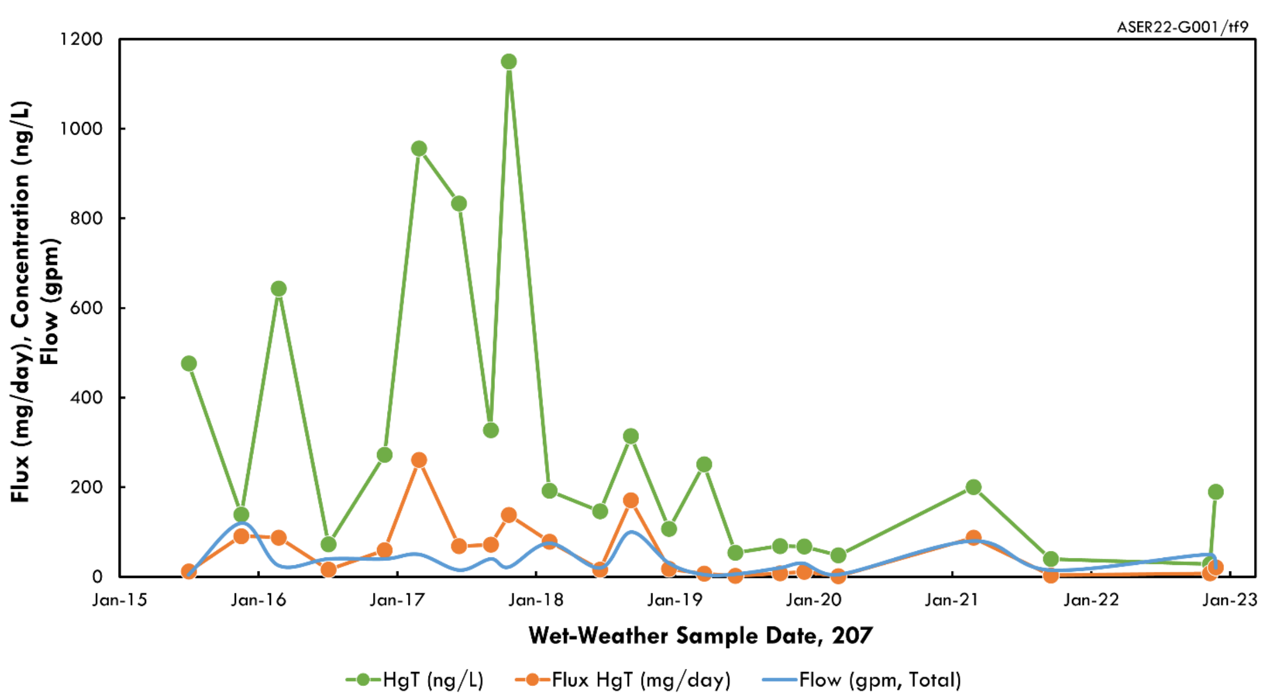


Figure 5.28. Outfall 207 storm flow, total mercury concentration, and total mercury flux, 2015–2022

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.

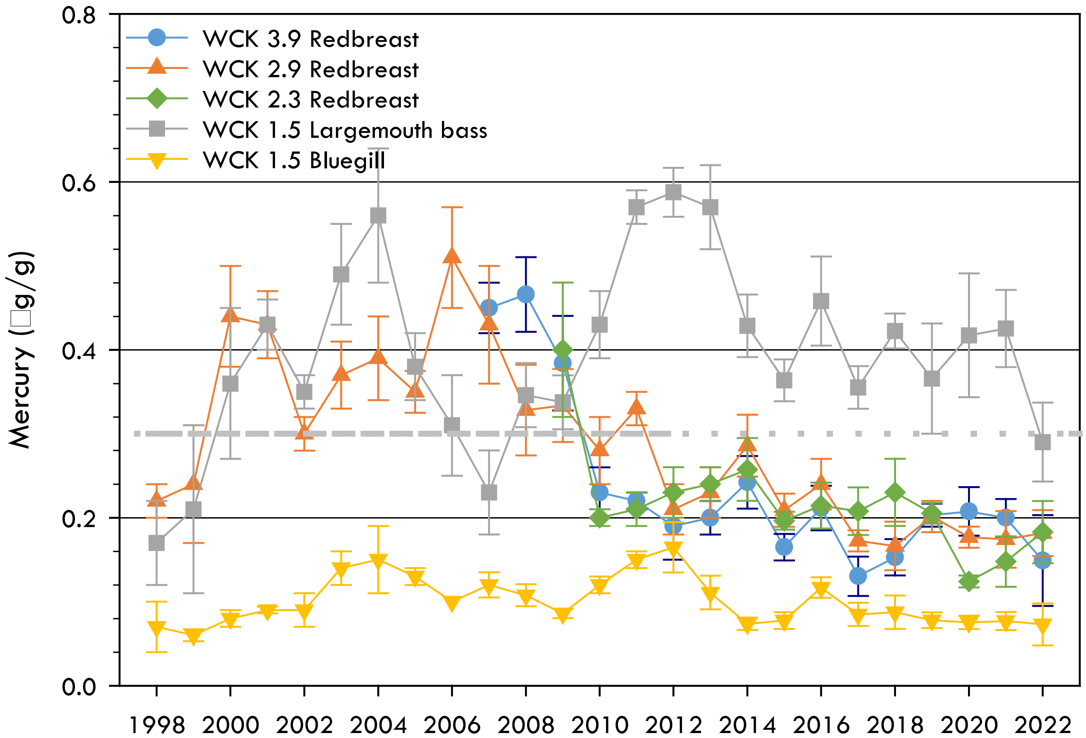
5.5.6.1. Bioaccumulation Studies

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).

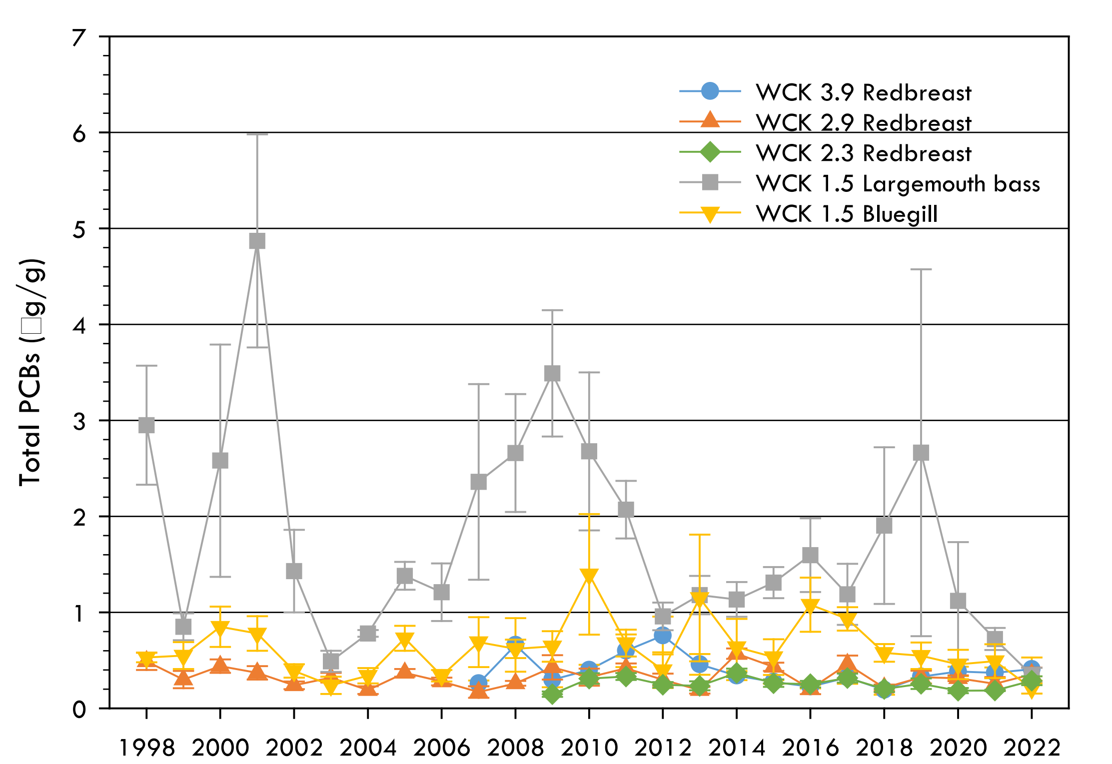


Notes:

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

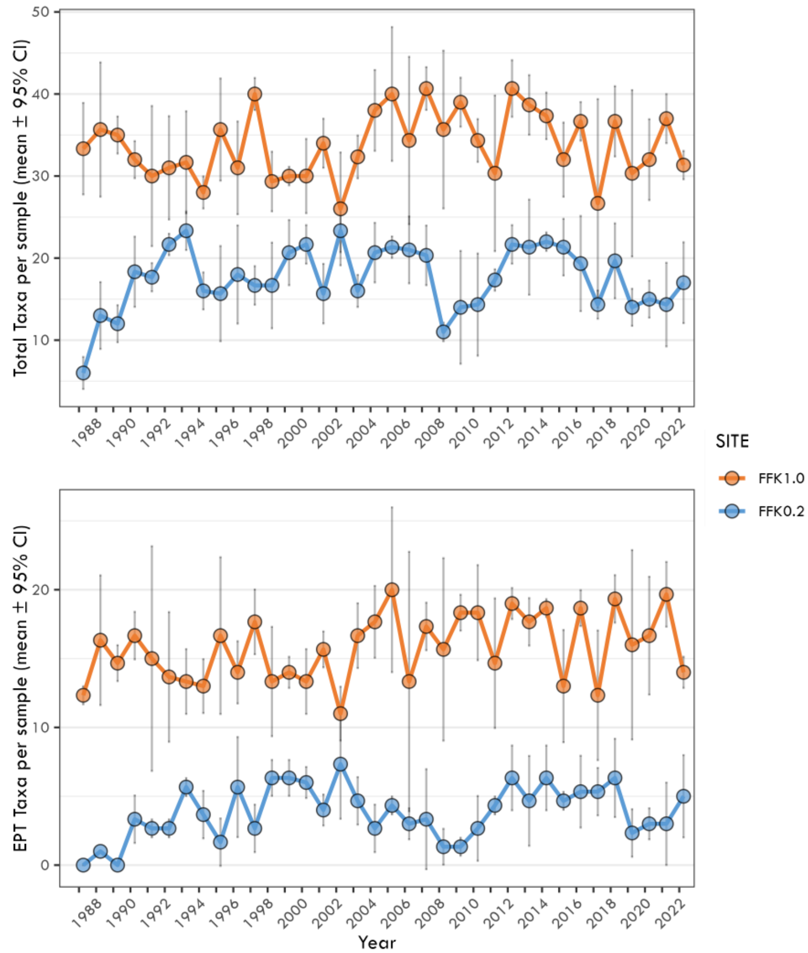
Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2022. Additionally, monitoring of the macroinvertebrate community in lower Melton Branch (MEK 0.6) continued under the OREM Water Resources Restoration Program (WRRP). Benthic macroinvertebrate samples 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

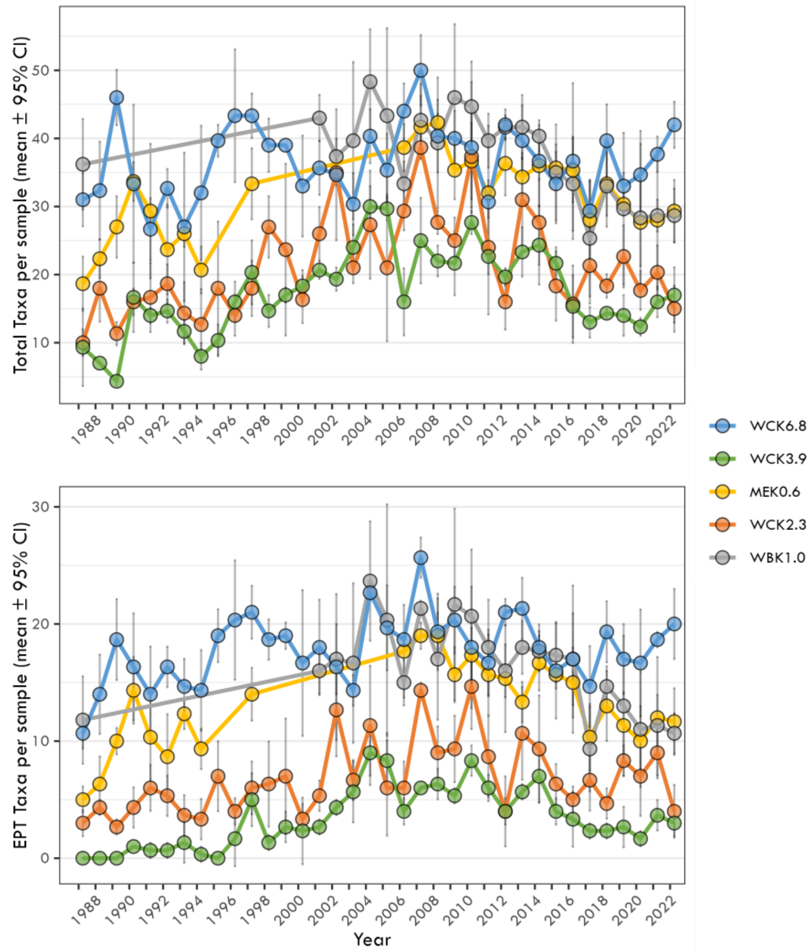
2021, reaching values observed before 2014, but then decreased in 2022. Similarly, the number of pollution-intolerant (EPT) taxa slowly increased in the 1990s and 2000s but then began to decrease in 2012. In 2014, EPT taxa richness was the lowest it had been since the early 1990s. EPT taxa richness values 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.



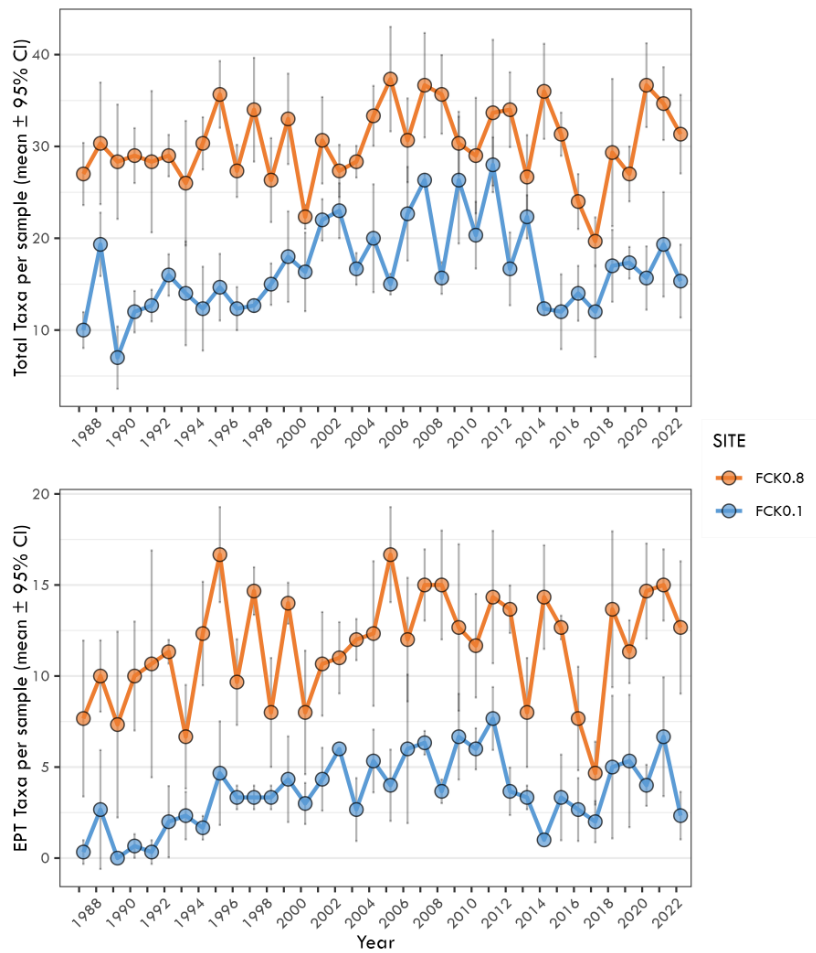
Note: *Taxonomic richness (number of taxa per sample), 1987–2022. FFK 1.0 serves as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).
Acronyms:
CI = confidence interval
FFK = Fifth Creek kilometer

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.

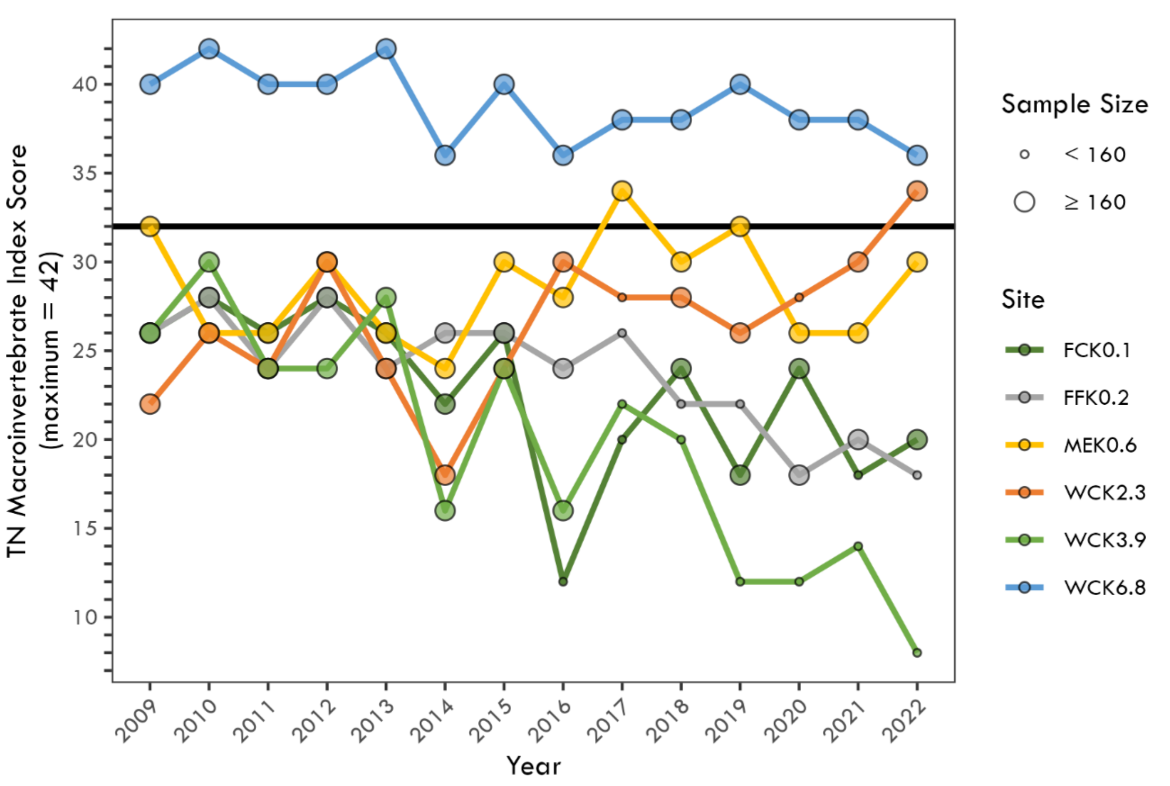
Invertebrate metric values for WCK 2.3 and WCK 3.9 continued to remain within the ranges of values found since the late 1990s and early 2000s, although total taxa richness and EPT taxa richness were lower at WCK 2.3 and WCK 3.9 over the past 7 to 8 years. As with FCK 0.1 and FFK 0.2, the total taxa richness 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] 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

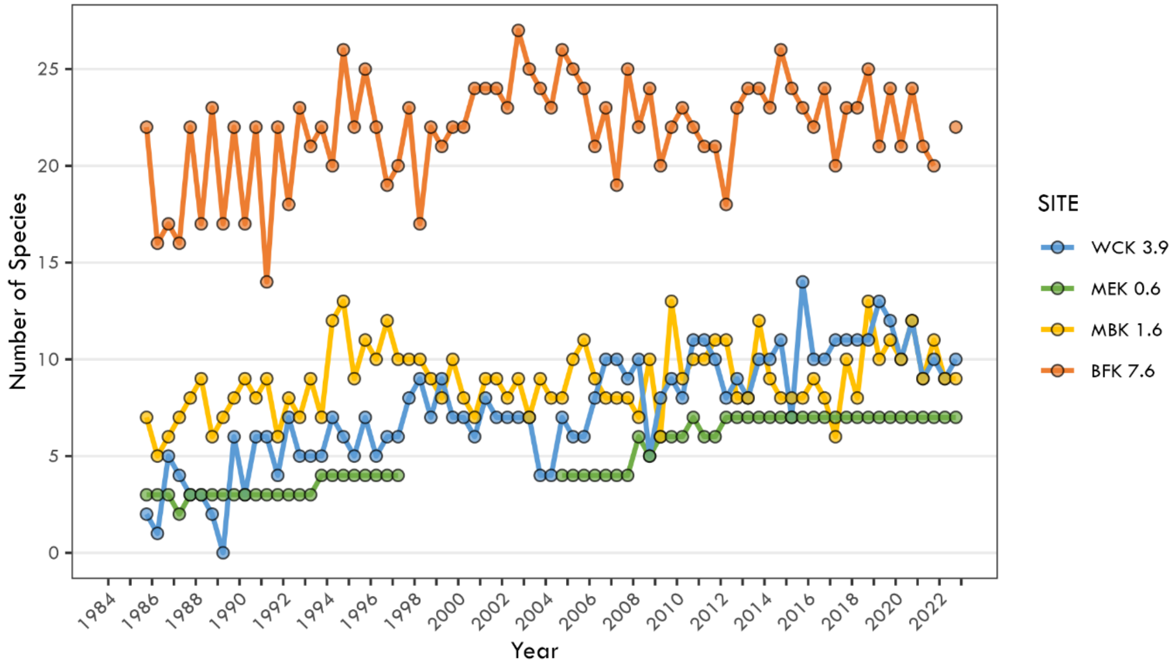
5.5.6.3. Fish Communities

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.

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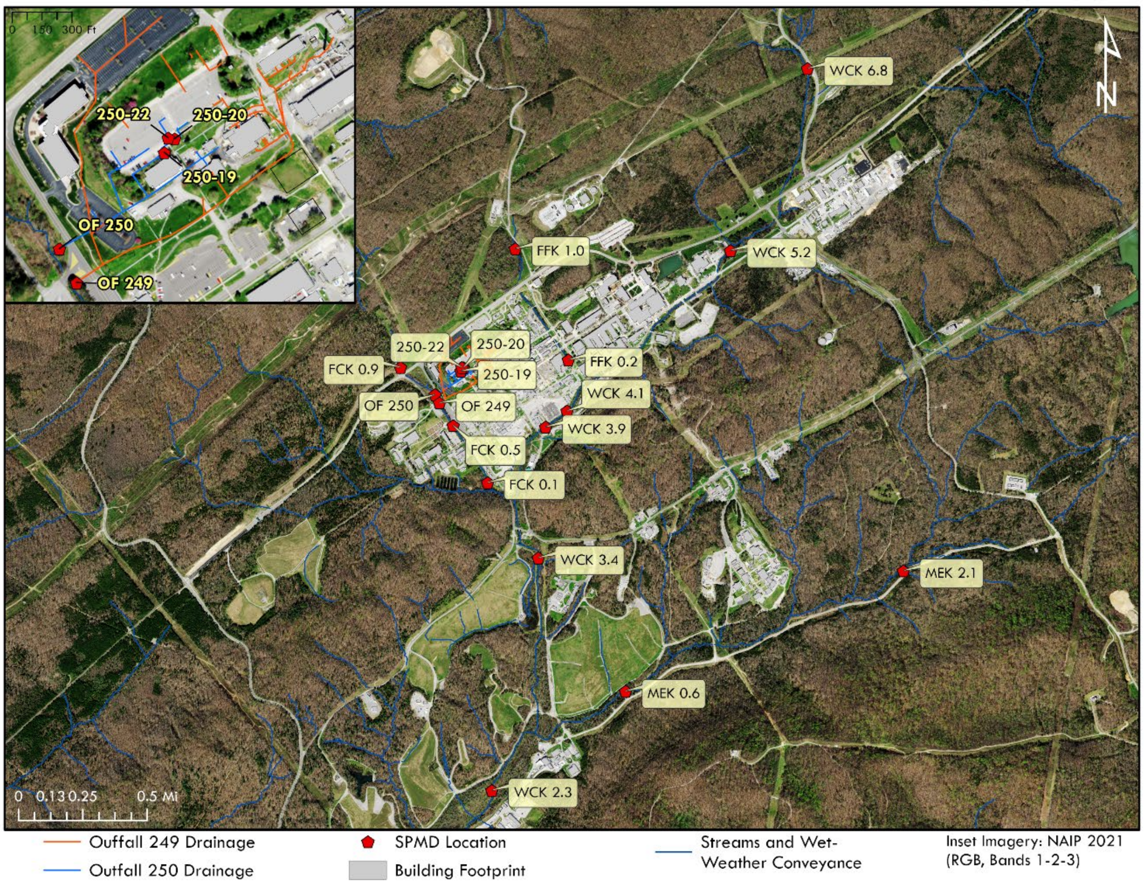


Acronyms:
FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
OF = outfall
SPMD = semipermeable membrane device
WCK = White Oak Creek kilometer

Figure 5.36. Locations of monitoring points for First Creek source investigation

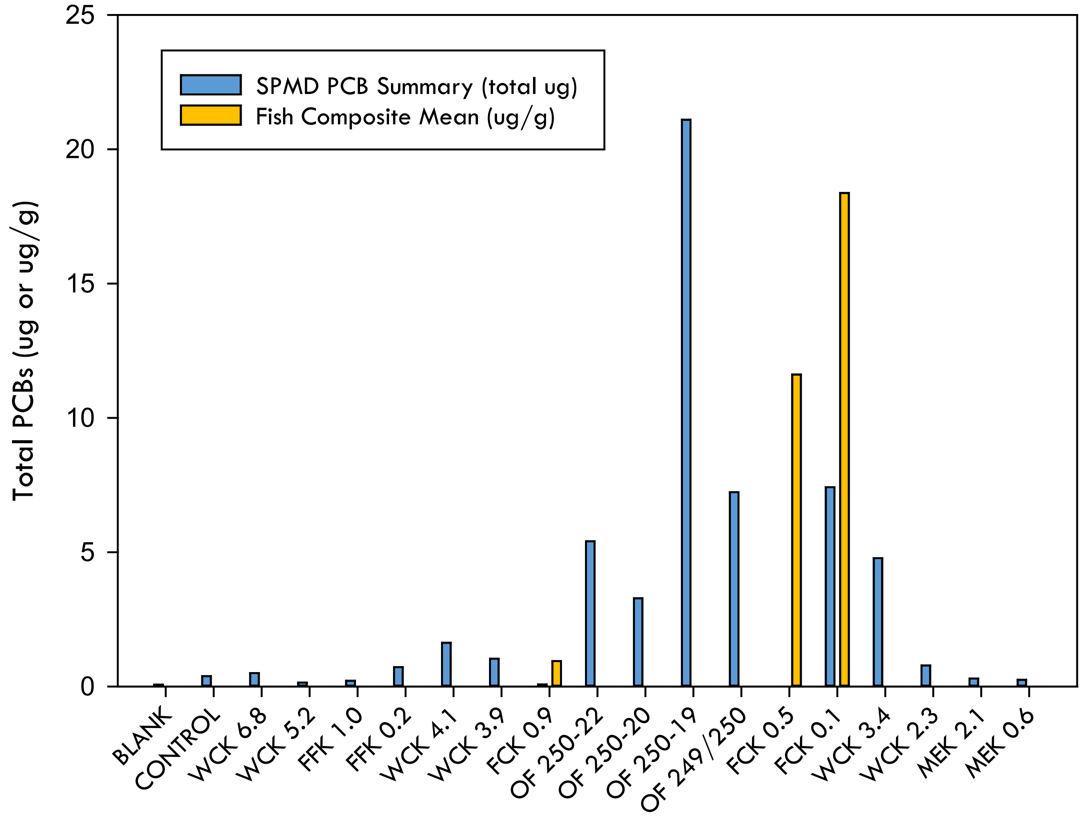


Figure 5.37. Total polychlorinated biphenyl content in semipermeable membrane devices in the White Oak Creek watershed and in First Creek forage fish composite samples (n = 3), 2022

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.

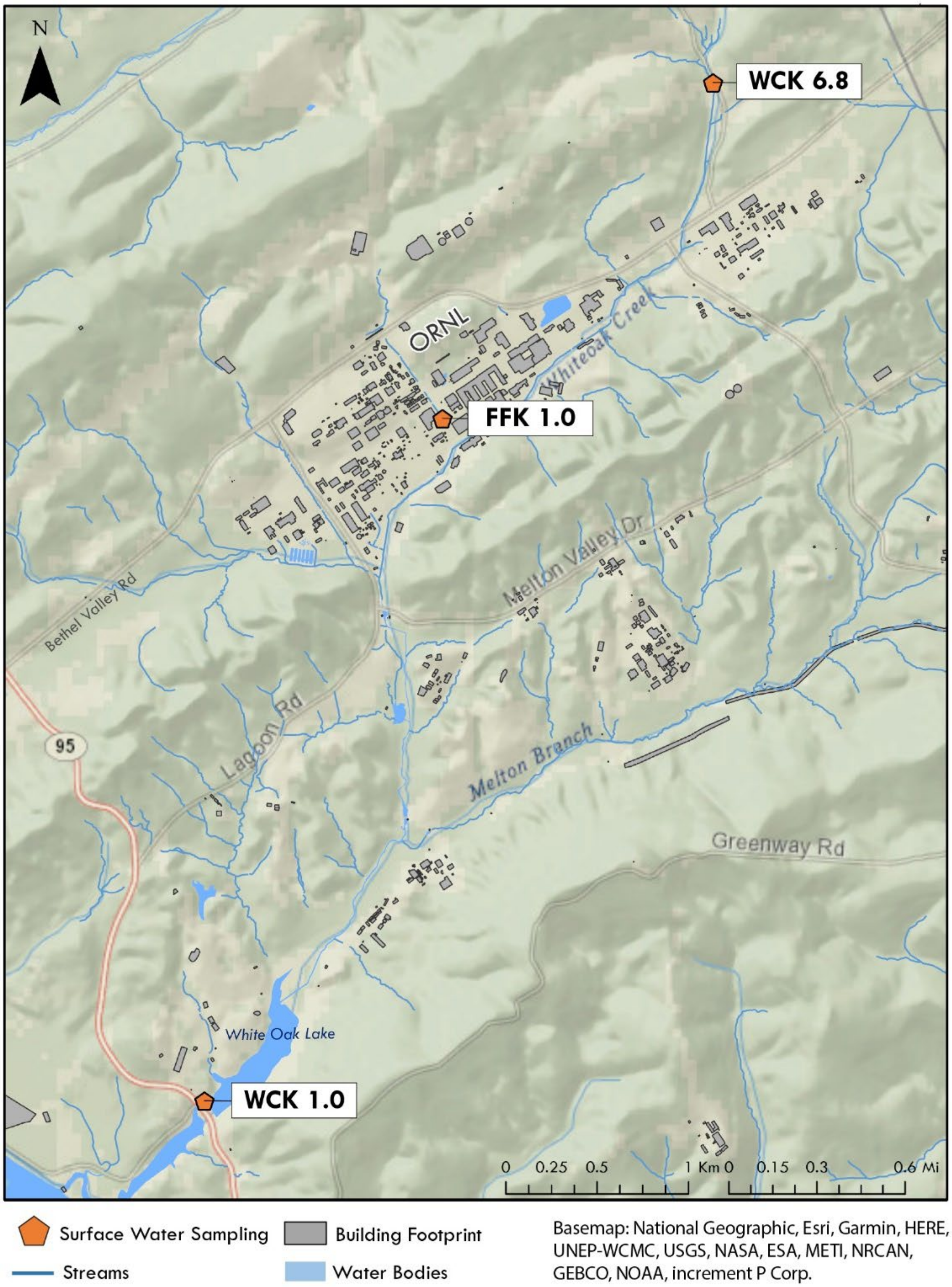
No radionuclides were reported above 4 percent of the DCS at the Fifth Creek location (FFK 0.1) in 2022. Beta activity and $^{89/90}$Sr were detected in samples from both sampling events at the Fifth Creek location and are related to known sources in the middle of the ORNL main campus. No $^{89/90}$Sr 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.

ORNL 2021-G00715/mhr
2021-EPSDM013.tf9



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.

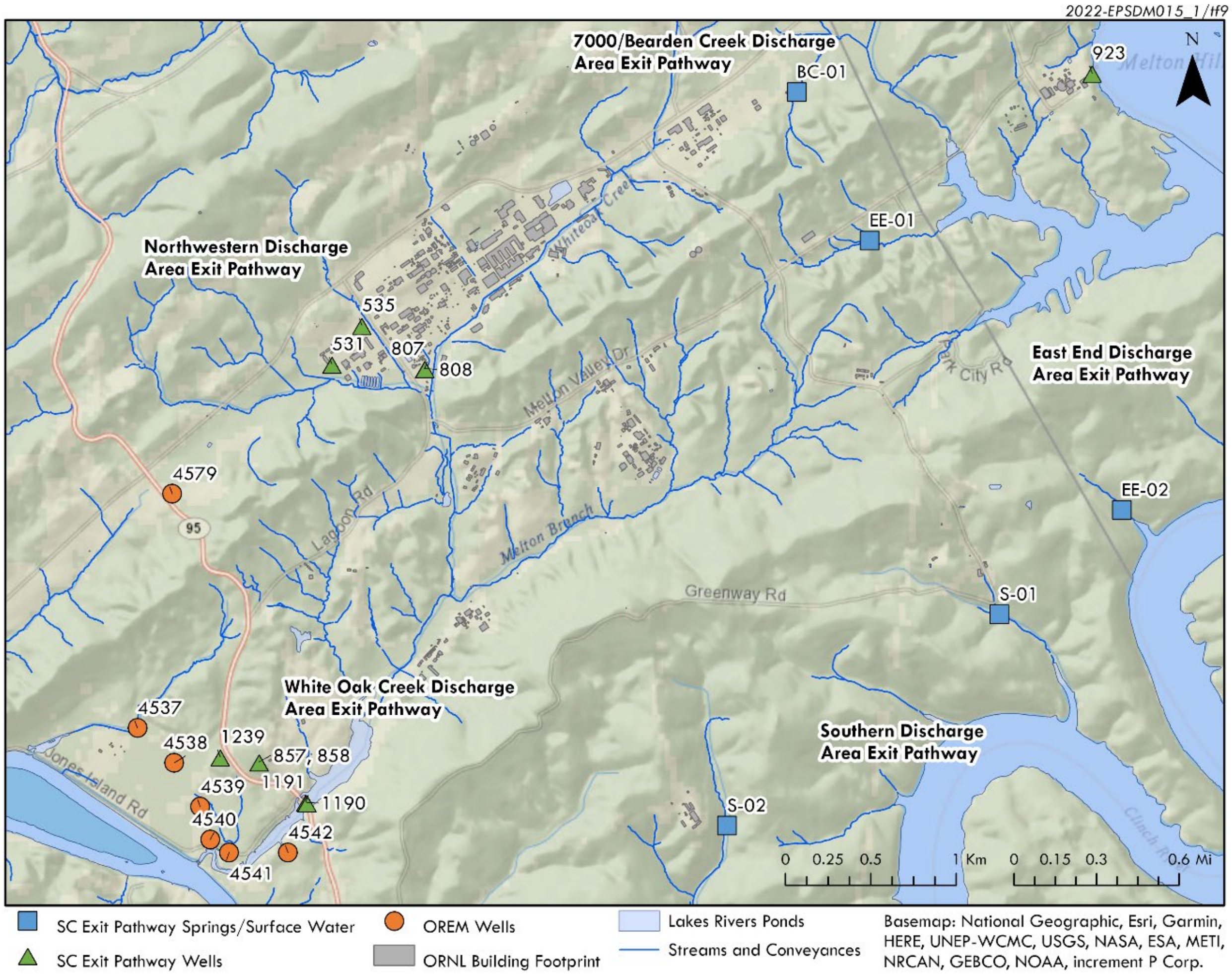
Exit pathway monitoring results

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.)

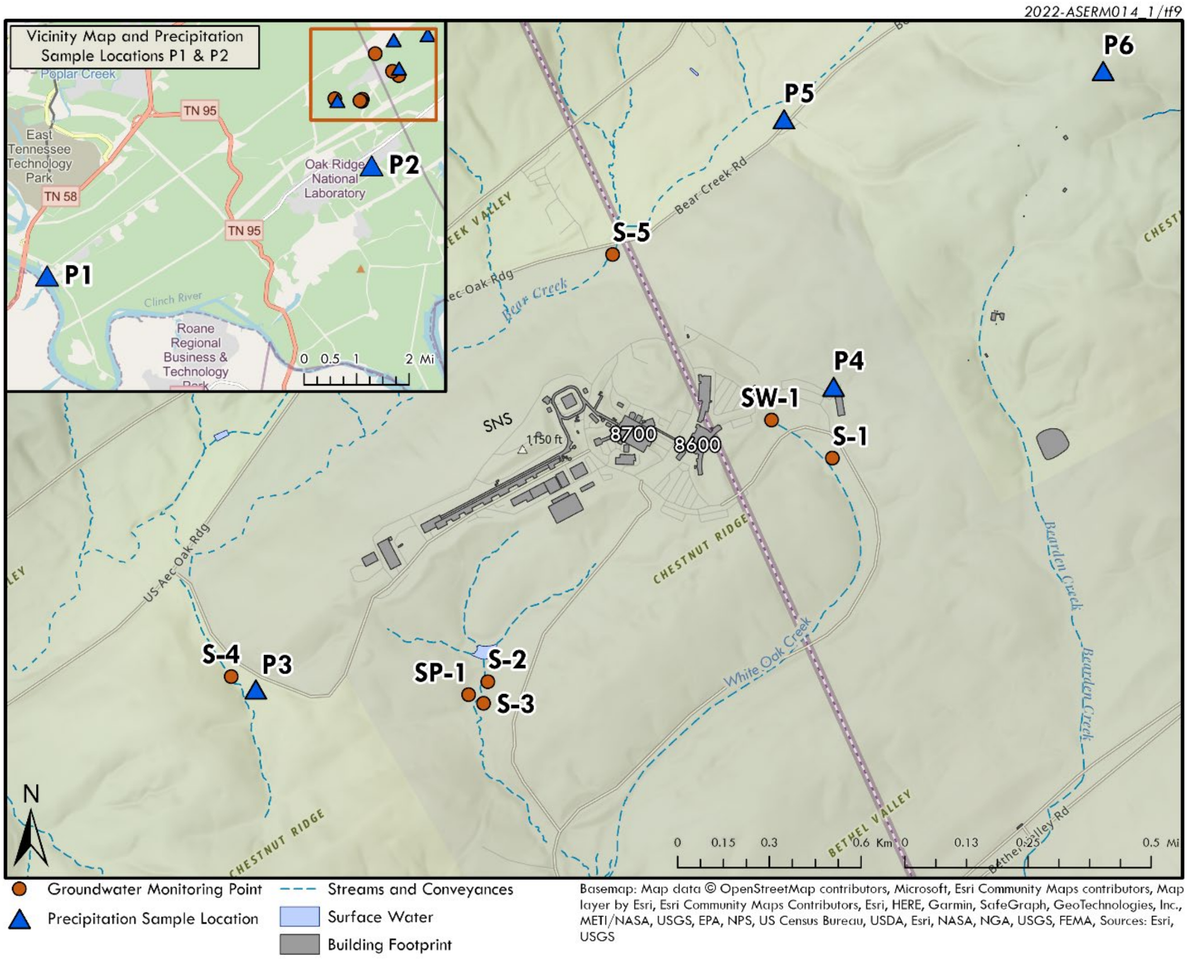
5.6.2.3. Active-Sites Monitoring—Spallation Neutron Source

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 ^3H data were evaluated to determine whether sampling could be optimized. The influence of flow condition on the proportion of ^3H 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 ^3H 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.

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